CIMS

Celebrating 75 Years

The Courant Institute of Mathematical Sciences at New York University

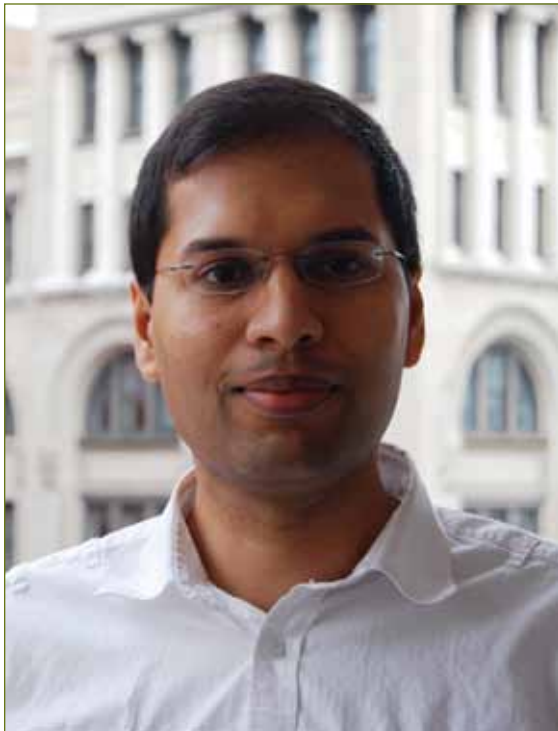# Subhash Khot wins NSF's Alan T. Waterman Award

Photo: Gayatri Ratnaparkhi

This award is given annually by the NSF to a single outstanding young researcher in any of the fields of science, engineering, and social science it supports. Subhash joins a very distinguished recipient list; few mathematicians or computer scientists have won this award in the past.

Subhash has made fundamental contributions to the understanding of the exact difficulty of optimization problems arising in industry, mathematics and science. His work has created a paradigm which unites a broad range of previously disparate optimization problems and connects them to other fields of study including geometry, coding, learning and more.

For the past four decades, complexity theory has relied heavily on the concept of NP-completeness. In 2002, Subhash proposed the Unique Games Conjecture (UGC). This postulates that the task of finding a "good" approximate solution for a variant of the standard NP-complete constraint satisfaction problem is itself NP-complete.

What is remarkable is that since then the UGC has proven to be a core postulate for the dividing line between approximability and inapproximability in numerous problems of diverse nature, exactly specifying the limit of efficient approximation for these problems, and thereby establishing UGC as an important new paradigm in complexity theory. As a further bonus, UGC has inspired many new techniques and results which are valid irrespective of UGC's truth. ∎
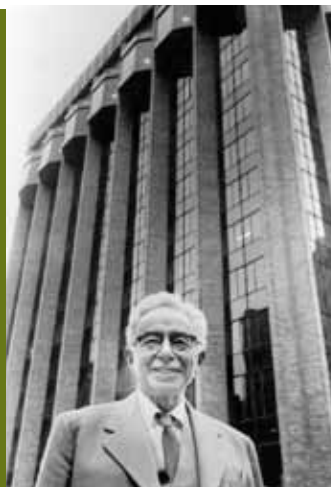
The Institute will be celebrating its 75th Anniversary over the course of the 2010-2011 Academic Year. Special events and activities will be planned to commemorate the occasion and to bring together CIMS and the broader scientific community.

This newsletter begins the celebration with an historical article on these first seventy-five years. While inevitably far from comprehensive, it captures the spirit of Courant — the man & the Institute.

(Photo on right) Richard Courant in front of Warren Weaver Hall

In this Issue:

The Courant Institute of Mathematical Sciences:
75 Years of Excellence

by M.L. Ball

Richard Courant

This article is the culmination of interviews with the following twelve faculty members of the Courant Institute of Mathematical Sciences: Marsha Berger, Sylvain Cappell, Jeff Cheeger, Steve Childress, Leslie Greengard, Ralph Grishman, Peter Lax, Andy Majda, Cathleen Morawetz, Louis Nirenberg, Michael Overton, and Raghu Varadhan. An additional participant was Lori Lax, wife of Peter Lax and daughter of Richard Courant. Thank you one and all for your time and heartfelt comments about this extraordinary man and the magnificent institute which bears his name.

— Mary Louise Ball

Perstare et Praestare – to persist and to excel.

Thus reads the motto of New York University, and it could be said, of Richard Courant himself. A man of remarkable foresight, inexhaustible enthusiasm, and indomitable will, it is impossible to imagine the Courant Institute being founded by anyone else.

But what was it that made this man so extraordinary? How was he able to create an institute whose applied mathematics became, and 75 years later, continues to be considered the world's best? And to have created not only an intellectually rigorous environment but a warm, collegial atmosphere revered by all associated with it, causing them to stay for years, even decades?

The answers are as multifaceted as the man himself and as illuminating as the times in which he lived.

Courant the Man

Descriptions of Richard Courant from present faculty who knew him run the gamut from obstreperous to congenial, but one theme runs throughout: once you met him, you never forgot him.

As Peter Lax described him, "Courant was an idealist and at the same time, a very strong skeptic; he was very contradictory. During the war, he traveled a lot. His wife Nina, a musician, once gave a party for her friends while he was away and one of the guests asked her, 'Nina, isn't it very inconvenient for you that Richard travels so much?' And she said, 'On the contrary. This way I can invite all the people he can't stand.'"

Lori Lax, Courant's youngest daughter and the wife of Peter Lax, remembers her father as ironic and scornful, yet also possessing a great sense of humor. She recalled, "He was extremely inconsistent and couldn't stay strict. On the other hand, he was far from kind and pleasant. I remember coming home one day with a very good report from school, and he said, 'Well, from a school like *that.*' But then there's the story of my sister Gertrud who was very unhappy when we came from Germany; she had lost all her friends and didn't understand English, and because of that, was placed in a class of students much younger than she. One day when she had been sent to the principal for misbehaving, my father, with a suspicion of a smile, gave her a quarter, because she had the courage to be bad!"

Lori continued, "Sometimes my father enjoyed a wave of soundless laughter. It might have been occasioned by a person he loved, or a story, or even some pungent moment in a piece of music. I think humor was his greatest strength."

Kurt O. Friedrichs

Courant's fondness for young people was universally remembered. According to Louis Nirenberg, Courant very much liked to be with them and be stimulated by them, and often invited graduate students to his house in New Rochelle. "Once we got there," Nirenberg explained, "we realized partially it was to weed his garden. I discovered recently that his teacher, Hilbert, did the same. Courant had a lot of initiative, a lot of imagination. And he had wonderful students: Kurt Friedrichs, Hans Lewy, and many others. He was full of warmth, full of humor, and very smart."

Post–World War II government funding, which propelled the Courant Institute onto the national stage, can be directly traced to Courant's enterprising nature and ability to forecast the future of mathematics, Nirenberg added. "He was one of the early mathematicians to get money from government agencies," he said. "He and Friedrichs wrote a book on shock wave theory, which was not his original subject at all, which helped him obtain funding from the Navy."

Another facet of Courant's personality which greatly influenced how the Institute developed was his affinity for people with different views. "It was his nature," said Peter Lax. "He was extremely close with people who were his opposite, like

Donald Flanders

Neugebauer, a very meticulous and workaholic scholar. Courant once said, 'Neugebauer has all the virtues and none of the faults of pedantry.' Courant was not a scholar in that sense. He didn't have the patience and the temperament. Neugebauer was utterly different from Courant, but they had an extremely intimate relationship.

"Another example of this is Donald Flanders," Lax continued. "He's the one who invited Courant to NYU; he was chairman at the time. Flanders was a descendent of Puritans who came on the Mayflower, and he himself was a Puritan. Courant was the very opposite of a Puritan. Flanders was very meticulous in marking exams because they had to be judged fairly. The result was that he got way behind. He was desperate and Courant offered to help. Flanders knew Courant was not as meticulous as he and he wasn't sure if he should agree to this. So Courant said, 'Test me. Give me some exams you've already marked, cover up the mark, and see how I do.' When his marks agreed with Flanders', he agreed to let Courant help. That was their first experience together, but with time they became very close friends, and their children are friends today."

Cathleen Morawetz's first memory of Courant was at her job interview, something she will never forget. "I had on this bright green coat and I was twiddling the button, and it came off and rolled under his desk," she said. "I was sitting on one side and Courant was on the other. He immediately got down on his hands and knees, and I got down on my hands and knees, and together we looked for this button.

"After getting my master's degree from MIT in 1946," she continued, "Courant invited me out to New Rochelle and I met his family, who were so different from anyone I'd ever met before. They remained very German. Mrs. Courant was the daughter of a very well known mathematician. When they left as refugees, they brought everything with them, not only their attitudes but also their furniture – heavy German furniture. And there was always lots of music. It was a very unique atmosphere; I'd never seen anything like it."

Once hired, one of Morawetz's first assignments was to edit the book *Supersonic Flow and Shock Waves*, co-authored by Courant

Raghu Varadhan, Cathleen Morawetz, and Olof Widlund.

and Friedrichs – a delicate balancing act. "Courant was a brilliant writer but sometimes he let style overpower correctness," she said. "Friedrichs was a poor writer but would never let anything pass that was not exactly accurate. They were opposites but very good friends. So I would fix up the English of Courant and bring it to Friedrichs, who would then look it over and decide it wasn't accurate. He would change the wording but then it was unreadable. I would then take it to Courant again, and so it went, back and forth."

She described Courant as "a fascinating person. Not a very good lecturer but a very good writer," she said. "He was very smart, and a very good mathematician. People tend to underestimate what a good mathematician he was, and he worked at it all the time."

And of course, one of the most well-known characteristics of Courant was his great love of the piano. Having taught himself to play the instrument as a teenager, it became a permanent fixture in his life. His wife Nina, an accomplished violinist, was as passionately devoted to music as he, and together they filled their home with music. According to Nirenberg, there was a joke that when Courant interviewed people for possible jobs, he would ask them if they played music. If they did, he would truly consider hiring them – unless they played the piano.

A Herculean Achievement – Twice

The fact that Courant developed one internationally renowned center of mathematical excellence and then created a second has as much to do with his personality as his mathematical brilliance. Rising to the directorship of the Göttingen Institute, only to be removed in 1933 by the Nazis, would have shattered most any man. But in the words of Peter Lax, it was Courant's "inexhaustible

optimism in the face of seemingly insurmountable obstacles" that propelled him to recreate Göttingen here in America.

According to Andy Majda, "Courant took the tradition of Göttingen – of mathematics as science – and brought it here because of the circumstances of pre-World War II Nazi Germany. Then he was lucky enough to be blessed with this incredible group of young students – Joe Keller, Peter Lax, Cathleen Morawetz, Louis Nirenberg, Martin Kruskal, Harold Grad – who later became some of the most important mathematicians of their generation. He and Kurt Friedrichs nurtured them in a remarkable way. He was also one of the few mathematicians who capitalized on WWII to get funding from the government, stressing NYU's role as an applied mathematics institute and tying this to national security. Now the Courant Institute is the world's most famous place to do mathematics and its applications. It's an incredible success story."

Sylvain Cappell reiterated the monumental quality of what Courant achieved. "Courant's talent at establishing this kind of extraordinary institution isn't just a matter of chance. The fact is, he did this twice in his life. First in Germany, he created an international-level research institution, and then he recreated it on these shores. Hilbert was the central intellectual figure in Göttingen, but Courant was the one who really carried it forward and was the organizational genius. Then he played the same role over here. Quite an extraordinary thing to have done twice in a lifetime.

Louis Nirenberg and Peter Lax

Computers, Technology, and Science at Courant Across the Decades

1954:
Official Instillation of the UNIVAC

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Cappell continued, "He brought a very sophisticated European tradition that melded pure and applied mathematics. Plus there was government funding available on a completely unprecedented scale as a result of the demonstrated military value of science during the war, and following that, during the Cold War years. I would also emphasize the fact that he had fantastic good judgment about whom to bring aboard. That gave the Institute a precious legacy both in terms of the mathematical genius and the human qualities in the people he brought. We're still the beneficiaries and heirs of that."

Equally as significant as Courant's ability to recreate Göttingen at NYU was the way he structured the new Institute, insisting that pure and applied mathematics be combined. "Courant had very original and very unusual ideas of collaboration," said Peter Lax. "Mathematics for most people is a very lonely profession. Of course there are collaborations but it is typically the lonely individual thinking about the problem. That was not Courant's idea."

Recalling his introduction to Richard Courant, Lax said, "My mentors in Hungary wrote to American mathematicians of Hungarian descent about me. My father, a physician, consulted von Neumann but more importantly Szegő at Stanford, who was actually an old friend from Hungary. Szegő said that Courant is wonderful with young people, and so my father took me to see Courant. I was not yet sixteen. I remember very well – Courant got very excited, and we talked about mathematics. But I had to finish high school, so I think the first concrete thing that developed from that meeting was that Courant became my father's patient."

Lax remembers those early years well. "I married one of Courant's students – my first wife, Anneli, a fellow graduate student," he said. "I was Friedrichs' student and got my Ph.D. in '49; my wife got her Ph.D. with Courant in '56. She was among his last students. My work with Courant went like this: he would bring up a problem and my task was to get hold of it technically. I would periodically report to him on the progress that I made, and he would comment on it."

> "Courant's talent at establishing this kind of extraordinary institution isn't just a matter of chance. The fact is, he did this twice in his life. First in Germany, he created an international-level research institution, and then he recreated it on these shores…Quite an extraordinary thing to have done twice in a lifetime." — Sylvain Cappell

Nirenberg concurred, adding, "Courant felt that mathematics was mathematics and there should be no separation between pure and applied."

The Institute's Early Years

In 1934 Courant was hired to develop NYU's mathematics graduate program, which was originally called the Graduate Center for Mathematics.

According to Peter Lax, "Friedrichs' coming to the Institute in 1936 was very significant. Then when Stoker, an American who had studied in Zurich, came in '37, they formed a triumvirate. And they had brilliant students. But the big uplift came during the war when suddenly there was federal money available for research. That was what turned a very modest enterprise into a much bigger one. Finally it became quite clear to the government what Courant had known for some time – how important technology and mathematics and science were to national defense, as exemplified by radar and the atomic bomb."

It was serendipity that brought Louis Nirenberg to the Courant Institute. In the summer of 1945, he was working on atomic bomb research at the National Research Council of Canada in Montreal. Two of his colleagues were Ernst Courant, Courant's oldest son, and his wife Sara. "She's the one who led me to Courant," said Nirenberg. "It was pure luck. I came down in the summer of '45 to be interviewed by Courant and Friedrichs. They agreed to give me an assistantship so I came back in the fall. At the time, the offices were in Judson Hall, on the south side of Washington Square Park."

He continued, "There were some young assistant professors, Max Shiffman and Bernard Friedman, and just a very few of us students: Eugene Isaacson, Martin Kruskal, Peter and Anneli Lax, Cathleen Morawetz, and Harold Grad. It was quite a small group of graduate students but really a very bright bunch of people. Courant's idea was unlike most mathematics departments; typically, after people graduate with a Ph.D., they're sent to other universities. Courant's idea was to keep the very good students, so he kept a whole bunch of us for a number of years. It was a great time."

1960s:
The IBM 7094

Peter Lax, Robert D. Richtmeyer and student.

1965:
The CDC 6600

Malcolm Harrison and Jack Schwartz.

The CDC 6600 was then the fastest machine in the world, although it could not do time sharing.

Ralph Grishman, another long-time faculty member, began his career at CIMS in 1964 after graduating from high school. "For a couple of years, the Institute had been offering a summer program for high school students to teach them how to program," he said. "I took that course for about six weeks over the summer, working with an IBM 7094."

The year 1964 was also when Steve Childress came to Courant as a post doc. "I had been working in aeronautical engineering and mathematics at the Jet Propulsion Laboratory in Pasadena, California, doing theoretical fluid dynamics. I was aware of the Courant Institute because of the early work on the fusion problem, the magneto-fluid dynamics laboratory run by Harold Grad, and also Joe Keller's work. Gerald Whitham had just come to Caltech and had spent some time at Courant. He recommended me for a post doc there under Harold Grad, and I jumped at the opportunity. Once there, I met Harold and Jerry Berkowitz and Joe Keller. Offices were in the Waverly Building. We moved to the new building in '65. Everyone was involved with designing the interior before moving in, so it was pretty exciting."

The Advent of the Computer

When the Atomic Energy Commission's much-sought-after UNIVAC supercomputer contract was up for grabs in 1954, it can be said that Richard Courant's tenacity, his Washington connections, and his fighter's will made sure it was awarded to NYU. A major turning point in the Institute's history, the UNIVAC guaranteed federal investment in the NYU mathematics department and the realization of Courant's long-held dream.

Peter Lax remembered the UNIVAC as "having a memory of 1000 words and able to do 500 operations a second, which is nothing today. And it was huge. It was built by Remington Rand, and the inauguration was an important enough occasion so that the CEO, James Rand, came and brought his board with him. The chairman of the board was General Douglas MacArthur, and also on the board was General Leslie Groves, head of the Manhattan Project. There's a photograph showing Courant with General Groves and General MacArthur, and I'm there too."

In 1965, NYU had another supercomputer, a CDC 6600 worth $3 million. In 1970, it narrowly missed being the victim of a bomb plot. Lax explained, "It was just a few days after the Kent State shootings, and the protesters calculated that the University and the police would not act very aggressively. They occupied the Courant Institute because we had the most valuable piece of property. They demanded that the University post bail for some Black Panthers or they would blow up the computer. The protest lasted two days. I was in the lobby with a number of Courant

Harold Grad and Cathleen Morawetz

colleagues, particularly from the Computing Lab – I was Director of the Lab – and when the occupiers left, I could smell smoke and said, 'Let's run up and see what's going on.' We went up and found a burning fuse, which two of my younger colleagues stomped on and put out. The rest of us went to the computer and disconnected the fuse, saving the computer. My wife said to me later that I was crazy to run into a room with a burning bomb fuse and I said, 'I was so angry, I wasn't thinking.'"

"In the early days," said Steve Childress, "when you wanted to study something, you would take your punch cards and put them in the machine; the next day you'd come back and if you were lucky, your program had run. If you'd made a mistake, you'd have to go back and start all over again. It could take days and days just to get a result – now it's seconds. Being able to generate and interpret large data sets and study a model very quickly – that revolutionized the field."

Ralph Grishman also described what it was like when computers were the new phenomenon. "After the summer course I took at Courant in 1964, a couple of the students were invited to be part-time employees in the fall," he said, "and I started doing research one afternoon a week with Jack Schwartz. We wrote a parallel processing simulator in Fortran, which was way before people were thinking about that, but Jack was always thinking ahead.

"I worked for Jack for four years, then took a break when I started graduate school," he said. "Jack then connected me with Naomi Sager who was doing natural language analysis and needed someone to do part-time programming. When I finished my physics Ph.D. at Columbia, I decided doing natural language was more interesting than physics. Jack, having founded Courant's

Mid-1970s:
The PUMA

Robert Dewar,
Ralph Grishman, and
Malcolm Harrison

(Right) PUMA memory board held by architect Ralph Grishman

The PUMA computer ran the same programs as the CDC 6600, with 4 processor boards replacing the 6600's thousands of logic modules.

Photo: Dan Creighton

computer science department in 1969, offered me a faculty position and I've been here ever since."

At the time, "there were not many departments offering computer science degrees – Courant wasn't, Columbia wasn't," he said. "Most of the faculty at that time had either science or math degrees." Michael Overton, now chair of the Institute's computer science department, was the first person hired with a Ph.D. in computer science, in 1979.

In the 1970s, the department was quite small, but in the 1980s, it grew considerably, establishing much-needed lab space on three renovated floors of 715-719 Broadway. These included robotics and parallel computing labs, both initiated by Jack Schwartz.

According to Overton, "Jack was absolutely instrumental in the growth of computer science at Courant in those critical years, the '70s and '80s. He had a huge impact on setting the research agenda here and establishing what areas were important, what areas to hire in," he said. "He was also remarkable for his breadth; the fact that he made significant contributions in many areas of computer science *and* mathematics – that was really very unusual."

Sylvain Cappell echoed this assessment of Schwartz. "Jack had analytic powers that were really breathtaking. He could take up a field and master it to the front lines and teach it in a matter of weeks. He did that many times."

Another key player in computer science at Courant was Martin Davis, a logician who became famous for his work on Hilbert's 10th problem, one of the celebrated problems Hilbert posed in 1900.

Over the last three decades, Courant's computer science department has experienced substantial growth, greatly expanding its significance and visibility. "We've hired a lot of very good people in the last ten years and now have a number of areas of strength that weren't there before," Overton explained, "such as machine learning, graphics and multimedia, algorithms and theory, cryptography, and verification."

Many Paths to Courant

The unique circumstances that led each of these twelve professors to the Courant Institute vary greatly, but the common thread has been the certainty that this was the best, most exciting place to be.

Raghu Varadhan arrived in 1963 from Calcutta, India. "I was interested in what was going on here," he explained. "I'd developed some interests while working in India and I was told this was the best place to pursue them. In those days it was easy;

there was plenty of money available for visitors. I thought I would come for a year, and I never left! I enjoyed being here and I liked my colleagues and never saw the point of moving elsewhere so I just stayed on. And I like New York City; I like big cities."

Cathleen Morawetz sought out Courant due to the urging of her father. "My father, John L. Synge, was an applied mathematician and he had met Courant. They had exchanged thoughts about the fact that their daughters had married and that this was going to mess up their careers. My mother was actually the one who encouraged me to have a career."

Sylvain Cappell immigrated to the United States from Belgium with his family in 1950. "In 1963 when I was in high school," he said, "I was the top national winner of what was then called the Westinghouse National Science Talent Search; now it's called the Intel National Science Talent Search. I began my career as a mathematical researcher, worked at several places, and eventually came to Courant in 1974."

Leslie Greengard, current Director of the Courant Institute, joined the faculty in 1989 and like so many others, has been there ever since. "This was the place I wanted to come to," he said. "I'm very social and I loved the atmosphere here. I couldn't see myself being anywhere else, and I still feel that way."

"It was the great people at Courant that brought me here to begin with," said Marsha Berger. "Peter Lax, for example. In the field that I'm in, he's the shining light. I first came as a post doc in 1982 and ended up staying, so I've spent my whole professional career at Courant."

Jeff Cheeger came from Stony Brook in 1989, becoming the Institute's first professor in the field of differential geometry. "For a long time prior to when I came, this was a field where the Institute wanted to establish some sort of presence. On the pure side of mathematics, traditionally Courant had been relatively narrowly focused with a massive presence in nonlinear PDE (partial differential equations) and probability, with more limited coverage of other areas. It was unique for the level of its applied mathematics and for having absolutely top people who did both."

Andy Majda's story involves oceans, Princeton, and NYU's current Provost. "I was a professor at Princeton when Dave McLaughlin, who was my Princeton colleague and is now NYU's Provost, got an offer to become the Director of Courant. I wanted him to stay at Princeton because I had worked hard to hire him – I can say I hired NYU's Provost – when I was running the Applied Math program there. He said to me, 'I'm going to NYU to become Courant's Director and I'd like to see what I can do to attract you.'"

1980s:
The Ultracomputer

Design Underway:
Mal Kalos, Allan Gottlieb,
and Jack Schwartz

Allan Gottlieb points to the Switching board of the Ultracomputer 3. These custom VLSI switches designed at NYU were the first to "combine" memory requests, an Ultracomputer innovation.

Photo: Dan Creighton

Majda continued, "My wife is a professor of Geosciences at Princeton and had some colleagues who were involved in climate atmosphere ocean science (CAOS) and were working at Princeton's geophysical fluid dynamics laboratory. These fields had had an interaction with applied mathematics twenty years earlier, in a very traditional mode. But applied mathematics had developed and matured a lot, with huge improvements in how people thought about numerical algorithms, asymptotic modeling, and the use of rigorous mathematics tools to prove things. And I thought these problems were unbelievably important for climate change science. So I thought, 'If Dave McLaughlin wants to attract me to NYU, he'll provide the resources for me to set up a program in climate atmosphere ocean science.' He did, and it's come true in a very, very nice way."

Cappell went on to explain how the melding of pure and applied math is also a critical component of the Institute's appeal. "We've worked to preserve the tradition of joining pure and applied math; it's not always easy to do. The National Research Council does assessments of departments all over the U.S. and they have now separated pure and applied mathematics into separate categories. Which is not, from our point of view, a good thing to do. We're always trying to build up discussions and exchanges which will serve as bridges between the two. Another thing which distinguishes us is that our record at identifying young talent is superb; this goes back to Courant."

Jeff Cheeger remembered that when he came to Courant, he received a very warm welcome from Peter Lax, Louis Nirenberg,

"Most large academic settings are very different from Courant — people don't have quite the same sense of attachment to their colleagues. Here, there is a feeling that we're part of something larger than ourselves. This stems from our history – from the culture established by our founders and from our continuing work as a mission-oriented institution. At the same time, no one could say that the place is calm – there's an incredible energy here and an astonishing variety of problems that people are exposed to. For people who thrive in a stimulating environment, there's no place like it."

— Leslie Greengard

What Makes Courant Special

When asked what makes the Courant Institute such a unique place, the answer given – consistently – was very simple: extraordinary scholars who are also extraordinary people.

"The place has always had a family feeling about it," according to Sylvain Cappell, "despite being a research institute where everybody has their own scientific concerns. People who have been associated with it – students, post docs, faculty – continue to feel like they're members of the Courant Institute even when they're working elsewhere.

"The Institute also greatly benefitted from the fact that a lot of its key people were great human beings," he added. "These are people of unusual warmth and generosity, and they provided a setting which is charming. I always say that my colleagues come in here like Englishmen to their club. It makes all the difference in the world. They could work at home. But here, they like hanging around, they like interacting, and they enjoy the feel of the place. It's very important for us to preserve that atmosphere because it's part of what makes this place distinctive."

and Cathleen Morawetz. "They are not just great scientists, but great people, and that certainly is very important in setting the tone of the place," he said.

He also emphasized that "the Institute is still a place of incredible breadth and quality. One amazing statistic is that of the nine Abel Prize winners, three are here: Peter Lax, Raghu Varadhan, and Misha Gromov."

Steve Childress said that when he started at Courant Institute, he knew he was going where a lot of interesting work was being done in the applied mathematical field he wanted to work in. "I had been around experimentalists in the theoretical fluid dynamics division at the jet propulsion laboratory at Caltech, but I was really interested in working with theorists such as Joe Keller and Harold Grad. It was an honor to be close to these guys."

"I have always had great affection for the Courant Institute," said Andy Majda. "The most important science part of my career was from 1973-75 when Peter Lax and Joe Keller taught me various things about mathematics and applied mathematics. It's

1990s:
Observing Fluids

The primary instability of a heavy flag in high-speed current is studied by Jun Zhang in the Applied Math Lab.
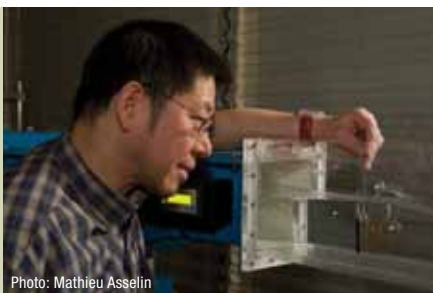
Photo: Mathieu Asselin

A potential application of extracting energy from the flows, using flexible sheets instead of turbines, is investigated experimentally and theoretically.
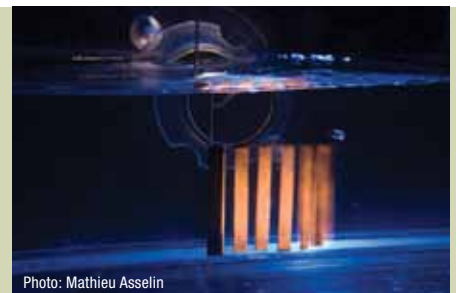
Photo: Mathieu Asselin

Groundbreaking of Warren Weaver Hall

a remarkable place, a place where all kinds of mathematics and sciences coexist. You do mathematics *and* the sciences, so Courant is not only on a very high intellectual level but it's driven by the sciences. I have had the most wonderful collection of supportive colleagues, spanning the entire Institute."

For Michael Overton, Courant is unique because "it's a place where you really have a lot of freedom to do what you want. When I came here, the senior faculty were very supportive of what I did, particularly Olof Widlund, chair of computer science at the time. Also, everyone wants to come to New York, so you have the best people from around the world coming through, and you get to work with them. The city is a real draw for students, too. We have outstanding Ph.D. students here and that's one of the reasons."

Leslie Greengard cited the genuine and lasting sense of community, rarely found in other institutions. "Most large academic settings are very different from Courant - people don't have quite the same sense of attachment to their colleagues," he said. "Here, there is a feeling that we're part of something larger than ourselves. This stems from our history – from the culture established by our founders and from our continuing work as a mission-oriented institution. At the same time, no one could say that the place is calm – there's an incredible energy here and an astonishing variety of problems that people are exposed to. For people who thrive in a stimulating environment, there's no place like it."

According to Marsha Berger, what made Courant distinctive early on was its emphasis on actually solving scientific problems of real interest. "The applied math that was done at Courant wasn't just paper and pencil but was really driven by problems of independent scientific interest – problems that needed to be solved," she said.

She added, "I think I'm really lucky that I ended up here. It's a great place to work. The fact that the computer science department and the math department are in the same institute is truly unique. I'm a faculty member in computer science with an appointment in math. Ph.D. students can work with anybody in either department. The fact that it's so seamless is unusual."

Sylvain Cappell offered a representative story of what makes Courant so unique. "Once I was meeting with a prospective hire," he said, "and I told him I had a set of criteria for identifying people who would particularly be interested in coming here: people who were interested in communication; who had a serious cultural interest of some kind, like opera or art; people who were members of some ethnic or cultural minority, because everything is accepted in this city; and people who had a spouse with career interests. And then along with all these criteria, I added one more. I said, 'It also helps if they're a little bit crazy, and happily, you satisfy all my criteria so you should accept our offer!' And he did."

The Future of Courant

By all accounts, the story of the Courant Institute's past is truly remarkable. Now the question to be asked is, 'Where is it going?'

As Sylvain Cappell put it, "You've got to work with where science is at, and where the world is at. Science is a lot bigger than when I was young. There were always some sciences that were moving along quickly but there were others that were kind of sleepy. That's not true anymore. *Everything* is moving, partially because advances in any science create opportunities for other sciences by providing exploratory tools or ideas or problems. This is true in mathematics on every scale. Applied mathematics has grown from being entirely based upon classical analysis to having other methodologies play a

2000s:
Measuring Ocean Data

David Holland prepares to deploy an AXCTD into the Jakobshavn Fjord in Greenland (2007). This is the first time such probes were used to acquire ocean temperature data.

Photo: Denise Holland

An Airoborn Expendable Conductivity Temperature Depth probe (AXCTD), 1 meter in length, launched from a helicopter into an ice-covered ocean.

large role, methodologies that come out of computational science and that involve statistical and numerical analysis.

He added, "The University as a whole has improved tremendously. NYU has managed to reposition itself more in the last 30 years than any other university in the United States. That's an amazing achievement, particularly when you realize that it's competing successfully with top-level institutions that have far larger endowments."

Jeff Cheeger commented that "the Institute continues to have a number of the very top people in areas such as nonlinear PDEs, in which for many years we were almost completely dominant. But we cannot expect to have the same kind of virtual monopoly as before, because competition in these areas from other top places has increased dramatically. Therefore, in pure math, it makes sense for the Institute to define itself more broadly than in the past, as with our small but high level presence in algebraic geometry."

He stated that since there are a number of areas of proven central importance in which Courant could sensibly build, he would emphasize choosing truly exceptional people in any of those areas, rather than strategizing to preselect an area. He also stressed the value of preserving the level in areas such as differential geometry, in which over the last twenty years, the Institute has built a world class presence. "Even in the face of ongoing raids from other top institutions," he said, "it is far easier to preserve the level than to be forced to rebuild it from scratch."

According to Andy Majda, the direction the Institute should go in should be data driven. "We have massive data sets available, from observations from satellites to sending up weather balloons," he said. "How to use these to improve our understanding and prediction with physics-based and math-based models is a great mathematical problem."

Steve Childress believes that neuroscience might represent a future direction for Courant. "This is supposed to be the century of the brain. I think its modeling is going to be one of the areas of applied mathematics that's going to be at the forefront of research," he said.
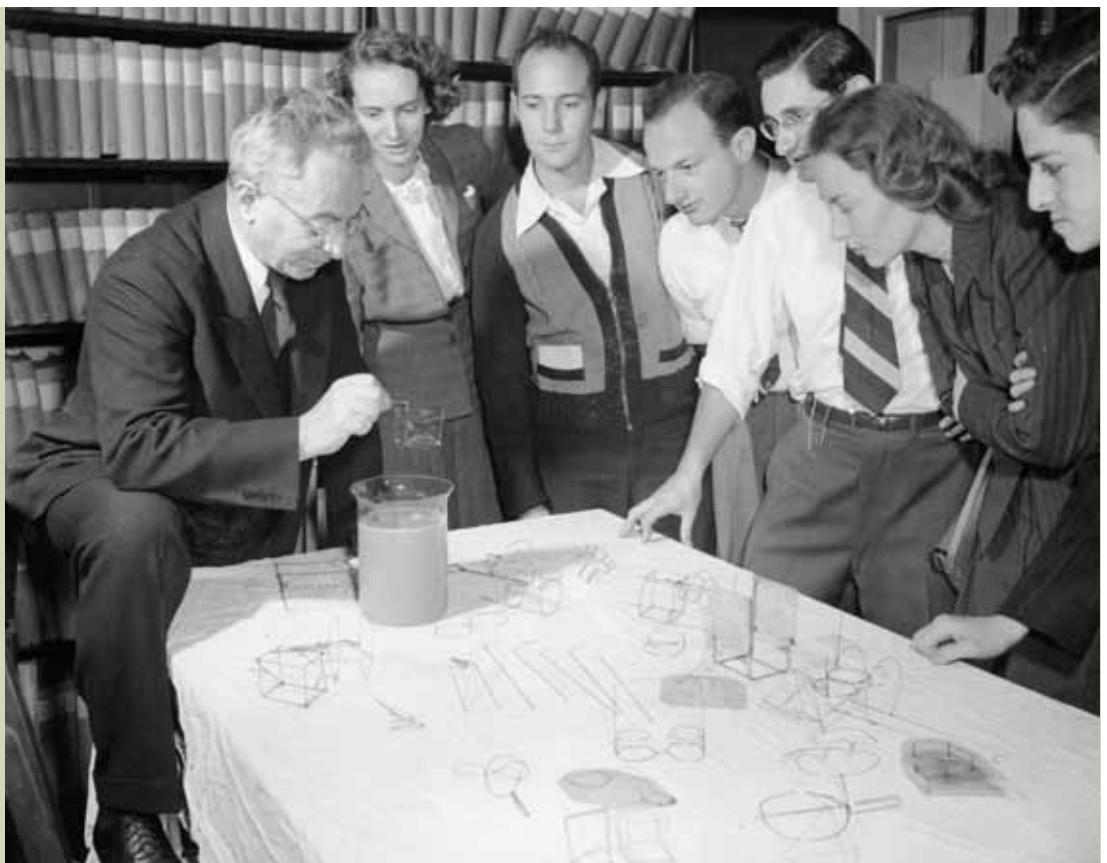
Marsha Berger observed that a very welcome change will be the upcoming merger with NYU-Poly. "Those of us who do applied work on the engineering side have had to look elsewhere to find collaborators, which is how I came to work with NASA. When Poly becomes the engineering school of NYU, this will open up a whole host of new applications and new potential collaborators."

Raghu Varadhan, a Courant faculty member for almost 50 years, summed it up. "In mathematics, fortunately, you can identify talent at a very young age. Already at the time someone completes his or her Ph.D., it's possible to see where that person will go. At Courant, we are able to identify and attract such talented people to come and work here. That's where the future is, so if we can keep doing that, the place will thrive."

By all accounts, it is. Surely, Richard Courant would be very, very proud. ∎

Observing Fluids

1950s Soap Bubble experiments with Courant. From right to left: Louis Nirenberg, Anelli Lax, Harold Grad, Eugene Isaacson, Joe Keller, unknown, and Richard Courant

Hacking with Startups

Photo: Elena Olivo

Students meet with Start-ups to create new products and demos.

Nearly 200 students from 32 different New York–area universities raced to create computer programs at the inaugural, 24-hour "Hackathon" this April 2nd–3rd in Warren Weaver Hall. "The hackathon is the first of many initiatives," said HackNY co-organizer and Courant faculty member Evan Korth, "and is designed to educate Courant students about the tremendous opportunities currently available in New York City."

At the event, students used datasets and technologies presented by some of the hottest NYC startups–including Foursquare, 10gen, Aviary, Chartbeat, and Hot Potato—to create their own products and demos. Three resulting projects were presented at the New York Technology Meetup on April 6 (a monthly event drawing about 700 area technologists), including "Aviary Tennis," by NYU students Tal Safron and Max Stoler. The game was implemented on top of the Aviary web-based image editing software and allows users to add traits to an image, share the image with a friend, and "lob" a continuously evolving image back and forth, as in a tennis match. ■

The Faculty

Faculty Honors

Marco Avellaneda was chosen as Risk Magazine's Quant of the Year, for "his groundbreaking work on the effect of short-selling restrictions on price dynamics. His paper, 'A dynamic model for hard to borrow stocks,' co-authored with Mike Lipkin of Katama Trading, was published in Risk [in June 2009], and has quickly become a classic of market microstructure literature."

Photo: Cheryl Sylivant

Mark Tygert won the 2010 Award for Initiatives in Research, "for his development of fast algorithms in mathematical physics, operator compression, and linear algebra, using deep, innovative ideas based on randomization and harmonic analysis." **He was also chosen as a 2010 Sloan Research Fellow** to support his research, which "explores a range of computations, including randomized algorithms and statistics, in order to improve electrical engineering, data mining, machine learning, and weather prediction."

SIAM awarded its 2009 Dahlquist Prize to Eric Vanden-Eijnden "for his research contributions to the development and analysis of numerical methods in stochastic dynamics, with applications to the study of multi-scale problems, rare events and free energy calculations."

Photo: Cheryl Sylivant

Leslie Greengard was named one of eleven National Security Fellows by the Department of Defense. Fellows are selected to conduct next-generation research projects as a part of the DoD's National Security Science and Engineering Faculty Fellowship (NSSEFF) program.

Sourav Chatterjee received the 2010 Rollo Davidson Prize, along with co-winner Gady Kozma of the Weizmann Institute. He received the prize "for [his] work on Stein's method, spin glasses and concentration of measure."

Olof Widlund has been named a 2010 SIAM Fellow, "for contributions to the theory of domain decomposition methods." SIAM Fellowships recognize distinguished members who are "leading thinkers and ambassadors of applied mathematics and computational science."

Andy Majda and Jalal Shatah were elected members of the American Academy of Arts and Sciences in the 2010 class of 211 Fellows and 19 Foreign Members. Academy Chair Louis W. Cabot said, "The men and women we elect today are true pathbreakers who have made unique contributions to their fields, and to the world."

Sam Roweis
(1972-2010)

We are devastated by the passing of Professor Sam Roweis on January 12, 2010. Sam was a brilliant scientist and engineer whose work deeply influenced the fields of artificial intelligence, machine learning, applied mathematics, neural computation, and observational science. He was also a strong advocate for the use of machine learning and computational statistics for scientific data analysis and discovery.

After earning his PhD in 1999, Sam took a postdoctoral position in London with the Gatsby Computational Neuroscience Unit founded by Geoff Hinton. Sam's enthusiasm and creativity played an important role in making the Gatsby Unit one of the top labs in computational neuroscience. At Gatsby, Sam started an incredibly fruitful long-distance collaboration with Lawrence Saul (then at AT&T Labs in New Jersey), which led to the Locally Linear Embedding algorithm (LLE). The LLE paper, published in Science in 2000, spurred an entire new sub-field of machine learning, called manifold learning, and gathered a considerable amount of interest from other technical fields, including applied mathematics. With LLE, Sam and Lawrence taught us to "think globally and fit locally": Given points in a high-dimensional space, local geometric relations among groups of nearby data points capture both local and global structure in the whole data set. This permits organization, visualization, and search in large, complex data collections. The method has had numerous applications in data visualization for biology, neuroscience, and the social sciences.

After his postdoc, some time at MIT, and a stint with the startup company WhizBang! Labs, Sam took a faculty job at the University of Toronto, to which Geoff Hinton had returned. Subsequently, he was appointed to a Canadian Research Chair in statistical machine learning. In 2005 Sam spent a semester at MIT. Capitalizing on his work on blind source separation, he co-authored a landmark 2006 SIGGRAPH paper with Rob Fergus and others on removing camera shake from a single photograph.

It was during this stay in Cambridge, MA that he met his wife, Meredith Goldwasser.

While at MIT and upon his return to Toronto, he focused on using machine learning and statistical methods to contribute to other sciences, such as astronomy and biology. He started a fruitful collaboration with NYU astronomer and secondary-school friend David W. Hogg. Their most visible success was a search engine for the sky, called Astrometry.net: given any picture of the sky from any source, it can instantly identify the location, orientation, and magnification of the image, as well as name each object (star, galaxy, nebula) it contains.

In 2006 he was named a fellow of the Canadian Institute for Advanced Research. Sam was not just a scientist, however, he was also an engineer. When Meredith took a job at Genentech in San Francisco, Sam took the opportunity to have a more direct impact on the world by joining Google's research labs in San Francisco and Mountain View in 2007. He was fond of saying that Google's search engine is one of the closest things we have to an intelligent computer.

In the summer of 2008, Sam and Meredith's twin daughters, Aya and Orli, were born in San Francisco. They were born very prematurely and had to be kept in intensive care for many weeks. Sam took an extended paternity leave from Google to take care of the twins.

Sam's stay at Google and the success of his computational astronomy work renewed his interest in academic research. He decided to join the faculty of the Computer Science Department at NYU's Courant Institute, and moved his family to New York City in September 2009. At NYU, his collaboration with David Hogg redoubled, as did his ongoing collaborations with Rob Fergus and Yann LeCun. His passing leaves many open threads, and many projects unfinished; at the time of his death he was working on beautiful, simple, but game-changing ideas for astronomical data analysis and remote sensing.

Our condolences go out to his family, as well as to his many friends in the broader community, especially at the University of Toronto and Google Research. He was a brilliant scientist with tremendous warmth and enthusiasm and a dear friend to many of us. ∎

Alumni Spotlight

Daria Bielecki, B.A in Mathematics '71, NYU University Heights; M.S. in Mathematics '73, Northern Illinois University; Ph.D. in Mathematics '83, Georgia Institute of Technology

Dr. Daria Bielecki has been a mathematician in the Advanced Systems Technology Branch at the Naval Research Laboratory (NRL) since 1988. In April 2009, Dr. Bielecki received the Navy Superior Civilian Service Award, the second highest award a Navy civilian can receive, for her 2003 development of the Vessel Tracking Project (VTP), which, as stated by the NRL, "features a layered defense approach incorporating support from sensors, databases and information feeds ranging from national technical means to open source information." The VTP, a culmination of much of Dr. Bielecki's work and research since 1988, automatically acquires and validates ship positional information 24/7—a process that, prior to the VTP, was done manually.

Before joining the NRL, from 1983 to 1988, Dr. Bielecki worked at the Naval Intelligence Support Center as a mathematician in the Ballistics Missile System Division of the Naval Weapons Technology Department, and in the 70s and early 80s she held teaching and teaching assistant positions at Northern Illinois University, Wills High School in Smyrna, Georgia, and then the Georgia Institute of Technology. ∎

The Tolls of Elsinore
by **Dennis Shasha**, Professor of Computer Science

Elsinore, in northern Denmark, was once one of the wealthiest cities of Europe. Its wealth derived from its location and a subtle threat of force. You see, its cannons dominated the narrow body of water called the Oresund. Any ship of size passing from the Atlantic into the Baltic had to pass the line of sight of those cannons. Elsinore took advantage of this strategic position starting in 1429 by charging a toll called the Sound Dues. In the early years, the toll was the same for all ships, but in 1567 the toll was charged based on the value of the cargo on a ship.

But who determined the value? The Danes came up with a brilliant idea. If the King of Denmark decided the declared valuation of some ship's cargo was too low, he had the right to buy the cargo for that valuation. This rule discouraged ships from setting obviously low values on what they carried. One frequent cargo was herring. It would swarm at certain seasons and provided a substantial portion of the protein of Europe. So much is historical fact. We now enter into fiction.

A group of herring merchants determined that Elsinore itself could store only a certain amount of herring or, as Shakespeare reminds us, something would be very rotten in the state of Denmark. In fact the amount that could be stored was exactly what could be sent in one shipment.

Suppose that the toll is 25% (in fact the Danes normally charged far less, but our fictitious King felt strapped for cash). If a shipowner claimed that a shipment was worth 1,000 gold pieces, then the toll would be 250 gold pieces if the valuation was accepted. Otherwise the King's inspectors could decide to purchase the shipment for 1,000 gold pieces. The inspectors made their decisions quickly, so ships never spent more than a day at Elsinore.

Warm-up: Suppose the shipper sends in one ship of herring having a sale price of 1,000 gold pieces. What value should he declare for his cargo when he speaks to the inspectors at Elsinore? His goal is to maximize the net sale price he finally receives. Assume that the inspectors know the true value.

Solution to Warm-Up: He claims the value is 800 gold pieces. If the inspectors decide to buy, he receives 800 gold pieces. If accepted, then he pays 200 gold pieces in toll but sells the cargo for 1,000 gold pieces so finishes by receiving net 800 gold pieces. If he sets the value higher, then the inspectors will accept the toll (which will

be more than 200 gold pieces) and the net sale price will be less than 800 gold pieces. If he sets the value lower, then the inspectors will buy the cargo for less than 800 gold pieces.

Two herring shippers decide to get together to try to maximize their collective net sale prices. Their plan is to send in two ships, one per day. Each would have 1,000 gold pieces worth of herring. The claimed value of the shipment would depend on the order of the ship in the series of shipments and on whether the inspectors had already bought the contents of a previous ship. Once the inspectors bought the herring from a previous ship, all future ships would declare a value of zero because they would know that Elsinore did not have the warehouse space to store a second shipment of herring. The inspectors might grumble, but the tradition of "take the toll and let the ship go or buy the shipment" was a contractual right, binding both the shippers and the King.

1. Suppose that there were just two ships and that they arrived separated by one day. Both cargoes are worth 1,000 gold pieces. What value should the first shipper declare for his cargo? Remember that the two shippers will share their net proceeds equally.

   The King, upon hearing of these low valuations, decides to build a second warehouse that can again store one shipment. To respond, the shippers recruit three of their friends. They schedule all five of their ships (each with 1,000 gold pieces worth of cargo) to arrive at the same time. The warehouse can fit the shipments of only two boats.

2. How should the shippers declare their cargo values so as to maximize their overall net sale prices?

   After this happens, the shippers get together for a beerfest in Luebeck and one asks, "Would we have been better off to send the ships in one at a time?"

3. What do you think? (Hard) How much better?

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In Memoriam: Bella Manel Greenfield (1915-2010)

Bella Manel Greenfield, one of the first two women to receive a Ph.D. in Mathematics at NYU in 1939, wrote her dissertation under Richard Courant on descriptions of the conformal classes of multiply connected planar domains. The daughter of immigrants from Poland, Bella graduated from Hunter College with an A.B. in 1935. After receiving an M.A. in Mathematics from Columbia University in 1936, she began her graduate studies at NYU. For financial support, she was given a job as secretary to Courant, but in 1937, Bella received a Blumenthal Fellowship and was able to give up her secretarial job. In 1938, she married a fellow student of Courant, Max Shiffman (Ph.D., 1938). After receiving her Ph.D. she wrote a second paper on conformal classes of planar domains jointly with Courant and Shiffman. After a hiatus from mathematics while raising her two children, Bernard and David, she turned to applied mathematics and engineering. Bella worked for the Ramo–Wooldridge Corporation (now TRW) from 1954 to 1958, where she was on the design team for the RW-30 airborne magnetic drum computer. In 1959, she moved to the RAND corporation, where she published several papers (under the name Bella Kotkin) in collaboration with Richard Bellman on numerical solutions to differential-difference equations with applications to chemotherapy and other medical subjects. She retired from RAND in 1965, but began a second career teaching mathematics in 1980 at the College of Notre Dame in Belmont, CA, and then at UCLA from 1982 to 1984.

Bella and Max were divorced in 1957, and in 1958 Bella married Emanuel Kotkin, who passed away in 1981. She married Moses A. Greenfield (Ph.D. Physics, 1941, NYU) in 1984 and soon after retired from teaching to devote herself to family and music as a classical pianist. In 1995, Moses established the Courant Institute's Bella Manel Prize for outstanding graduate work by a woman or minority.

Bella is survived by her husband Moses, sons Bernard Shiffman and David Shiffman, step-children Richard Greenfield and Carolyn Sargent (Advisor to the Provost for Faculty Housing and wife of Thomas Sargent, Professor of Economics), ten grandchildren (including Jonathan Shiffman, J.D., 1997, NYU, and Daniel Shiffman, Assistant Arts Professor, Tisch School), and two great-grandchildren. ∎

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Your donations to the Courant Annual Fund are more important than ever. This unrestricted income supports students and their conference travel, enhances the activities of our student clubs, and helps fund the cSplash and WinC outreach programs. The Annual Fund provides matching funds to secure grants from other sources, enables the Institute to invite distinguished speakers for both technical and public lectures, and assists in creating improved public spaces in both Warren Weaver Hall and the Broadway building. Please join the Courant Director's Circle with a donation of $1,000 and above. This entitles you to join special events at the Institute, including a Circle only event in the fall, and the exclusive Director's Toast before the holiday party. Your donation will help support a truly extraordinary range of scientific and educational initiatives. ∎

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