Fall 2015

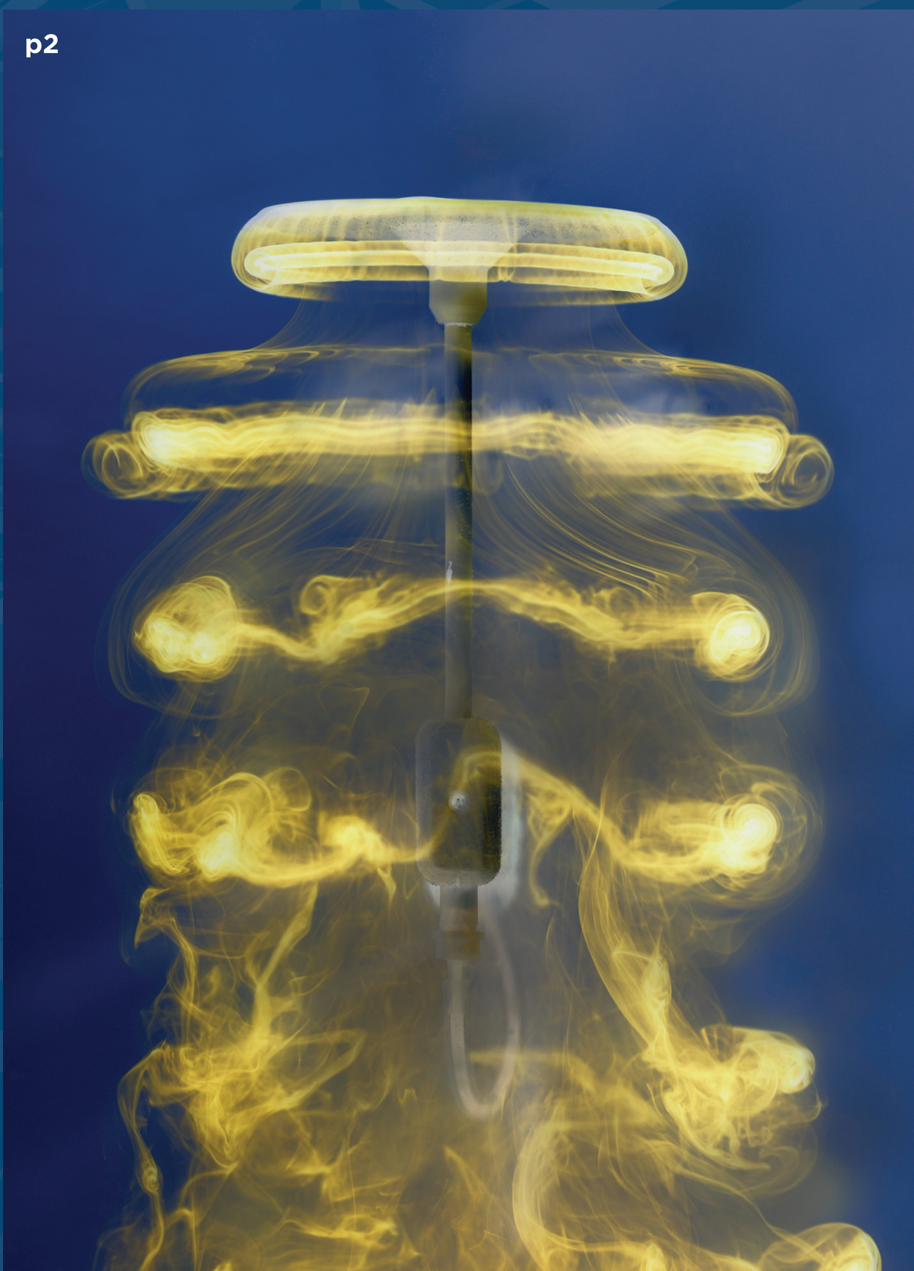
*Published by the Courant Institute of Mathematical Sciences at New York University*

# Courant Newsletter

## Leif in the Applied Math Lab

Volume 12, Issue 1

p2



p6

Changing Shapes: Denis Zorin's computational technologies for design and simulation

p5

Glen de Vries endows Chair in Health Statistics

p8

NYU GSTEM opens doors for girls with a passion for STEM fields

**ALSO IN THIS ISSUE:**



NYU | COURANT INSTITUTE OF MATHEMATICAL SCIENCES

# Leif in the Applied Math Lab

by April Bacon


Leif Ristroph shows Steve Childress a 3D-printed wing used in an experiment that reveals the most efficient flapping wing using an evolutionary algorithm. Leif Ristroph received his B.S. from UT Austin, studying under fluid mechanics experimentalist Harry Swinney. He then received his M.S. (2009) and Ph.D. (2011) at Cornell where he was an NSF-IGERT Graduate Fellow. He worked with Jun Zhang during a summer 2007 stop at the Institute, became an NSF Postdoctoral Fellow in 2011 and a full-time faculty member in 2013.

## Winging it: Can we understand the hydrodynamics of schooling and flocking?

In the Courant Institute's Applied Math Lab (AML) on the ground floor of Warren Weaver Hall sits a large bucket-shaped pool of water. Inside this pool, a simplified plastic wing is circling the tank—swimming—as it is being pumped up and down at a set frequency. Though this simulated "flapping" is forced, the swimming speed of the wing, explains Leif Ristroph, Assistant Professor at NYU's Courant Institute, is "emergent, meaning it's not set, so the wing is free to choose its swimming speed based on the fluid dynamics."

This rotational experiment was conceived and constructed some ten years ago in the AML, and because the wing goes around and around in a circle, it can "fly" forever, making it easier to study how a wing generates thrust. But Leif (which rhymes with "life") noticed something unusual one day: "I started to see weird jumps in the speed. I'd be changing the flapping frequency so it flapped a little bit harder, and instead of just incrementally increasing the swimming speed, which is what you'd expect, the speed would suddenly double."

Leif says he operates as part "manic explorer" and part "lab-coat scientist," and this jump in speed piqued the interest of the former. The data was "screaming"—it was directing Leif where to go and, like any good "explorer," he happily obliged.

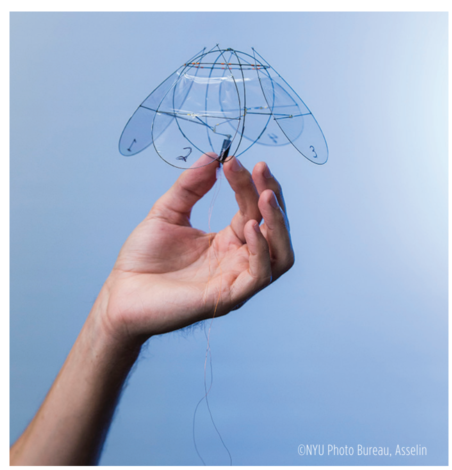
"What we realized," he says, "is that the wing was schooling with itself in this weird way. It's making a flow behind it, and then it's swimming back into it. We realized this was a great and simple way to study the interactions that [could be] happening in a school or a flock… No one knows whether fish or birds actually use these types of flows, but if they do, this is the set-up to study it in."

Mike Shelley, Co-Director of the AML and Lilian and George Lyttle Professor of Applied Mathematics at the Institute, explains that "following their nose is what good experimentalists like Leif do." With the data gathered from this unique setup, Mike and his group used the equations of fluid dynamics to create simulations of the schooling wing. On a computer screen, the simulation appears as a wing swimming in a box. The wing "is swimming and it has periodic boundary conditions so the wing swims out of one end and pops back in the other one automatically," says Leif. Just like in the experiment itself, the wing in the simulation "produces some beautiful flow, some vortices, and then it goes and plays in it."

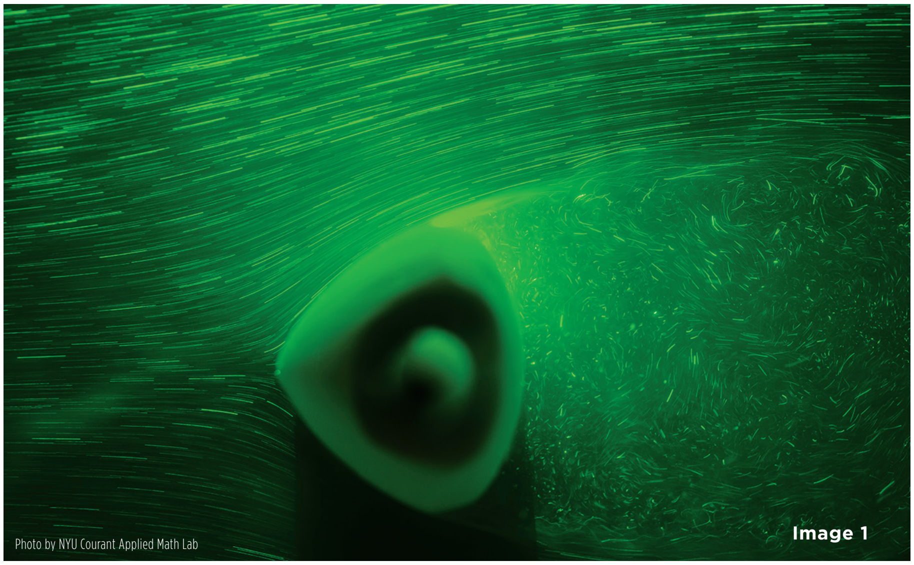
"Once you can describe [the phenomenon] in terms of a mathematical model," he says, "then you start to say that you understand it, because you know the terms that go into your equations and you know all the effects that are there. You can make predictions about what would happen if you change something. We declare victory at that point."

## Airborne Jellyfish: Can we dream up new types of flyers?

Whether derived from biology (think, internally, blood pumping; externally, a fish swimming in water) or geology (internally, the molten liquid in the Earth's core; externally, oceans and atmospheres), Leif says there is no shortage of good fluid dynamics problems involving what is called "fluid structure interactions." In fluid structure interactions, "you have a flow and an object and the two things can both change." In the case of the flapping wing, the wing forces the water to move around it, but the water also pulls on the wing. "So it's a two-way conversation," says Leif.




Leif Ristroph holds a jellyfish-shaped ornithopter that he and Steve Childress designed. The flyer has attracted a fair amount of media attention, notably being featured in the New York Times' "ScienceTake," and it's also caught the eye of about fifty "garage scientists," from whom Leif has received requests for plans so they can make a flying jellyfish of their own.




The shapes of landscapes and landforms come about because wind and water remove material and reshape surfaces. The Applied Math Lab studies these processes using simply-shaped bodies that are sculpted by flows, such as the erosion of clay objects shown here or the dissolving of hard candy in a water current.

For his work on the "elucidation of the principles of animal flight and the application of these principles to flying robotic devices,"Leif received the American Physical Society's 2014 George E. Valley Jr. Prize.

One such fluid structure interaction problem resulted in a jellyfish moving about in an unlikely fluid: the air. Usually the lab is trying to understand the physics of something mathematically, at least in part, but the goal here for Leif and collaborator Steve Childress, a Professor Emeritus at Courant, was simply to construct a flyer that was shaped like no other. They were guided by the question: what is the simplest form for a flyer? The result was an airborne, four-winged jellyfish that won't tip over. Robotic flyers need sensors so that they can keep themselves upright, which adds weight to the flyer. The aerodynamics of the flying jellyfish, however, is highly stable all on its own. Currently powered through an attached wire, the engineering goal is to tweak the aerodynamics to allow an on-board battery pack and the scientific goal is to understand mathematically how the very complex aerodynamics of the ornithopter work. While there is no functional purpose in mind for the flyer, Leif suggests it could be an art object, a toy, or a device with which to collect data from the atmosphere.

### Playing in a Mathematician's River: What is the simplest approach to studying erosion?

Up until 2011, Leif had been focused on biological and aerodynamics problems and decided he wanted to try a geophysical problem, namely, geomorphology, or how landscapes are formed by erosion. "Air and water are both fluids—and [with erosion] they're carving the structure very slowly," says Leif. Most experimentalists in the field might try to replicate wind blowing over a mountain, but Leif, as an outsider, took a different approach similar to many AML experiments: he stripped down the problem to just the bare minimum of physical ingredients.

"Erodible material, simple flow. Let's see what happens," he says.

The simple flow would be generated by the AML's water tunnel, or what Leif calls a "mathematician's river"—a 40-gallon tank of water that has tunnels through which water exits the tank at one end, re-enters at the other, and flows at equal velocity all the way through before exiting once again. So all that was needed was the right erodible material to suspend in this flow.

At this intuitive stage of the experiment, Leif searched for the "trick"—in this instance, the erodible material—that would make the experiment successful. Finding that trick (every experiment has at least one, he says) can involve a bit of trial and error. In case you don't have a mathematician's river handy, here's what happens to the following materials in a steady flow of water: sand disintegrates, a lollipop dissolves instead of eroding, chalk is too hard to erode at a speed conducive to lab study, and soap lathers so that nothing but frothy bubbles can be seen ("Probably the tunnel has never been so clean," our experimental physicist says). But through this "systematic progression to the beautiful experiment," finally the right material came along: a special type of pure clay called bentonite.

In the then tightly-controlled experiment, Leif and collaborators watched the interaction between clay and water, and recorded videos from which data could be collected.

Here's what happens inside the tank: the water and clay conspire to make a surface where the shear stress—the force of the two layers (the water and the clay) pulling on each other in opposite directions—is uniform at the clay's boundary. The flow meets the body at a thin boundary layer where, as Mike explains, "all the action is." Here, one can see the material begin to wear away and slowly take a shape. The interaction between the two then "works itself out to some answer," says Leif, "Which would be, in this case, the shape of the object."

What they found was that, regardless of the speed of the water flow or the initial shape of the clay (cylinder, sphere, etc.), the clay would always over time become the same slightly conical shape (see Image 1) and would then maintain that shape until it disappeared. This phenomenon of maintaining the same shape is called self-similarity. In a subsequent experiment, the lollipop was revisited, and it turns out that with dissolution, the lollipop is polished into a super *round* shape, but then the same thing happens—once that super round shape is formed, the candy shrinks in a self-similar way.

"What we're trying to figure out is why, in the end, is this *self-similar* shrinking—why is that the final state of the system? We have

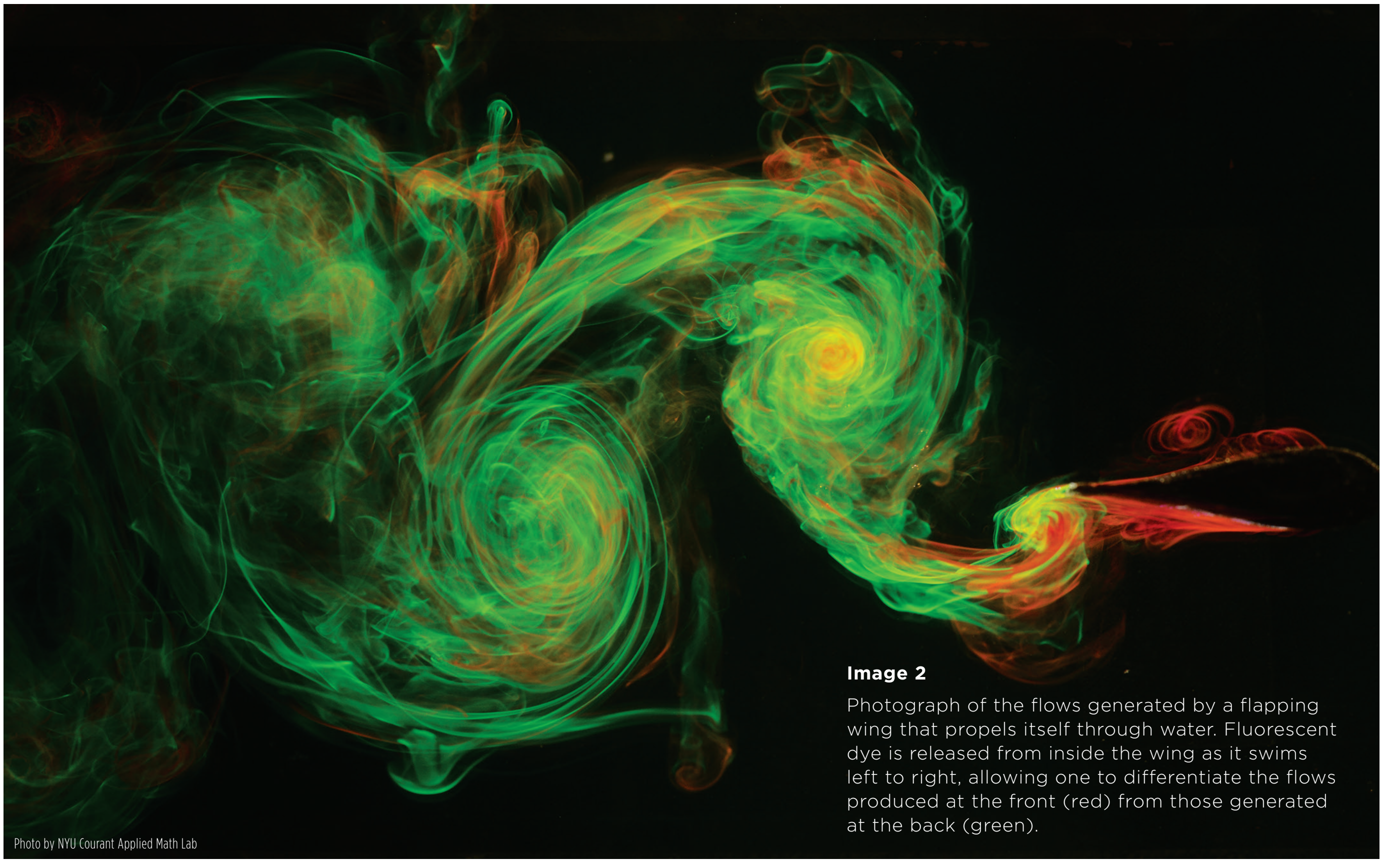


Photo by NYU Courant Applied Math Lab

**Image 2**

Photograph of the flows generated by a flapping wing that propels itself through water. Fluorescent dye is released from inside the wing as it swims left to right, allowing one to differentiate the flows produced at the front (red) from those generated at the back (green).

some loose arguments for it, but we'd also like to see if this happens in other systems."

Melting is one such system, for which Leif says, "You probably have to chill the whole tunnel because if you put ice in room temperature water it's gone—in the flow it's gone in seconds. So we have to think about the right strategy for doing that."

A fourth system arrived along with Neil Balmforth (University of British Columbia), who was visiting the Institute to give a seminar talk. When discussing the clay experiment with Leif, he noticed the clay's conical shape resembled an oriented meteorite, which is a meteorite that, it is thought, kept its orientation from the point it entered Earth's atmosphere all the way down to the surface—much like the directed, constant flow inside of the tunnel. Out of that conversation a new experiment was born: the study of ablation. "That's of course why it's so great to talk to such a variety of scientists around here," says Leif. "It's great that Courant has so many seminars because you have all of these speakers coming through [with such diverse backgrounds]."

The "trick" for the ablation experiment is still in the works. Leif did try one experiment which involved a hair dryer (a hot flow) aimed upward at a suspended ball of wax, but it ended prematurely due to protests from his lab companions. "It was blasting molten wax all over the lab. I had an umbrella above it to try and catch some of it, but it didn't work very well."

## Unreasonable beauty: What is the most efficient flapping wing?

In contrast to a busy day during the school year when any of the AML's full-time faculty might be joined in the lab by its two postdocs, two grad students, and four or five undergrads, on an August afternoon this summer it is relatively quiet. Two visiting high school interns are in the lab, one looking at simulations on a computer, another tinkering. A video plays that Leif and postdoc Sophie Ramananarivo captured of a wing flapping in the tank, with fluorescent dye fed into the wing to make the flow visible (see Image 2). Leif and Steve stand, watching the video of the wing flap on an endless loop.

In this experiment, the swimming speed of flapping wings was improved by mimicking biological evolution: the shapes of wings are described by mathematical "genes," and mixing and matching genes from different wings led to better swimmers. There were 15 generations of these wings, and eventually the improvements resulted in the wing in the video, the fastest wing. By visualizing how this wing manipulated the flow around it, and also conducting simulations of these flows, the team is beginning to take the first steps towards building an aerodynamic theory for such motions and shapes.

After a few more cycles of the recording, Leif points to an area of the wing that looks like twirling mist: "I like the little tumbleweeds that flow down the wing," he says, then falls into silence for a few more rounds. The flow is mesmerizing. At the start of the video, the wing is still, but then, in lifting up, wafts off a first gorgeous green and orange spiral from its nose, which flows outward and is followed by more softly-spiraling vortices. When the wing stops flapping, there is hardly any delay before the flow flatlines once again.

Of the beauty of the flow, Leif says under his breath: "That's unreasonable." He immediately looks to Steve, who shakes his head in a knowing silence: "Yes."

# Glen de Vries endows Chair in Health Statistics

by April Bacon

Glen de Vries, Co-founder and President of the technology company Medidata, has endowed a Chair at the Courant Institute.

"This gift establishes the Glen de Vries Chair in Health Statistics at Courant," said Gérard Benarous, Director of the Courant Institute of Mathematical Sciences. "Simply put, it is a remarkable gift which will allow us to attract a top scholar and will permanently bolster our strength in the field. We are deeply grateful for all that the chair will enable the Institute to accomplish, and all the more that it has come from Glen de Vries at Medidata, our neighbor in lower Manhattan, a pioneer in modern healthcare, and president and co-founder of a company central to the tech industry in New York."

"We need more people to go into academic disciplines and ultimately fuel what happens in the healthcare and life-sciences industry," said de Vries, who studied probabilistic algorithms at Courant and received a bachelor's degree in molecular biology and genetics from Carnegie Mellon University. De Vries, in 2013, also established the first student fellowship at the Center for Data Science. "I want to help make sure that people who are motivated to be in [the data science for healthcare] world from an academic perspective have terrific opportunities and terrific training," he said.

De Vries speaks with passion about the "gargantuan" effect—not just quantitatively, but *qualitatively*—that data science is having on the healthcare industry: better managed clinical trials and better methods of gathering and analyzing data from clinical trials mean better and more personalized care for patients, as well as better healthcare management on the large-scale, too. "[Data science is] going to change the way everybody thinks about the equation of treating certain diseases and managing public health," said de Vries. "Really, this is the manifestation of, at least from a pharmaceutical perspective, what personalized medicine is really about."

"So 20 years ago, if you created a drug that really worked for a third of the people you gave it to, or half the people you gave it to, that was an incredible victory," de Vries explained. "Now we're looking for drugs for a much narrower set of people because our criteria for who should take [certain drugs] has become much more stringent."

"Patients are so unique," de Vries continued. "When it comes to healthcare, every level of an individual's state of health can be important: all the way down to an individual's genome and up to the whole person, including phenotype, behavior, and environment. All of this information can and should be used to dictate how you treat that patient." Medidata is enabling life science companies to do just that.

The idea for Medidata grew from one encounter in the mid-90s. De Vries was a research scientist at Columbia Presbyterian Medical Center, and his "boss's boss's boss" asked him to run a clinical trial. It was a new experience for him, so as a self-described "computer-nerd," he asked a surgical resident and friend across the hall for advice on the best software to manage the trial—software he soon discovered did not exist. "That was really the moment when I started thinking that this is interesting, and maybe there's a better way to do this."

Glen de Vries

Photo by Saskia Kahn

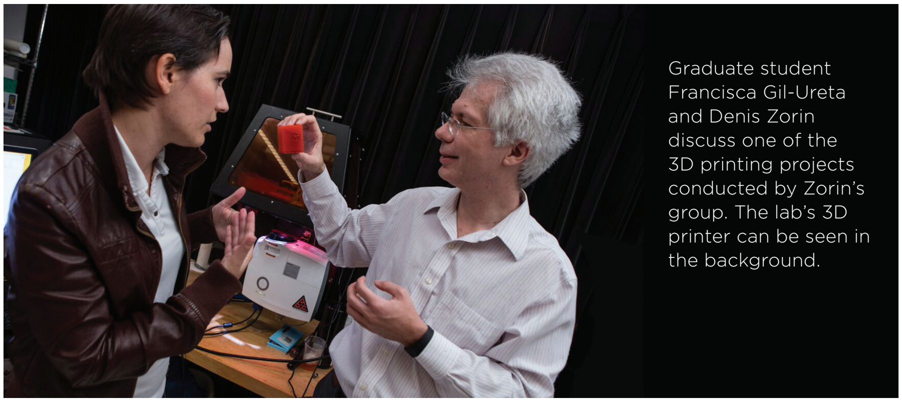
(Left to right) Gérard Benarous, Glen de Vries, and David Sontag celebrate at a November 18 reception following Sontag's lecture "How Will Machine Learning Change Health Care?" The events in celebration of the Glen de Vries Professorship in Heath Statistics were held in Warren Weaver Hall.

Medidata was founded a few years later, in 1999, in de Vries' sixth floor Manhattan walkup, with the idea that the company could use the expanding infrastructure of the internet to approach clinical trials in a new way. With Tarek Sherif, Chairman and CEO of Medidata, at his side, the company has now become the largest public technology company to ever be founded and have headquarters in Manhattan. As a provider of cloud-based solutions, it enables more than 500 companies to improve clinical development and, therefore, patient care. "I thought I'd only be studying in one therapeutic area, and now I get to look at interesting problems in endocrinology and cardiology and virology [etc.]," said de Vries.

Of his work with Medidata as well as his gift to the Courant Institute, de Vries concluded, "I'm in this crazy, lucky place where it's possible to give back to the community in the biggest sense."

# Changing Shapes: Denis Zorin's computational technologies for design and simulation

by April Bacon



Graduate student Francisca Gil-Ureta and Denis Zorin discuss one of the 3D printing projects conducted by Zorin's group. The lab's 3D printer can be seen in the background.

Denis Zorin received a Ph.D. in Computer Science at Caltech. He joined the Courant faculty in 1998 after a year at Stanford as a Research Associate. He is the recipient of an ACM Gordon Bell Prize, and won three IBM Partnership Awards, an NSF Career Award, and a Sloan Foundation Fellowship (2000).

"If you see the same basic questions coming up in several contexts, it's worth looking at those questions," says Denis Zorin, Professor and Chair of Computer Science at Courant. The statement is in regards to three of his current projects, which at the application level appear to be quite different: designing a library of 3D-printable patterns which produce different deformation behaviors, simulating vesicles in a flow, and developing new tools for making high quality surfaces in computer generated graphics. But the root of each of these projects is the same: "As far as the geometry is concerned, it's really the same questions asked in different contexts," says Denis, a world expert in geometric modelling and geometry processing.

What 3D printing and simulating blood flow have in common, Denis explains, is that "both require you to deal with changing shapes." In both cases "we need to solve equations on complex surfaces efficiently, and how we deal with geometry—how we represent geometry, how we modify it efficiently with complicated shapes—these are the two algorithmic and mathematical areas that underlie both of these topics, and, of course, are directly connected to the third one."

Another commonality among the projects is that they put advanced computational tools in the hands of other people—each, in its own way, opens up possibilities for others to create better products, better technologies, and better graphics. Each can impact a broad range of applications, often in ways that are hard to guess.

## A new world of design possibilities

When it comes to manufacturing, Denis explains, we're used to either mass production, or construction of very complex objects, like a power plant or a plane. In either case, the cost of engineering design and production is offset by the scale of the project. With additive fabrication—3D printing in which an object is manufactured by material being added layer upon layer—unique objects can be created one at a time. "The exciting thing," says Denis, "is that, in many cases, the cost to make [objects] with a complicated structure is the same as [or cheaper than] the cost of making a solid block of material [such as a simple cube]. … This opens a whole new world of design possibilities."

Additive fabrication has the potential to change manufacturing, especially for customized, one-of-a-kind products, and to bring the power of design and manufacturing into the hands of more individuals. But while the technology exists, taking advantage of its capabilities requires specialized knowledge that the average person doesn't have. That's where Denis and his collaborators—including Courant Professor of Mathematics Bob Kohn, and Computer Science PhD students Julian Panetta and James Zhou—come in. Building on previous work in shape and topology optimization, they've constructed a library of structures that can be used to assemble complex objects with desired behaviors — for example, contracting, expanding, and twisting under pressure.

"You can have just about any behavior that's physically possible," says Denis. Even behaviors which seem impossible, such as a cylinder expanding (rather than contracting) in the middle when pulled on each end (an already-known structure that is useful for sealing gaps). All the user has to do is specify the desired behavior, run the software optimizing the structure, and print.

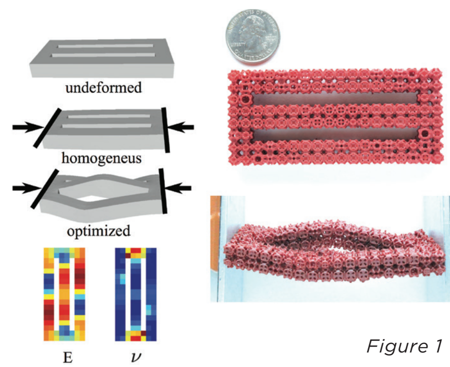



*Figure 1*

Figure 1 shows an example of how deformation behavior can be modified by applying different structural patterns. Each of the three connected bars differs only by how the structural patterns vary along each. Because of this structural difference, under compression, the middle bar bends up while the others bend down.

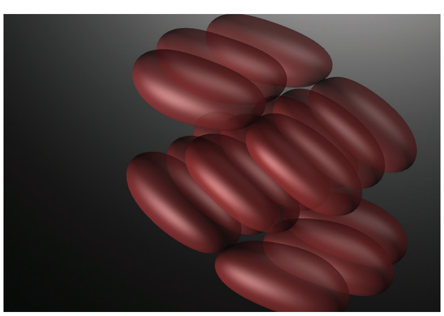
Denis' interest in the project was piqued after an encounter with a founder of SOLS, a startup company that designs shoe inserts. With the inserts, "you want some customized interface between yourself and the shoe," explains Denis—the insert should be soft or hard in the right places, and weight should be distributed uniformly. "It required a carefully chosen structure, that was designed by hand. So we have asked ourselves the question if it can be designed automatically for each person."

Other personalized objects include prosthetic devices, which Denis says are increasingly being made with 3D printing—"that's really a revolution there, to make [prosthetics, such as limbs] perfectly fit." The technology can also be used in dentistry, and some of the work by Denis and collaborators is supported by a grant shared with faculty members at the NYU College of Dentistry, who are interested in printing bone scaffolds. "They want the person's own bone to grow into the scaffold," explains Denis, "but they have to have a very particular structure for that. It has to have pores of certain size … and at the same time the structure needs to maintain strength so that when you bite [down] it doesn't break."

The results of the microstructure design work are not only "practical," but also "aesthetically appealing," says Denis: "because it turns out that there are a small number of structures—different ways to connect the rods in the microstructure—that are sufficient to capture a pretty big space of different material behavior."

Other recent projects address different aspects of automating the design process. In one, Denis and collaborators employed concepts used by mechanical engineers to create computations that can simulate "how [an] object will respond to different kinds of loads," such as the pressure one can apply by hand. The computer simulations enable object designers to both identify and see how to fix parts of an object that are susceptible to breaking without having to be an expert at engineering analysis. And in a new project, Denis says, they are designing materials that result in different degrees of roughness and softness. The projects as a whole make large advances toward ensuring high quality, highly-customized objects and toward the ultimate goal of increasing the accessibility of engineering design.

## A simulated view of blood flow



A simulation of interacting vesicles in shear flow.

For a decade, Denis and collaborators have been working to create accurate, efficient, and robust simulations of the flow of blood. The complexity of this work is multilayered. For one, a single drop of blood contains "several million cells," says Denis, and, also, the behavior of blood flow is "interesting and unpredictable because of the complex structure of the fluids, unlike, say, water, or some other very homogenous fluid." As an example, the wall of a blood cell doesn't always maintain its flexibility. If the walls of cells become more rigid, the blood flow may have a harder time getting through smaller blood vessels.

"There are many, many moving parts in our software," explains Denis, "It's a pretty complicated approach that we're taking." But the researchers hope that their methods will enable innovation in technologies that wouldn't be possible with an approach that is "more conventional or that is already used in practice in engineering." A good simulator, for example, could be used to help design "a cell sorter that will direct flow to some microfluidic device in a particular way, sorting some type of cells one way, another type [a different way]."

Denis began working on the flow of vesicles in the early 2000s with then-graduate student Lexing Ying and then-postdoc George Biros. Ying has since moved on to other research areas as a Professor at Stanford, while Biros, who is now a Professor at UT Austin, remains one of Denis's main collaborators on the work. The initial inspiration for the project was Courant Professor Charlie Peskin's work on heart simulation, and the goal was to make these simulations more accurate. But the heart and the flow within the heart were too complex, especially in addition to the already complicated nature of blood flow, so instead they decided to start with small scale flows—such as small blood vessels, long molecules, or "any kind of membranes immersed in fluid," says Denis—and a direct approach: "[immerse] lots and lots of cells in the fluid and see how these flows behave."

The simulations use integral equations. "What integral equations allow us to do is to only look at the surface of the [boundary], nothing more. And this makes the problem much simpler computationally in a certain sense," explains Denis. To do this, Denis and collaborators adapted the Fast Multiple Method, a ground-breaking method for computing certain types of integral solutions developed by Courant Professor Leslie Greengard and collaborator Vladimir Rokhlin in 1987.

As a computer scientist, Denis is drawn to the computational aspects of the work because he says, "along the way we were able to design a few algorithms which [I believe] actually apply much more broadly," and will be useful extended even beyond the work of simulating the flow of vesicles. ■

### Surface Matters

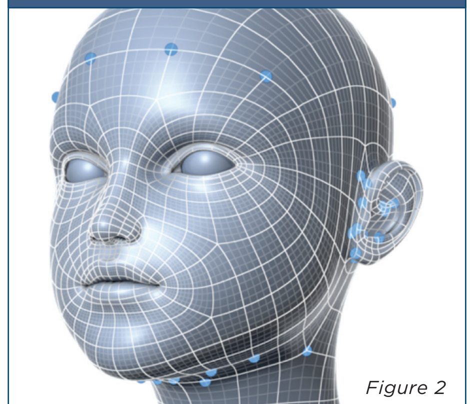


*Figure 2*

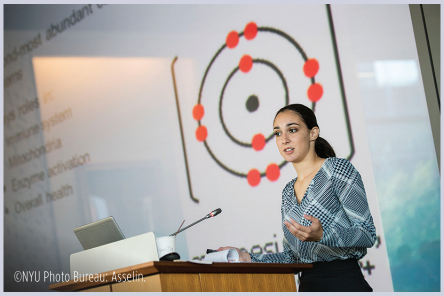
The work in geometric modelling conducted by Denis and collaborators aims to develop more flexible approaches to representing smooth surfaces and automatically converting triangle meshes to this form. High-order surface approximations are essential for many applications, including accurate shape optimization for 3D printing as well as flow simulation.

One aspect of the work aims to automatically convert a fine mesh to a set of smooth quadrilateral patches: a surprisingly difficult task, requiring algorithms building on advanced concepts from differential geometry. Another aspect is the development of smooth representations allowing flexible local refinement, while retaining surface quality. In Figure 2, one can see an adaptive transition to a finer resolution near the ear and in the neck region, achieved while maintaining high surface quality and smoothness of parametric lines.

While a lot of computer graphics geometry-related work is driven by applications in computer animation and games, Denis explains, it has been and continues to also be used widely for scientific visualization, scientific computing and computer-aided design.

# NYU GSTEM opens doors for girls with a passion for STEM fields

by April Bacon




Tal Moriah presents at the GSTEM symposium on Friday, August 14.


Lucy Cheung adjusts cameras inside of a 3D printed skull for her project "3D Image Acquisition," mentored by Stephen Holler.


GSTEM students work together to construct a model bridge in Brooklyn Bridge Park.

This past summer, thirty-seven high school girls came from areas across the New York metropolitan area and formed a new community in Manhattan. They were participants in the third annual Girls' Science, Technology, Engineering, and Mathematics (GSTEM) program at NYU's Courant Institute, a project funded by the Alfred P. Sloan Foundation and with some student scholarships provided by the Winston Foundation, the Courant Institute, and an anonymous Courant alumna.

GSTEM, which accepts applications from girls across the nation, is led by Matthew Leingang, Principal Investigator on the grant and a Clinical Professor of Mathematics at Courant. As he explains, the program "is designed to address two problems that have surfaced in the research about women leaving science and STEM fields." The first is "a lack of mentorship and [the second], a lack of community in the field. So one goal is to provide the girls with top-notch research experiences mentored by a STEM professional and the other is to build [GSTEM] into a community."

This year's group spent just over four of the program's six weeks working in a lab before presenting their work at a culminating symposium on August 14. The presentations tell of an impressive array of research experiences, including studies to find predictive data for gentrification, to understand balance in zebrafish, to define the level of background noise at which the human ear can still discern phonemes, and to map how genes are arranged in chromosomes.

## Aileen Venegas

This final area was explored by Aileen Venegas, a high school student from Long Island. Aileen was working with Trushant Majmudar, a Clinical Assistant Professor of Mathematics at Courant who has been a mentor in the program since its inception in 2013. As Trushant explains, the work is part of a collaborative project with a lab run by Prof. Ana Pombo of the Max Delbrück Center in Berlin, and the goal of the research is to understand which genes are interacting and which are not in both stem cells and neurons. Aileen's work was to analyze the structure of the two with an eye for the similarities and the differences.

"I was nervous," Aileen says of the project. "But [Trushant] gave me PDFs and books and was very helpful and he guided me through it … I was able to understand it all," she says with justified pride.

In addition to her mentor, Aileen sang the praises of the whole GSTEM community, including the tutor who taught Matlab and the programming language "R" to her and other students with no previous coding experience.

She also adds that "just the girls" got to go on Friday fieldtrips, trips which included speakers who introduced girls to professionals across a wide variety of fields. "We saw the Brooklyn Bridge," she says, to which Trushant interjects, "I've never been there."

"We went to the Federal Reserve," she says.

"I haven't done that," says her mentor.

"And we went to Google."

"I haven't done that. So now you know more New York than me," he concludes with a smile.

Aileen says she has always been interested in biology. "When I was growing up I wanted to be a doctor. When I realized I had more passion for mathematics instead of science, I started researching in it. I stumbled upon biomedical engineering. That's what I'm planning to pursue in college."

"You'll be a perfect fit," says Trushant.

## Tal Moriah

The "vertical community" GSTEM seeks to build, as Matthew Leingang explains, includes peers, graduate student tutors, the GSTEM coordinator, graduate students in the lab they work in, mentors and guest speakers.

One of the mentors from NYU's Chemistry Department, Assistant Professor Daniela Buccella, says she's also seen "that by having alumni from the previous years come and speak with the current students, they're expanding their network."

Daniela is a big part of the reason why there are so many GSTEM mentors coming from the chemistry department. She has encouraged her colleagues because GSTEM is not only important for the girls, "but also for the labs themselves," she explains, so that undergraduate and graduate students, some of whom are considering careers in education, have the opportunity to mentor someone. And the relationships that are created there seem to stick: "Every student that has been in my lab," she says, including those who have now gone off to college, "has been in touch with both their undergraduate and graduate [student mentors]."

Tal Moriah, who was mentored by Daniela this year, makes it clear that GSTEM is a tightly-bonded community: "The girls in my tutoring group are so close," the Long Islander says at the symposium's conclusion. "We're actually going to sit in Washington Square Park right now."

Tal was working on a project seeking to better bind magnesium to the chemical Aptra. According to Daniela, the project is representative of the broader work being done in her lab "to develop indicators for tracking metal in biological samples, specifically in cells, in order to study how disrupted metal homeostasis relates to disease." Aptra is one binding group that the lab is using to bind to the metals in order to visualize them.

In the project, Tal was running titrations—a technique in which the solution of a known concentration is used to determine the concentration of an unknown solution. In her presentation, Tal joked that she had probably run 40 titrations (an amount she later admitted was probably hyperbole), many of which were required for the experiment, and once when one of the machines stopped working. Despite having to redo the test, Tal didn't get discouraged and said she was grateful for the patient guidance of her lab.

"I'm a huge fan of things not going right," says Christine Keefe about similar experiences some of the others girls have had. Christine is this year's GSTEM coordinator who brings to the task an impressive track record as a champion for girls in STEM fields. "Because that's what real science is, putting out fires, you know? We had a couple of days where [the girls] said 'Oh, nothing's working!' and I said, 'Wait a minute, it sounds like everything's working! It sounds like you already came up with a solution!' And I think that's one of the big ideas behind this experience, is that they learn what real science is versus Hollywood science."

Tal wants to go into engineering and says her experience in the Buccella lab has made it easier for her to decide whether to go into "chemical engineering or any sort of biomedical engineering."

Tal's concluding thoughts on the program? "Yay GSTEM, yay!"

## Amy Chan

As Christine explains, the statistical success of the program will begin to be clear by the end of this academic year, when the 2013 cohort enters their sophomore year of college. This is because "Girls that withdraw from STEM typically do so within the first two years of college," she says. But at the program's celebratory conclusion, it seems unquestionably true that the experience has been formative for the girls. And there is already some anecdotal evidence of the program's ability to give girls a big leg up.

Amy Chan, originally from Westchester, participated in GSTEM's first two years and, although she applied for a biology internship in her first year, was placed in Keith Woerpel's chemistry lab at NYU. She was working with Keith's group on the chemistry of peroxides, compounds that have two oxygen atoms connected together. Keith explains that "the number one treatment for malaria involves a compound with two linked oxygen atoms, so we've been interested in seeing whether they're useful for any other medicinal purposes." Amy "really thrived in the environment," Keith says. "She was doing hard chemistry to be honest."

"The first summer I worked on developing a methodology for installing a peroxide functional group into a ring," says Amy, "and then the second year I applied that methodology in an attempt to synthesize what we believe to be an anticancer drug. That was very important to me because my grandmother passed away from stomach cancer when I was seven years old.

"I've learned so much from Keith and the graduate students I had the privilege of working with. My experience there was—I would say life changing, because I'm now a chemistry major at Yale!" says Amy, who, in her freshman year, is taking Multivariable Calculus, Intro to Microeconomics, Intro to Classical Buddhist Art, and Freshman Organic Chemistry.

Placing into Freshman Organic Chemistry "is rarefied air," says Keith. "Essentially she vaulted a year ahead of what a student would normally start off with."

Not all of her GSTEM friends ended up in the area of their lab placement, but Amy says that the experience all of the girls received was "very rewarding," whether it introduced them to their career path, or "the complete opposite." She is still good friends with a lot of the GSTEM girls, and says "I have friends who [had both experiences]. I have a friend who is now studying poli-sci although she researched in an inorganic chemistry lab…And I have a friend who conducted computer science research, and she's a dual math and comp-sci major at Brown now."

Amy concludes by recommending the program to any girls who have even a remote interest in STEM subjects. "I fell in love with not only the research I was doing," she says, "but with the family I became a part of in the lab, and the community I found with the other girls I met during GSTEM." ■

## MORE HIGH SCHOOL ACTIVITIES

**The Center for Mathematical Talent (CMT)**
The CMT at Courant coordinates activities for students in the New York City area who would like more mathematics than is included in the usual mathematics classroom.

**Find out more:**
www.math.nyu.edu/cmt

**CSNYC**
CSNYC in partnership with NYC announced an $81 million public/private partnership to make Computer Science education available to every student in NYC public schools. NYU Courant's Evan Korth is co-founder (with NYU Trustee Fred Wilson) and was founding Executive Director of CSNYC.

**Find out more:**
www.csnyc.org/

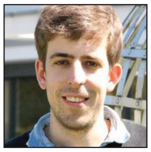
**cSplash**
Courant Splash is an annual one-day lecture series at the Courant Institute of New York University, aimed at mathematically-inclined high school students in the New York metropolitan area.

**Find out more:**
www.csplash.org/

**New York City Girls Computer Science and Engineering Conference**
Organized by Courant's Women in Computing (WinC), this annual one-day conference for 9th and 10th graders gives young women a taste of the tremendous creativity and innovation involved in computer science and engineering and science careers, and shows young women how these fields can help change the world.

**Find out more:**
nyuwinc.org/hs-conference/

## **WELCOME** TO OUR NEWEST FACULTY



**Afonso Bandeira**, Assistant Professor of Mathematics in association with the Center for Data Science, received his Ph.D. in Applied and Computational Mathematics from Princeton University (2015). His research interests are in data-inspired applied mathematics, often involving probability, optimization, mathematical signal processing, theoretical computer science, machine learning, and statistics. Bandeira is currently an Instructor of Applied Mathematics at MIT and is looking forward to arriving to the Institute in the Summer of 2016.

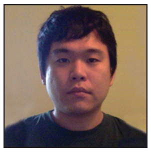
**Sophie Marques**, Clinical Assistant Professor of Mathematics, received her Ph.D. in Algebraic Geometry from the Université Bordeaux I & Università degli Studi di Padova. She was formerly a Visiting Assistant Professor at Courant. Her research interests include ramification theory and holomorphic differentials.

**Daniele Panozzo**, Assistant Professor of Computer Science, received his Ph.D. from the University of Genova (2012). Most recently, Panozzo was a senior postdoctoral researcher at ETH Zurich. His research interests are in digital fabrication, geometry processing, architectural geometry, and discrete differential geometry. He will join the Institute in Spring 2016.

**Anasse Bari**, Clinical Assistant Professor of Computer Science, holds a Ph.D. in Computer Science with a focus on data mining from George Washington University. He has over eight years of experience in software engineering. Bari has recently worked for the World Bank Group and he is the co-author of the book *Predictive Analytics for Dummies.*

**Carlos Fernandez-Granda**, Assistant Professor of Mathematics in association with the Center for Data Science, received engineering degrees from Universidad Politécnica de Madrid and École des Mines de Paris and a Ph.D. from Stanford. His research focuses on developing and analyzing optimization-based methods to tackle inverse problems that arise in applications such as neuroscience, computer vision, and medical imaging.

**Alena Pirutka**, Assistant Professor of Mathematics, received her Ph.D. in Mathematics from Université Paris-Sud XI, Orsay (2011). Her research interests focus on algebraic geometry and number theory, in particular on studying rational points and zero-cycles on algebraic varieties, Chow groups and cohomological invariants of algebraic varieties, birational invariants and questions on rationality properties of algebraic varieties.

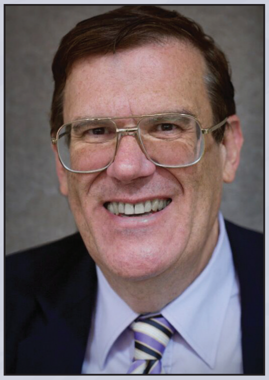


**Kyunghyun Cho**, Assistant Professor of Computer Science in association with the Center for Data Science, was previously a postdoctoral researcher at the University of Montreal and obtained his doctorate degree at Aalto University (Finland) in early 2014. His main research interests include neural networks and generative models and their applications, especially to natural language understanding.

**Alfred Galichon**, Associate Professor of Mathematics and Economics, received his Ph.D. in Economics from Harvard University (2007). His research interests are in optimal transport and its applications, matching, consumer theory, hedonic models, risk sharing, risk measures, and quantile regression. Most recently, Galichon was Professor of Economics at Sciences Po, Paris, and Visiting Professor of Economics at MIT.

**Randy Shepherd**, Clinical Assistant Professor of Computer Science, earned his M.S. in Computer Science from NYU (2012). His research interests include software engineering, agile and lean start-up methodology, functional programming (specifically Scala) and CS education and teaching methods. He joins us after a 15-year career developing software across a variety of industries such as gaming, finance, advertising and media.

# In Memoriam: Robert Dewar



Robert Dewar was a genius in software design, certainly one of the best of his generation in Programming Language design, implementation, and optimization. In addition, he was a tireless teacher and an exemplary stylist in all he wrote. His students and his colleagues learned immensely from his example, his lucid prose, his elegant code, his brilliant lectures, and his invariably original ideas on everything computer-related.

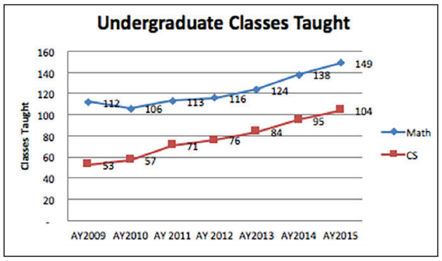
Robert came to the Courant Institute in 1975, recruited by Jack Schwartz to add to the young CS Department an expert in language design and implementation. Robert was a member of the Algol68 committee (which continues its long life as the WG2.1 group of the International Federation for Information Processing). Robert was also the virtuoso implementer of SNOBOL, a pattern-matching language with a notoriously complex semantics. Robert provided a portable implementation that was orders of magnitude more efficient that the original one (and was dubbed Spitbol on this account).

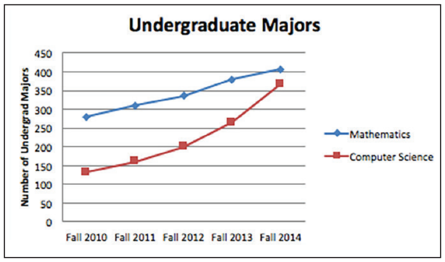
Robert was chair of the Department from 1978 to 1980. In 1982, in collaboration with Jack Schwartz, he launched a project to provide a formal executable definition of Ada, a newly-designed general-purpose programming language. This was the beginning of the Ada-Ed project at CIMS, which ran for over a decade, provided the first freely-available compiler for the language, stimulated research in optimization and software prototyping, and eventually served as a testbed for the evolution of the Ada language.

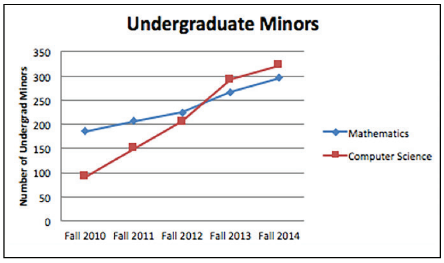
Along the way Robert, in collaboration with Matthew Smosna, wrote an original textbook on the architecture of microprocessors, created some of the first programming utilities for the new IBM PC, and wrote (with his long-time collaborator Ken Belcher) the first complete implementation of COBOL for a personal computer.

In 1995, after the Ada-Ed project created the first implementation of Ada95, Robert (in collaboration with Richard Kenner and Ed Schonberg) created AdaCore, an Open-Source software company to develop Ada-related software. Robert was its chief designer, software architect and CEO. Robert retired from

# Undergraduate enrollment on the rise at Courant




Over the past five years, the Courant Institute has seen a dramatic increase in enrollment numbers as the demand from majors and non-majors alike has gone up for both Computer Science and Mathematics courses. Each department has responded to the need by employing new teaching faculty who demonstrate excellence in the classroom and sophistication in curricular issues. The Mathematics Department has brought on board new clinical faculty with a strong background in advanced mathematics, and Computer Science, in addition to new clinical faculty, has recruited many industry professionals from across New York City as adjuncts.

Computer Science courses have seen an across-the-board increase in enrollment. “It’s a part of a national trend,” explains Denis Zorin, Chair of the Computer Science department. The increase in enrollments is different from previous waves. Now, “a lot of growth comes from non-majors,” he says, who are finding it advantageous to add computer science skills to their main domain of studies. The Web programming and applications minor in particular has seen large increases in enrollments of students from different majors and schools such as Economics, Business, Art, and Biology. In response to the demand, the department has significantly revised its non-major curriculum to adapt it to the needs of students with diverse backgrounds.

Much of the new demand in mathematics coursework has come from Economics, for which, Vice Chair for Undergraduate Affairs Matthew Leingang says, a new sequence of courses was created. But, also, more students are taking on double majors or additional minors in Math, so there have naturally been enrollment increases in those core classes. One exception is Calc I and Calc II, which have not increased even though Calc III has, because, as Matthew explains, “many of our students are entering with credit for Calc I or Calc I+II from examinations like AP Calculus, A levels, International Baccalaureate, etc.” There has also been an enrollment increase due to a new honors analysis/algebra track, which, as Matthew says, was designed “to enhance opportunities for the strongest pure math students.”

---

NYU in 2005, and guided the development of AdaCore until his death. In addition to his multiple software activities, Robert became a very public advocate of open source software development, and found himself in demand as expert witness in legal disputes over software patents (with his profound knowledge of the history of software engineering it was always easy for him to find the prior art that made proposed patents unenforceable!).

On a personal level Robert was a perfectly unique individual, infinitely energetic, unfailingly upbeat, always ready to provide ideas if you asked for advice, and had an endless store of wit in all situations. His judgment could be harsh (his colleagues provided him with an old-fashioned ink stamp labelled “JUNK” that he used with glee) but he was incredibly generous with his time and his wisdom, and a casual comment of his could illuminate an issue that had someone hopelessly stumped for days. At the same time, he never heard an argument he did not want to engage head-on, and his colleagues all recall epic discussions on technical, legal, political, or musical issues that went on for days (and which he usually won by force of conviction and unbeatable persistence). He was a born teacher, and his lectures were justly celebrated, but it came down to the fact that he seemed to be able to think faster and more clearly than most.

Robert was also a devoted family man, and he displayed for years an extraordinary dedication to the care of his wife Karin, who suffered from early-onset Alzheimer’s disease. As in all his other endeavors, he maintained a fundamental optimism in the face of what was a heart-breaking situation.

Finally, he was also a born entertainer, in the widest sense (because he had such a wide repertoire). He brought immense joy to singing: he was a long-time member and benefactor of the Village Light Opera Group, where the title role in “The Mikado” was one he owned. He had the same enthusiasm when playing one of his multiple wind instruments (he played the bassoon in the Broadway Bach Orchestra, and was a member of the Heckelphone society), leading a performance of an obscure piano work for six hands for which he had just found the score, or conducting the rewritten Gilbert & Sullivan operettas that he created for the enjoyment of computer nerds everywhere. The entire CIMS, NYU, and computer science community were profoundly lucky to have known him, and to have basked in his irrepressible life force.

—Ed Schonberg

# Courant and ECNU form a new math institute in Shanghai

The Geography buiding which houses the NYU-ECNU Institute of Mathematical Sciences

NYU's Courant Institute and East China Normal University jointly formed the NYU-ECNU Institute of Mathematical Sciences in 2013, with the goal of extending NYU Courant's renowned research and educational programs from Washington Square to Shanghai. Under the leadership of Courant Director Gérard Benarous and of Co-Deputy Directors Fanghua Lin (NYU Courant) and Xingbin Pan (ECNU), the foundation of that vision has been built.

The math institute at NYU Shanghai (NYUSH) is housed in ECNU's Geography building in Puxi (along with other NYUSH research institutes) in a beautiful river- and lake-dotted setting typical of Shanghai, the largest city by population in the world. Within its first three years, the math institute has presented a multitude of weekly seminars and lectures by mathematicians from around the globe; built a growing undergraduate major with an honors program; and attracted a standing/affiliated faculty of eight, plus a first full-time tenured faculty member, Vladas Sidoravicius, who comes from the celebrated IMPA (Instituto Nacional de Matemática Pura e Aplicada) in Rio de Janeiro. It has also already hosted four international conferences and co-hosted a fifth.

## Mathematics Education at NYUSH

NYUSH as a whole currently enrolls about 300 students. Mathematics is a core part of every student's education, and approximately 20 freshmen and 20 sophomores are math majors. The 12 students in the inaugural class of 2017 are currently in their junior year, and are studying abroad at the Washington Square campus, many taking senior honors or first year graduate-level courses. The undergraduate math major has been "quite successful" says Co-Deputy Director Fanghua Lin, and is "modeled after the program at Courant," offering comprehensive training in mathematics and its applications, with experience in analysis, algebra, differential equations, and probability theory. There is also an honors track, for which, Fanghua explains, the leadership at the institute has built a new curriculum. The math institute is also planning to have a Ph.D. program and will admit its first Ph.D. cohort in the near future.

## Mathematics Research at NYUSH

Faculty members from East China Normal University and Courant together have formed an active and strong group of researchers in Analysis/PDE, Probability Theory, and in a new Applied Mathematics Laboratory. Faculty in Analysis and PDEs are looking mainly at problems from classical and complex fluid equations, including the theory of liquid crystals, and classical field theory in mathematical physics. The specific issues under study include those of an evolutionary nature involving the effects of several scales, as well as geometric variations in static systems.

The new Applied Mathematics Laboratory at NYU Shanghai focuses on fluid problems that are inspired by biological locomotion and by geophysical phenomena. The lab uses state of the art techniques such as optical interferometry and laser Doppler velocimetry to measure and visualize the interactions between activated structures and unsteady flows.

Faculty in Probability Theory and related areas focus their research mostly on stochastic models with interesting spatial structure, often originating in statistical physics. Examples are the theory of phase transitions and critical phenomena in percolation and Ising models, and especially in disordered versions like spin glasses where there is a random environment. These include both models that are static in time where one is interested in dependence on external parameters such as temperature and dynamical models where asymptotic behavior in both space and time have interesting co-dependence.

With the recent addition of Courant Professor and NYU Provost David McLaughlin as an affiliated faculty member, the research portfolio of the institute will soon expand, says Fanghua, "in the directions of large-scale computations and mathematical neural science." ■

## AT A GLANCE

### The NYU-ECNU Institute of Mathematical Sciences

**Director:**
Gérard Benarous, NYU Courant

**Co-Deputy Directors:** Fanghua Lin (NYU Courant) and Xingbin Pan (ECNU)

**Standing/Affiliated Faculty:**
Fanghua Lin, David McLaughlin, Chuck Newman, Xingbin Pan, Vladas Sidoravicius, Dan Stein, Danping Yang, Jun Zhang, Feng Zhou

**Visiting Faculty:**
In the past three years, visiting faculty have come from universities and research centers in Argentina, China, England, France, Israel, Italy, Tunisia, and the U.S. See a list of all faculty at shanghai.nyu.edu/research/math/faculty

### International Conferences

**May 2014** Theory of Probability and Mathematical Statistical Physics

**June 2014** Mathematical Theory of Liquid Crystals and Related Topics

**April 2015** Local and Nonlocal Nonlinear PDEs

**June 2015** Mathematics of Nonlinearity in Neural and Physical Science

**Aug. 2015** Recent Progress in the Theory and Applications of Liquid Crystals and Related Topics (co-sponsor of the conference held at Beijing Normal University)

**March 25-27, 2016** (tentative dates) 2nd International Conference on the Theory of Probability and Statistical Physics

## PUZZLE SPRING 2015

# Brighten Up

by Dennis Shasha
Professor of Computer Science

You are given two bags, each containing some number *NumPerBag* of flares. You know there are *NumBad* bad flares in one of the bags but not which bag. The other bag has only good flares. Each time you test a flare, you use it up.

Here is the first scenario: You want to take *NumBad*-1 flares with you and want to know that all are good. Further, you want to use up as few flares as possible in the selection process. It is fine that when you are done, you may not know which of the unused flares you leave behind are good.

***Warm-up.*** If all the flares in the bad bag are indeed bad, then how many flares would you need to test?

*Solution to this warm-up.* Test just one flare in one bag. After that you would have at least *NumPerBag*-1 = *NumBad*-1 good flares to take from the bag you know has only good flares.

For general values of *NumPerBag* and *NumBad*, consider two strategies:

***Balanced.*** Take a flare from the first bag and test it, then one from the other bag and test it, and continue alternating until you find a bad one or you reach *NumBad*-1 flares left in one of the bags, in which case you know the remaining ones in that bag are good; and

***Unbalanced.*** Keep taking one flare from a single bag and testing it until you find a bad one or reach *NumBad*-1 flares remaining in that bag.

1. Which strategy uses up fewer flares in the worst case?

2. Now imagine you want to take *NumBad* flares (not just *NumBad*-1) on your trip with the guarantee all are good. Which strategy would give you the best chance of achieving this? For this question, the number of flares you use up in testing is unimportant.

Now here is a variant of the puzzle for which I have no good solution.

***Upstart Flare Puzzle*.** Given *NumPerBag* and *NumBad*, suppose you want to take *d* more than *NumBad* with the guarantee all are good. What is the best strategy to use (it may be a hybrid), and what probability of success as a function of *d* can you achieve?

***For the solution, email:*** courant.alumni@nyu.edu

# Shafi Goldwasser presents the 30th Courant Lectures

This past spring, Shafi Goldwasser presented the 30th Courant Lectures to full audiences. Goldwasser is the RSA Professor of Electrical Engineering and Computer Science at MIT, a Professor of Computer Science and Applied Mathematics at the Weizmann Institute, and a 2012 ACM Turing Award laureate, granted for her groundbreaking contributions to the science of cryptography. On April 27th, she spoke on "The Cryptographic Lens" and on April 28th, gave the lecture "On Time and Order in Cryptography."

"Going beyond the basic challenge of private communication," begins the abstract for her first lecture, "in the last 35 years, cryptography has become the general study of correctness and privacy of computation in the presence of a computationally bounded adversary, and as such has changed how we think of proofs, reductions, randomness, secrets, and information." Goldwasser discussed related developments in the theory of computing and cryptography, showing how they may aid in the transition from local to global computation.

On April 28, Goldwasser explored the theory of secure multiparty computation (MPC), a framework for modeling and engineering systems that allow parties to share and compute on data, while retaining privacy. The theory is essential to the ongoing revolution in data science, but lacks a concept of time in sharing data. Goldwasser discussed new extensions to MPC that take into account time and order in communication, improving the relevance of the framework to the problem of using big data to "make medical discoveries, predict global market trends, save energy, improve our infrastructures, and develop new educational strategies."

**Correction:** Our last issue incorrectly listed the location of the CDC 6600 as being in Warren Weaver Hall's basement when, in fact, it was housed on the 2nd floor. The first computer at Courant was the UNIVAC. In later years the Institute operated an IBM 7090 which was replaced by the CDC 6600, the Institute's first supercomputer.

# THE GENEROSITY OF FRIENDS

*Donations from friends and alumni of the Courant Institute greatly assist our educational and research missions*

Your donations to the Courant Annual Funds and Fellowship Fund are very important and much appreciated. These gifts support students and fellows and their conference travel, enhance our student extra-curricular activities, and fund outreach programs like cSplash, Women in Computing (WINC), the Center for Mathematical Talent and the summer GSTEM internship program. They also enable the Institute to invite distinguished speakers for both technical and public lectures, and assist in maintaining an up-to-date learning environment and comfortable public spaces in Warren Weaver Hall and the Broadway buildings. Please consider contributing at the Director's Circle level of $1,000 or more. Your donations of any amount help support the Courant Institute's extraordinary range of scientific and educational initiatives.

**The Courant Institute recognizes with gratitude the following alumni, faculty, and friends who made gifts during the 2015 fiscal year (September 1, 2014 - August 31, 2015).**

### Giving Societies

* **NYU President's Society Members**
*gifts of $5,000 and above*

Σ **Courant's Sigma Society**
*Donors who have given in each of the last five years*

## The Director's Circle

### Gifts of $1,000 or more

Steve Allen and Caroline ThompsonΣ
Ernest BattifaranoΣ
Joan S. Birman
Gilbert Alan Clark
Glen de Vries*
Douglas P. Doucette
Lynnel Marg Garabedian*
Robert B. Gordon
David G. KornΣ
Edward P. Krugman
Tomas Lajous
Martin L. Leibowitz*
Arthur Levitt, Jr.*
Patrick P. Lin
Yue-Sheng Liu
Joshua N. Newman*Σ
Sashi P. Reddi
Kurt S. Riedel*
Charles M. Robins
Chris Rorres
Louis K. Salkind and Deborah J. Rennels*Σ
Jeffrey S. SaltzmanΣ
Lawrence Sirovich and Carole Hochman SirovichΣ
Thomas C. Spencer
Joseph SpindenΣ
Lu TingΣ
Peter Alexander VasseurΣ
Benjamin S. White*Σ
Brad WilsonΣ
Xin Xiong
Robert A. YoungΣ
Sascia Yuan
Yunyue Zhu*

### $500-$999

Babak Atri
Joel L. CunninghamΣ
Susan R. Dickey
Bruce A. Esposito
Paula Blankstein Esposito
Andrew B. FlintΣ
Craig A. Friedman
Daniel L. Gastel
Yeting Ge
Daniel B. Gordon
Philip Greenwald
Dmitri I. Krakovsky
Morris J. MeisnerΣ
Neeta S. Nabar
Anthony Nicholas Palazotto
Enlin PanΣ
Cory J. Plock
Ivan P. Polonsky
Paul H. RabinowitzΣ
Robin Roy
Philip S. Shaw
Brian G. Smith
Alan A. Weiss
Burton WendroffΣ
Michael YanowitchΣ
Bernard Kwangsoo YooΣ
Ernest Zhu

### Up to $499

Spencer E. Alt
Sara Landis Angrist
Janis Elia Archer
Jeffrey M. Augenbaum
George E.R. Ault
Robert E. Ayache
Evan C. Ayala
Paul M. Bailyn
Jonathan J. BakerΣ
Evan Barba
Wayne W. Barrett
Dr. Joseph D. and Mrs. Patricia R. Becker
Neil E. BergerΣ
Michael E. Bernstein
Geoffrey C. BerresfordΣ
Jalal Besharati
Ion Bica
Francisco J. Bido
Albert A. BlankΣ
Daniel M. Blaustein
Craig Seth BrassΣ
Robert C. BrighamΣ
Robert F. Brodsky
Ryan H. BrothersΣ
Adrienne Brown
Matthew M. Callaghan
Paul J. Capobianco
John Morrison Carpenter
Man-Yee V. Chan
Robert Paul Chase
Sindhura Chava
Hua Chen
Michael Chen
Vera Cherepinsky
Soumith Chintala
Jen-Lung Chiu
Philip ChungΣ
Jason S. Clague
Richard J. ColeΣ
Benoit Couet
Laura Beth Cruz
Lisa H. Cyphers
Paul Vartan Czkwianianc
Teymour T. DarkhoshΣ
Thomas K. DeLilloΣ
Stephane Pinhas Demri
Sidney P. DiamondΣ
Vincent J. Digricoli
Yu Ding
Kenneth P. Dressler
Gordon L. Ebbitt
Jan S. EdlerΣ
Michael E. Eigen
Constance Engle
Xiaosong Feng
Richard D. FeuerΣ
Martin Feuerman
Norman J. FinizioΣ
Anthony A. Fiordaliso
Nicholas Fiori
Thomas R. FlackΣ
Daniel B. Forger, Jr.
Richard Foy
Bijoy M. George
Rochelle L. Goldsmith
Henry V. Goldstein
Dmitry Goykhman
Betty J. Grad
Samuel M. GraffΣ
Sister Elizabeth C. Graham
Barry GranoffΣ
John Grant
Michael K. Greco
Frank A. Greco
Milton HalemΣ
Zheng-Chao Han
David Blake HarrisonΣ
Keith HarrowΣ and Madeline Trieger HarrowΣ
Dalia Navon HartmanΣ
Miriam HausmanΣ
Suzanne A. Hecht
David Hertzberg
Bernhard HientzschΣ
Pearl R.S. HochstadtΣ
Mengyan Huang
Carol HutchinsΣ
Barry E. JacobsΣ
Da Jiao
Frank P. JonesΣ
Robert H. Kagel
Allan Akira Kaku
David J. Kantor
Jay M. Kappraff
Susanne E. Karam
Ioannis Karanikolas
Muriel Karlin
Oleksiy Karpenko
Henry E. Katz
Daigo W. Kawasaki
Robert F. Kelly
Eric Y. Kemperman
Robert A. Kennedy, III
Mary B. KerinsΣ
Caroline Davitte Kerr
Alexandra Khosid
B. Melvin KiernanΣ
Hong W. Kim
Hyun Jae Kim
Evelyn M. KirschnerΣ
Morris M. Klein
Peter G. Kleinmann
Paula Shafran KoerteΣ
Lucien F. KranerΣ
Leslie R. Kriesel
Yoon-Wook Kwon
Chanseok Oh & Kyungmi Kim
Julie E. Landstein
Arnold LapidusΣ
Eugene Manual LaskaΣ
David S. Lazarus
Nam Le
Alain Ledon
Irene Huen LeeΣ
Kong Lei

Make your gift conveniently and securely online at
**www.nyu.edu/giving/Courant**

Every effort has been made to include all donors to the Courant Institute during FY2015 (September 1, 2015 to August 31, 2015). If you wish to report any errors or omissions, for which we sincerely apologize, please contact Ms. Robin J. Roy, Director of Development, at robin.roy@cims.nyu.edu or at (212) 998-6974.

Opher Lekach
Peter V. Lessek
Brian R. Lessing[Σ]
C. David Levermore
Bernard W. Levinger
Robert M. Levy
Dorothy Mussman Levy
Shen Li
Burton B. Lieberman
William J. Lindorfer
Seth B. Lipschitz
Arieh Listowsky[Σ]
Jim S. Litsas
Walter Littman
Donald W. Loveland[Σ]
Yuan Samson Lui
Mihaela M. Mack
Kurt Maly
Edward Man[Σ]
Matthew Manilow
Charles A. Marino
Max Martinez and Karen D. Martinez, Esq.
Anne-Claire McAllister[Σ]
Victor S. McBarnette
Donald J. McCarthy
Kevin B. McGrattan[Σ]
Gregory P McNulty
Charles A. Miglierina
Joseph S. Miller
David L. Millman
James W. Moeller
Van John Molino
Raymond Enrique Moradel
Carlos Julio Moreno
Burt J. Morse
Garibah Abubakar Musah
Sara S. Naphtali-Krumbein
Srinath Nathan
Mr. and Mrs. Harlan E. Nebenhaus[Σ]
Joyce A. Newman and Stuart B. Newman
Kam Chuen Ng[Σ]
Duk-soon Oh
George Olchowy
Harold Z. Ollin[Σ]
Jacek Ossowski
Donald E. Palzere
Ming Pan
Michael A. Perlman
Gregory Piatetsky
Stuart S. Piltch
Julian F. Prince[Σ]
Kewal K. Puri
Hedley K.J. Rainnie
Ajay Rajkumar
Kennard W. Reed, Jr.
Linda Yauch Reese
Charles Andrew Reich
Michael J. Reinertsen
Peter A. Rejto
Jie Ren
Charles Wesley Rice[Σ]
Robert N. Rico
John M. Rinzel[Σ]
Hope A. Ropke
Susan P. McKibbin Rose
Nicholas J. Rose
Rochelle S. Rosenfeld
Robert L. Sachs
Chelluri C. A. Sastri
Peter M. Sbashnig
Richard E. Schantz[Σ]
David E. Scherr
James Ernest Schmitz
Jonathan Schwartz[Σ]
Bernard D. Seckler and Evelyn Mehler Seckler
Arnold Shak
Seymour Sherman
Arthur S. Sherman
Jianjun Shi
Christine S. Siegel
Bertram Siegel and Carole E. Siegel
Riley W. Simmons-Edler
Ramlala P. Sinha
Max Elliot Sklar
Yury A. Skobov
Patrick R. Smith
Jonathan A. Smith
Randlow Smith
Pravish Bhushan Sood
Richard D. Soohoo
Michael J. Sormani and Margaret A. Sormani
John A. Sottile
Meredith N. Springer[Σ]
Michael St. Vincent
Alan H. Stein[Σ] and Marsha E. Stein[Σ]
Joseph Steinberg
Gladys Cohen Steinberg
Michael B. Stoeckel
Peggy Tang Strait
Ivan E. Stux
Kenzi Sugihara
Michael P. Swirnoff
Sitaram Tallapragada
Longjun Tan
John Tavantzis
Jean Taylor
Edward H. Theil
Margie H. Thompson
Maja-Lisa Wessman Thomson[Σ]
Charles Tier[Σ]
Wai Hon Tsui[Σ]
Alexander S. Tuzhilin
Julius J. Vandekopple[Σ]
Kesava C. Vatti
Rohin R. Vazirani
Charles A. von Urff
Wan-Ho Wah
Junhua Wang[Σ]
Donald R. Warren[Σ]
Andrew H. Weigel
Henry Weinberg[Σ]
Nathaniel S. Weinman
Abraham S. Weishaus[Σ]
Stewart N. Weiss
Robert A. Weiss
Elia S. Weixelbaum
Benjamin P. Wellington
Michael Williams[Σ]
Ivy Fran Winick
Peter Wolfe
Young C. Wong
Kurt C. Wulfekuhler
Arline S. Wyllie
Wen-Qing Xu
Marvin Yablon[Σ]
Raymond J. Yatko[Σ]
Donald Poy Yee
Jacqueline Michele Yee
Ofer Zajicek
Kathleen A. Zammit
Anthony J. Zeppetella
Xiao H. Zhang
Hongyuan Zhang
Xiaoqing Zhang
Hongjun Zhu

## Corporations & Foundations

*Corporations, foundations and other organizations providing research and philanthropic support and/or employee matching gifts. You can double or triple the value of your gift by participating in your employer's gift matching program. Please visit www.matchinggifts.nyu.edu to see if your employer matches your gifts to education.*

Accountnet, Inc.
Alfred P. Sloan Foundation
AXA Foundation
BlackRock
David K A Mordecai & Samantha Kappagoda Charitable Trust
Dow Jones & Company
ExxonMobil Foundation
Facebook, Inc.
Fidelity Charitable
Goldman Sachs & Co.
Google Inc.
Gordon & Betty Moore Foundation
Gordon Foundation
Gotham Asset Management, LLC
Hudson River Trading LLC
Human Frontier Science Program
IBM International Foundation
Intelli Communications Inc.
International Business Machines Corp.
Jack Kent Cooke Foundation
Jane Street Group LLC
Joan & Joseph Birman Foundation
May and Samuel Rudin Family Foundation
Medidata Solutions Inc.
Microsoft Corporation
Netherlands Organisation for Scientific Research
Northrop Grumman Corporation
Nvidia Corporation
Oracle Corporation
Raytheon Company
Schwab Charitable Fund
Simons Foundation
Stux Capital Management, LLC
The Boeing Company
The D. E. Shaw Group
The J. P. Morgan Chase Foundation
The Winston Foundation, Inc.
Vanguard Charitable
Wells Fargo Foundation
Zegar Family Foundation

**New York University**
Courant Institute of Mathematical Sciences
Warren Weaver Hall
251 Mercer Street
New York, NY 10012

To join our community of Courant donors, please visit the new NYU online giving page at giving.nyu.edu/courant or contact **Robin Roy** at robin.roy@cims.nyu.edu or call **212-998-6974**.

## **STAY** CONNECTED

You can continue to make connections with fellow alumni, faculty and friends by attending lectures and other events in New York and all over the globe! See Institute news and activities on the Courant website (**CIMS.nyu.edu**) and Courant Alumni webpage (**CIMS.nyu.edu/alumni**).

Send us news of job changes, moves, and meet-ups with Courant alums at **alumni.news@cims.nyu.edu**. We also invite all Alumni to keep colleagues and friends up-to-date on life events such as career achievements and family milestones; submitted items will be considered for publication in the Newsletter or online.

Please make sure your contact information is up to date by visiting the NYU Alumni website at **www.nyu.edu/alumni** or send your email and postal address, phone or employment changes to **alumni.relations@cims.nyu.edu** and we'll take care of the rest.

There are benefits to being an NYU alumnus/a. Check out the NYU Alumni webpage for campus and library access, insurance, entertainment and dining, university club memberships in your area, and much more, including NYU alumni networking events wherever you go!

**On the Cover:** Fluid flows are as beautiful as they are complex, as shown in this photograph which won the American Physical Society's Milton van Dyke Award for art in science. Here, a disk located near the top of the image flaps up and down while immersed in a downward flow of water. Ink, which appears light against the blue background, is released from in front of the disk and is swept into vortex rings that wash downstream. Read more about the work of the Applied Math Lab inside.

**Facebook.com**
Courant Institute of Mathematical Sciences Alumni

**LinkedIn.com**
Courant Institute of Mathematical Sciences

**Courant Newsletter Staff:**
Editors: Robin Roy and Shafer Smith
Writer and Managing Editor: April Bacon
Graphic Designer: Chris Cantley