ANNUAL REPORT 2010

SIMONS FOUNDATION

The helicoid

Similar to the blade of the water pump described by Archimedes in the third century BCE, this surface was proved to be minimal by Jean-Baptiste Meusnier, a mathematical feat that won an award from the French Academy in 1776. What we see at right is a helicoid cut off by a cylinder parallel to its core axis, and not allowed to twist on forever. A fundamental property of minimality is that it persists even when a surface is rescaled. Scaling down the entire surface by a large factor, we would begin to see the formation of closely stacked parallel planes connected by a core that becomes enormously twisted. If we scaled up by a large factor, we would begin to see just one almost planar surface becoming flatter and flatter.

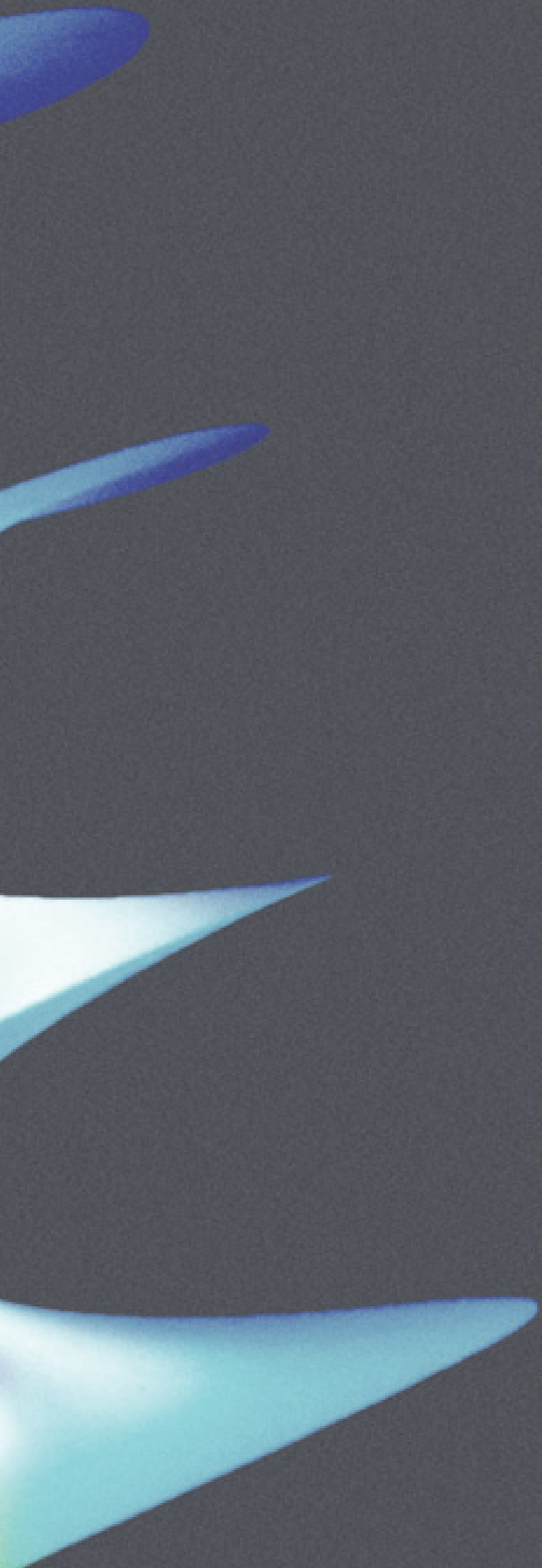


TABLE OF CONTENTS

MARILYN SIMONS

President

Unprecedented challenges have characterized our world these past two years. We've watched power shift and budgets contract. The economic uncertainties of our time threaten growth and development as we scale back to live within our means. Research and education have been cut back, just when we need them most. Yet, though it's a difficult time for research funding, it's a stimulating time for research. With new advancements, new tools for discovery, new technologies to rapidly share ideas, and many outstanding researchers, there's so much potential for intellectual achievement. We need to expand our knowledge to help build our future. We need to invest in people and ideas.

At the Simons Foundation, we're committed to our support of research in mathematics and the basic sciences. During the past year, we celebrated the inauguration of the Simons Center for Geometry and Physics at SUNY Stony Brook and welcomed an outstanding group of mathematicians and theoretical physicists to the center. Over the course of the year, permanent members and visitors have participated in workshops on superstrings in Ramond-Ramond backgrounds, quantum Liouville theory and quantum integrable systems, to name just a few topics. It's inspiring to see eminent scholars so engaged in complex and abstruse ideas in pursuit of a deeper, more fundamental understanding of the universe.

A Mathematics and Physical Sciences (MPS) program, under the direction of David Eisenbud, was implemented this year to formalize our research funding in those areas. Immediately, an interim postdoctoral fellowship program was introduced to ameliorate the impact of funding cutbacks. The MPS program went on to request applications for collaboration grants, interdisciplinary grants and a new institute for the theory of computing, all to be awarded through a peer-reviewed process. These grant programs support strong researchers extending the frontiers of our knowledge in both pure mathematics and the more theoretical aspects of physics and computer science.

Our SFARI program continues to expand under the leadership of Gerry Fischbach. With the help of our scientific advisory board, the foundation has been able to increase and focus its support to scientists interested in understanding autism. This group of more than a hundred grantees came together last fall for an annual conference, discussing topics ranging from genetics to cognition and behavior. Subjects included eye tracking as an early measure of autism, recurrent copy number variants in hotspots of the genome, neurons produced from induced pluripotent stem cells from individuals with autism, and cortical anomalies. The conference was one of the year's highlights, bringing together a premier group of researchers, all so strongly committed to advancing the field.

It was an active and productive year, reflecting the steadfast efforts made by staff, partners, advisors and grantees. I want to extend deepest thanks to Gerry Fischbach and David Eisenbud for leading the way so ably. I am also grateful to my cofounder and husband, Jim Simons, who is always visionary and guiding.

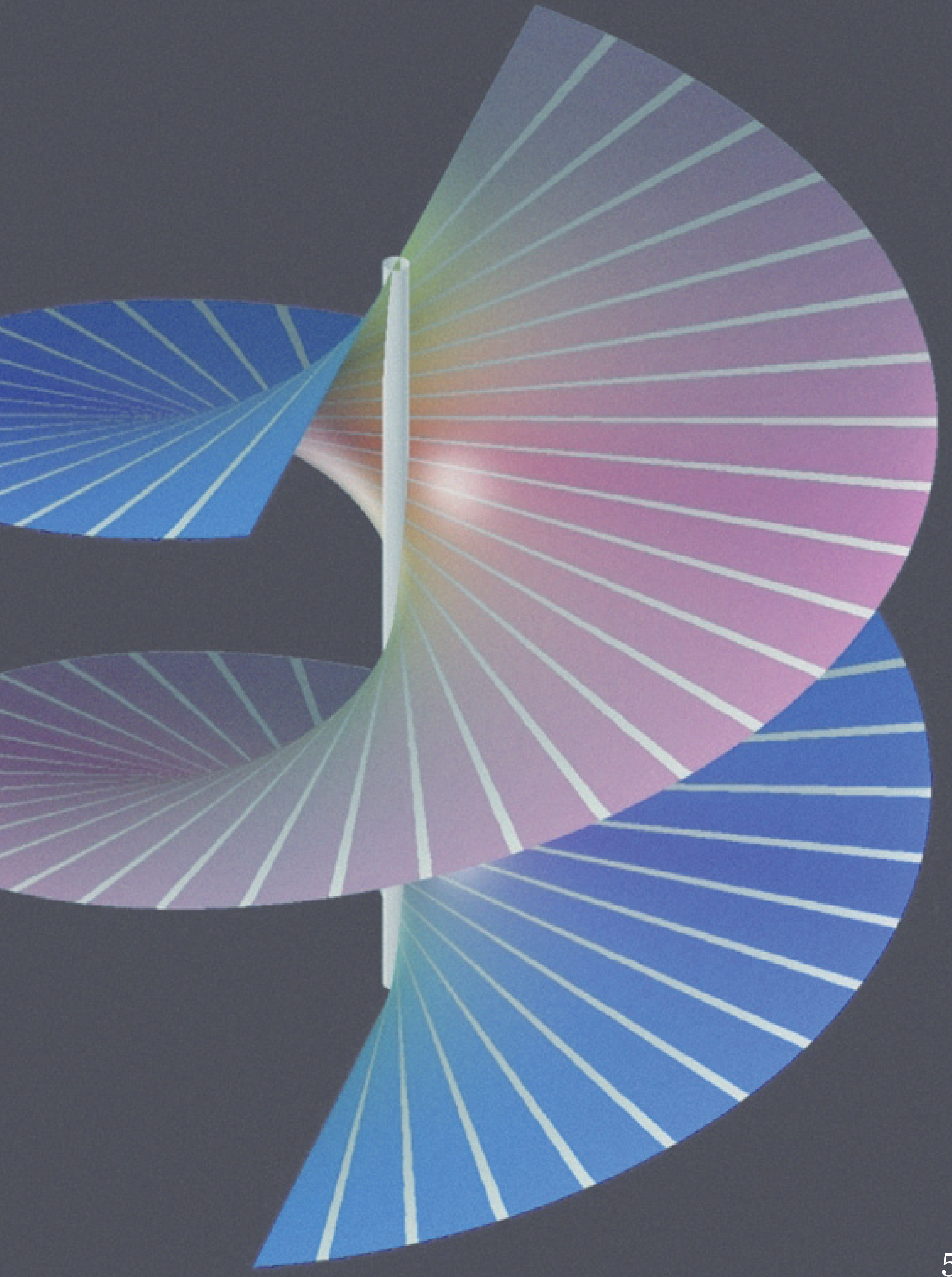
It is a wonderful opportunity for us at the foundation to support outstanding people and ideas that can truly have an impact in shaping our future. Now more than ever investment in research by private foundations is crucial to filling the gaps in funding, to stimulating further research and, most important, to pushing the boundaries of knowledge. I hope you enjoy reading about our efforts in this direction in the pages that follow.

Sincerely,

Marilyn Simons, Ph.D.
President
Simons Foundation

The helicoid

Rotating a stick at constant speed while you slide it up an axis (the 'straw') at constant speed sweeps out a helicoid. The simplicity of this construction belies the importance of this surface, which is relevant not only to geometric analysis, but also in materials science, where it is a model for the formation of dislocations and irregularities. Moreover, the helicoid and the catenoid hide a secret that is impossible to see by looking at the surfaces: they are isometric. This means that if you cut a catenoid along one of its generating catenaries, you could bend it, without any stretching whatsoever, onto a helicoid. The catenaries of the catenoid would lie precisely over the straight lines that sweep out the helicoid.



DAVID EISENBUD

Director, Mathematics & the Physical Sciences

I joined the Simons Foundation a year ago to help establish a suite of programs to support fundamental research in mathematics and the physical sciences. Of course the foundation was active in these fields long before my arrival; its support for the Mathematical Sciences Research Institute in Berkeley, for the Institut des Hautes Études Scientifiques in Bures-sur-Yvette in France, for the Institute for Advanced Study in Princeton and for the Simons Center for Geometry and Physics in Stony Brook is well-known. But Jim and Marilyn Simons also wanted to add programs that would have open application processes and affect the whole community. We agreed that the focus of the new programs would be 'the theoretical sciences, radiating from mathematics.' As a working definition we took this to mean mathematics, theoretical physics and theoretical computer science.

It's been an exciting year! We have launched four major programs, described in the pages of this report, and there are more to come. Our interim postdoctoral fellowship program has recruited truly outstanding young scientists and has done much to support the job market for the best new Ph.D.'s. And while it's too early to report on the newer programs, I can describe a little of what has happened in-house to pave the way for their launch.

When we started, I convened a roundtable of a dozen highly experienced scientists from our target fields to discuss the needs of those fields, focusing on those that could not be satisfied with funding from federal science agencies. By now we've convened a few more such gatherings: one on theoretical computer science (related to a new Institute for the Theory of Computing that the foundation will help establish), one on theoretical physics and one on mathematics in Africa. We've also been grateful to receive advice from many individual mathematicians and scientists. To all those who have contributed their thoughts and their time, my thanks.

Despite their tight connections, the fields of mathematics, physics and computer science have different needs. To help us understand which programs would be most effective in physics, Andrew Millis, a distinguished scientist from Columbia University, has joined our staff as part-time associate director.

People from all over the foundation have lent their help in tackling the challenges involved in implementing these brand-new programs, but I especially want to thank my assistant, Meghan Criswell, and my program manager, Elizabeth Roy; their aid has been crucial.

The support of basic research seems to me to be of the greatest importance to our society and culture. The Simons Foundation has the mission of providing just such support. I'm grateful for the opportunity to help realize this goal.

David Eisenbud

David Eisenbud, Ph.D.
Director, Mathematics & the Physical Sciences

THE SIMONS CENTER FOR GEOMETRY AND PHYSICS, STONY BROOK

Mathematician Sir Michael F. Atiyah

In 1968, Jim Simons came to Stony Brook University as the chair of the mathematics department. His goal was to transform a weak department into a strong one, comparable to Stony Brook's celebrated physics department, the most notable member of which was the young Nobel Prize–winning physicist C. N. Yang.

Soon after Simons' arrival, he began to meet periodically with Yang; Yang would describe the problems he was grappling with in an area of physics called Yang-Mills theory, and Simons would listen politely, often not understanding. They continued in this manner for two years. During the third year, however, Simons had an insight that startled them both: the mathematics Yang was developing was in fact related to geometric objects called fiber bundles, a subject Simons knew very well. Simons and Yang quickly organized a seminar in which to explore these ideas further with other Stony Brook mathematicians and physicists. This seminar, mirrored by similar efforts at other scientific centers, gave birth to a deep new interaction between geometry and physics. Over the 40 years that followed, this interaction has flourished and intensified, much to the benefit of both fields.

Today this kind of meeting of the minds has an official home at Stony Brook: the Simons Center for Geometry and Physics. The center, which has been operating on a limited scale since the summer of 2009, opened the doors of its five-story permanent building—which features a bridge to both the mathematics and physics buildings—in November 2010. To celebrate, it held an inaugural conference on November 2nd and 3rd with lectures by luminaries such as Sir Michael Atiyah and Edward Witten and a performance by the Emerson String Quartet.

The mission of the center, born of the successful collaboration between Yang and Simons, is to bridge the communication gap between mathematicians and physicists.

"It's not easy for mathematicians and physicists to talk to each other, even when they're talking about the same subject," says physicist Michael Douglas, the center's first permanent member. "When two groups invent the same ideas but in a different language, it can take a long time to realize that they're talking about the same thing. But that realization can be incredibly fruitful."

In the past 50 years, physicists have pushed their discipline well past the mathematical foundations that exist for it, says John Morgan, the center's director, formerly chair of the mathematics department at Columbia University. And physicists keep coming up with mathematical statements that turn out to be correct, he says, but no one knows what the underlying mathematical context for their ideas is. In other words, there is a reciprocal desire for information. “Mathematicians feel that the physicists have access to some kind of truth here, but it’s a huge mystery as to what’s going on,” he says. “We mathematicians feel that we’re missing something, and the physicists feel that they need what we’re missing.”

Bringing mathematicians and physicists into the same physical space is crucial for the kind of breakthroughs the center hopes to engender, Morgan says. “There is a chance for real progress if mathematicians and physicists can start talking together, and understanding each other’s language and point of view,” he says. “We want to give them the time, space and ambiance to interact.”

The building’s architecture was designed to foster the sorts of serendipitous encounters between mathematicians and physicists that can give rise to new collaborations. At the same time, the structure provides the quiet retreats that researchers need to engage in deep reflection.

The lower part of the building consists of a two-story glass-enclosed atrium opening onto a 250-person auditorium, a 100-person seminar room, an artists’ gallery and a café. Above this public space is a more private area to be used mainly by the center’s members, postdocs and visitors that is made up of three floors of offices opening onto a central three-story atrium. “When people come out of the offices, everyone sees each other and will intentionally bump into each other,” says Mark McCarthy, an architect at Perkins Eastman, the firm that designed the structure. Blackboards and clusters of comfy chairs are liberally sprinkled throughout the center so that casual chats can easily progress to more serious discussions.

The design employed sustainable green building practices, incorporating, among other things, solar shading along the glass facades, a green roof over the auditorium and a rainwater collection system. The building is in the final stages of being granted “gold” status by the Leadership in Energy and Environmental Design program, McCarthy says.

In addition to a director and one permanent member, the center currently hosts ten postdoctoral fellows. It will eventually have six permanent members, 12 three-year postdoctoral fellows and approximately 18 visitors at any given time, Morgan says. Each year, the center will also run eight week-long workshops that it expects will attract many additional attendees, and a four-week summer workshop for about 100.

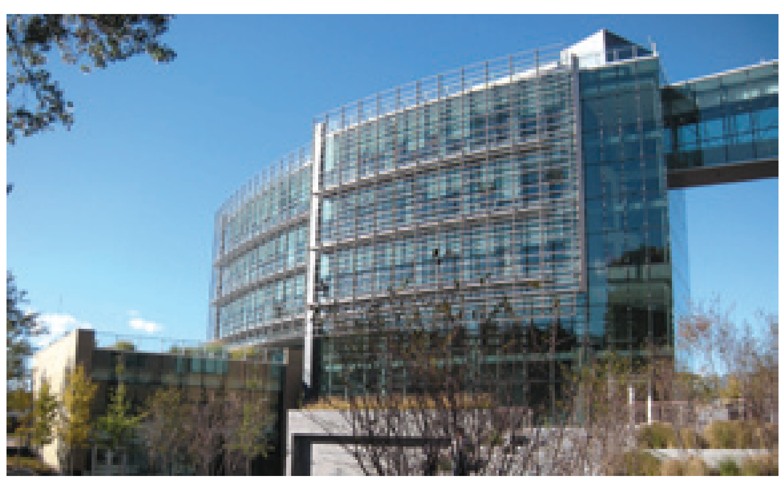
The Simons Center project was made possible by an endowment from the Simons Foundation that supported construction and programming. Stony Brook University also contributes to the center, supporting the director and permanent members and funding building maintenance.

Stony Brook University was a natural choice for such a center, Douglas says, and not just because of Jim Simons’ long-standing connection to the university. “It’s one of the places where, historically, the math and physics departments have worked together closely,” he says. “It’s very common to have a physics department that is very strong in string theory, but then you walk over to the math building and they don’t do it there. Stony Brook is rather exceptional in having strong math and physics departments that share these interests and have been working together over decades.”

The primary focus of the center, at least in the beginning, Douglas says, is likely to be the relationship between string theory and mathematical fields such as algebraic geometry, largely because this connection is being pursued by a relatively large group of researchers, including many current members of and visitors to the center. At the same time, the center has already sponsored workshops that focus on other areas of the interface between mathematics and physics, such as general relativity and quantum computing. Ultimately, Douglas hopes, the main focus of the center will be some field that doesn’t even exist yet.

“In my mind, the center could be a success purely within the area of relating string theory to algebraic geometry,” he says. “But the real success I would hope for is that by bringing together people who would not have come together before, we will discover entirely new interfaces between mathematics and physics.”

Although the center has been partially up and running for more than a year, 2011 marks the beginning of its full-fledged activity, Morgan says. “It’s a pivotal moment,” he adds. “I’m very excited to see how it all plays out.”



THE CHERN MEDAL: HONORING A MATHEMATICAL 'EMPIRE BUILDER'

2010 Chern Medal winner
Louis Nirenberg

The first Chern Medal, named after Shiing-Shen Chern and sponsored in part by the Simons Foundation, was awarded to Louis Nirenberg of the Courant Institute of Mathematical Sciences.

Nirenberg, like Chern, is a mathematician of great breadth and a lifetime of achievements who has made important contributions to geometry, complex analysis and nonlinear partial differential equations. Among his many results is the best estimate known of the size of the "singular set" in the mathematical model of an incompressible fluid. A singular point is a place where the fluid becomes infinitely turbulent (that is, its velocity is infinite or undefined). One of the greatest unsolved problems in mathematics is to determine whether such points actually exist. Nirenberg's result shows that if they do exist they are few and far between, confined to a one dimensional set of measure zero. In other words, it is harder to find these points than to find a needle of zero length in a haystack.

Nirenberg is particularly noted for his groundbreaking work in nonlinear partial differential equations. These are equations in which the unknown quantity is a function rather than a number and conditions are prescribed for the way the function varies from point to point. Nirenberg proved many workhorse theorems that experts on partial differential equations now use routinely as starting points for analyzing these equations. As Simon Donaldson wrote in *Notices of the American Mathematical Society*, "The awesome number of citations to Nirenberg's papers is one measure of the central nature of his contributions to this huge field."

The creation and awarding of a new prize is not taken lightly by the International Mathematical Union (IMU), which organizes the quadrennial congress at which the medal is awarded. Only three IMU prizes existed before the Chern Medal: the celebrated Fields Medal, the Rolf Nevanlinna Prize in computer science and the Gauss Prize in applied mathematics. The first two are restricted to mathematicians under age 40. "There was a feeling among the executive committee that we did not have a prize for senior people in mathematics, pure or applied, reflecting lifetime accomplishments," says László Lovász, president of the IMU through 2010. The Chern Medal, named for one of history's true leaders in mathematics, is intended to fill this gap.

Chern, who was born in 1911 in Jiaxing, China, and died in 2004 in Tianjin, touched several cultures during his lifetime. In the 1930s, he studied with geometers Wilhelm Blaschke in Hamburg and Élie Cartan in Paris. After being evacuated from wartime China in 1943, he came to the United States, where he leaped to international prominence with his proof of a formula called the generalized Gauss-Bonnet theorem.

In 1946, Chern went back to China, where he helped found the Institute of Mathematics of the Academia Sinica, but in 1949, just before the communist takeover and with the assistance of Robert Oppenheimer, he returned to the States. There he remained for the next 50 years before going back to his native land to stay in 1999.

Unlike the other awards bestowed by the International Mathematical Union, the financial award that accompanies the Chern Medal is divided into two equal parts. One half ($250,000) is presented to the recipient, while the other half goes to any mathematical organization of the recipient's choice. (Nirenberg designated the Courant Institute.) A prize divided in this way is a particularly apt memorial to Chern, who recognized that math is not only created by great mathematicians but also nourished by great institutions.

Chern was the most distinguished geometer of his generation. The Chern-Gauss-Bonnet theorem concerned the total curvature of even-dimensional curved spaces, called manifolds. His proof made it clear that structures called fiber bundles—which now play an important role in mathematical physics—carried a great deal of information about the global properties of a manifold. This theorem was hugely influential and inspired a great deal of work by many mathematicians (including Chern himself) in the following years. Chern was certainly not motivated by physics at that time; what mattered to him was that the proof was beautiful. "The proof was clearly forged by white-hot inspiration," says Hung-Hsi Wu, a former colleague at the University of California, Berkeley. Later in his career, Chern, together with Jim Simons, constructed related measurements on fiber bundles (the Chern-Simons invariants), which physicists subsequently found quite useful in their application of fiber bundles to string theory and quantum field theory. "These invariants were inspired by their intrinsic beauty, and we had only the vaguest of notions that they would find application outside of mathematics," Simons says.

Chern's contribution to mathematics went far beyond the theorems he proved. He built Berkeley into an important center for research in geometry and helped lead the department to become arguably the finest in the world, a level of distinction it still enjoys. In 1979, Chern played the leading role in establishing the Mathematical Sciences Research Institute (MSRI), located in Berkeley and sponsored by the National Science Foundation, and served as its first director. "From the beginning Chern nurtured an open and welcoming atmosphere," wrote Daniel Freed in a 2009 article. "Visitors to MSRI were engaging with mathematics and (even young) mathematicians all day long. I learned early the world of difference between a mathematics department and a mathematical sciences research institute."

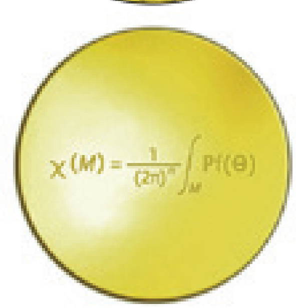
Chern also inspired legions of graduate students as a formal advisor and an informal mentor. Robert Bryant, the current director of MSRI, remembers that Chern invited him to his office and to restaurant lunches, even though he was just a visiting graduate student. "It wasn't just his mathematical prowess that inspired people; it was the way he took care of them. He was very generous with his time for young people," Bryant says.

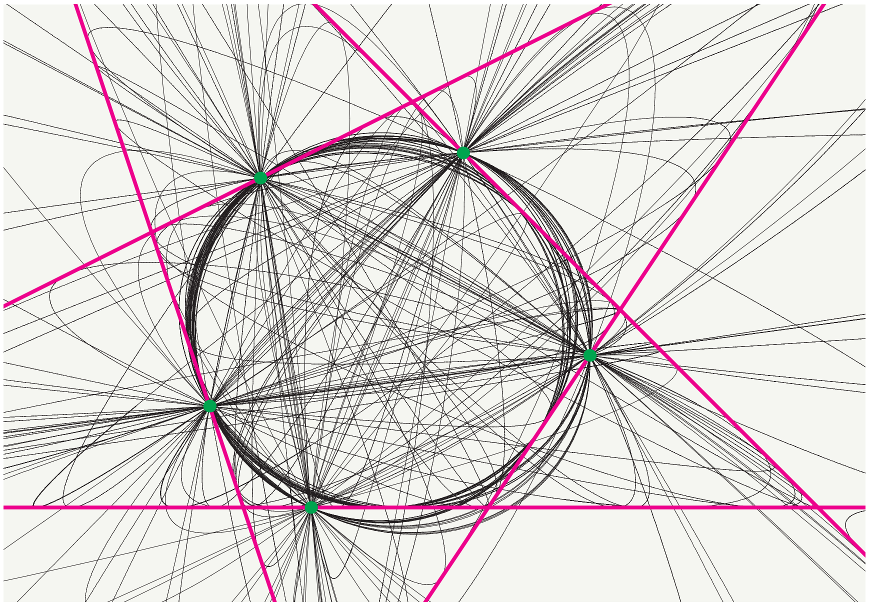
In the mid-1980s, Chern founded the Nankai Institute of Mathematics at his alma mater, Nankai University in Tianjin. (After his death, the institute was renamed in his honor.) He proposed the idea of holding the International Congress of Mathematicians in Beijing in 2002. He was also instrumental in bringing U.S. mathematicians to China and in opening a pipeline for Chinese graduate students to come to America.

After Chern's death, his daughter, May Chu, proposed the idea of commemorating her father with a medal. The S. S. Chern Foundation needed an additional source of endowment money for the projected half-million-dollar prize. "I thought of Jim Simons' wonderful relationship with my father and asked him if he could help," Chu says. The Simons Foundation was proud to help commemorate the life and work of a man who had done so much to inspire cultural collaboration and progress in mathematics. In fall 2007, the IMU agreed to administer the new prize.

At the opening ceremony of the 2010 International Congress of Mathematicians in Hyderabad, the president of India, Pratibha Patil, presented the newly minted Chern Medal to Nirenberg. The following day, Professor YanYan Li of Rutgers University gave a public lecture on Nirenberg's research. Film director George Csicsery presented a film about Chern's life entitled *Taking the Long View*. Robert Bryant lectured on Chern's mathematical work, and May Chu recounted her father's personal life.

Chern had a great talent for making connections. He connected East to West, students to mentors and colleagues to colleagues. He founded two leading math institutes and turned geometry from a niche subject into one of the most dynamic fields of mathematical research. And he did it all with extraordinary modesty. As Hung-Hsi Wu wrote in 2005, "Professor Chern was an empire builder, in the best sense of the word."





PROGRAMS IN MATHEMATICS & THE PHYSICAL SCIENCES

Conics tangent to lines or passing through points. Courtesy of Frank Sottile. www.math.tamu.edu/~sottile/3264

In fall 2010, the Simons Foundation's division of Mathematics and the Physical Sciences (MPS) launched three new grant programs to advance progress in mathematics, the physical sciences and computer science.

Math+X: Encouraging Interactions

The Math+X program offers matching endowment grants to U.S. universities to create tenured chairs shared between a department of mathematics and a partner science or engineering department. The goal of this program is to increase the interaction among mathematics and other disciplines by nurturing collaboration and promoting interaction among mathematics and other departments.

Additional funding will be provided for the chair to support one post-doctoral fellow and two graduate students in each of the two target departments. A committee of distinguished scientists from mathematics and the target disciplines will select the recipients.

New Institute for the Theory of Computing

Computation has revolutionized science, technology and society and is among the most important scientific developments of the 20th century. This discipline has enabled numerous technological advances and forged connections among mathematics and other sciences, providing fruitful insights as well as illuminating new problems. Computation affects not only computer science and technology but also mathematics, physics, biology, economics and sociology.

The MPS program has invited applications for grants to establish an institute focused on the theory of computation. This institute will bring together a critical mass of researchers from around the world to accelerate fundamental research on computation and to further develop the discipline's interactions with other areas of science—from mathematics and statistics to biology, physics and engineering. In fall 2010, the MPS program invited applications for grants to establish such an institute.

The institute will promote sustained collaborations and partnerships and become a meeting place for visitors at all levels of academic seniority and a center for the training of postdoctoral fellows. To help attract top researchers and the strongest postdoctoral fellows, the institute will provide excellent working conditions conducive to collaboration among its visitors and outstanding scientific leadership to determine the institute's activities. The institute will host a frequently changing group of computer scientists as well as mathematicians and scientists from other fields.

Collaboration Grants for Mathematicians

In fall 2010, the Simons Foundation invited applications for grants to mathematicians for collaboration and travel. The goal of the program is to support the "mathematical marketplace," substantially increasing collaborative contacts in the community of mathematicians working in the United States.

Grants will be $7,000 a year for five years to support travel and collaboration and to enhance the research atmosphere within the recipient's academic department. The applicant must have a tenure-track or tenured position at a U.S. institution of higher education, have a current record of active research and publication in respected journals, and not have other significant sources of research funding, such as National Science Foundation "principal investigator" grants or National Security Agency grants.

A selection committee of distinguished scientists will consider the proposals. Funding decisions will be based on the quality of the applicant's previous research and the likely impact that a grant for collaboration and travel would have on future research, for both the applicant and the applicant's students and/or postdoctoral fellows.

SIMONS POSTDOCTORAL FELLOWS PROGRAM

University endowments and state funding of educational institutions have suffered in the recent economic downturn, and this has led to drastic cuts in universities' hiring of postdoctoral fellows.

In response, the Simons Foundation has created an interim postdoctoral fellows program to fund new postdoctoral positions in excellent environments in order to help support the postdoctoral market and encourage talented young scientists to stay in research.

The foundation initiated its postdoctoral fellows program in fall 2009. All told, the program will support 69 postdoctoral positions at 46 universities. These are three-year positions in mathematics and theoretical physics, starting in the academic years 2010 and 2011, and two-year postdoctoral positions in theoretical computer science, starting in 2010, 2011 and 2012.

The foundation delegates the choosing of fellows to the host universities, which in turn were chosen for their ability to attract and nurture top new Ph.D.'s.

PROFILES: SIMONS POSTDOCTORAL FELLOWS

"The answer to this kind of question is surely quantitative; the cells are counting signaling molecules from their neighbors."

MADHAV MANI

When a baby is conceived, the DNA in that single cell encodes all the instructions needed to grow a complex organism. But at any given moment during development, how do those instructions, combined with a particular cell's environment, tell the cell to start on the specialized path toward becoming, say, a muscle cell, or part of the spleen?

Simons fellow Madhav Mani is bringing his expertise in applied mathematics and physics to bear on this fundamental mystery. He studies how certain far-apart sites on a fruit fly embryo—biologists' favorite model organism—all go through particular stages of growth at the same time, and grow at the same rate. "The answer to this kind of question is surely quantitative; the cells are counting signaling molecules from their neighbors," Mani says. "The solution will use ideas from such fields as statistical physics and dynamical systems, and the same language and constructs that physicists use."

After earning an undergraduate mathematics degree at Cambridge University and an applied math Ph.D. at Harvard University, Mani is using his fellowship to spend three years at the Kavli Institute of Theoretical Physics at the University of California, Santa Barbara. In addition to his biology research, he intends to build on his Ph.D. research by delving into the mechanics of interfaces between soft substances, such as fluids.

The postdoctoral fellowship gives Mani the luxury of three years in which to plunge into these deep questions without worrying about cranking out grant proposals and papers, he says. "I think these three years are going to be risky and enjoyable."

Morrow is now at the University of Chicago, which he describes as "one of the best places in the world" in which to study arithmetic geometry, as his field is called.

MATTHEW MORROW

As children learn in elementary school, a whole number can be either prime—indivisible—or composite, meaning that it can be written as a product of other whole numbers. Prime numbers are like atoms, and understanding how they fit together is at the heart of the mathematical field called number theory. In a similar way, polynomials—objects such as x^2+1 and x^3+3x-4—can be either indivisible or written as a product of other polynomials. Graphs of these polynomials create a link between number theory and the geometry of curves that number theorists have been exploiting with great success for a century.

Simons postdoctoral fellow Matthew Morrow studies a variant of this link that concerns how two-dimensional surfaces relate to properties of numbers. His work is connected to elliptic curves, which played a fundamental role in Andrew Wiles' proof of Fermat's Last Theorem and which are the subject of one of the Clay Mathematics Institute's million-dollar Millennium Prize Problems.

Morrow is now at the University of Chicago, which he describes as "one of the best places in the world" in which to study arithmetic geometry, as his field is called. By bringing him there for three years, unburdened by heavy teaching loads or the need to write grant proposals, the Simons fellowship gives him "an environment in which I can absolutely maximize my research potential," he says.

PROFILES: SIMONS POSTDOCTORAL FELLOWS

"The free resolution is a central construction in modern algebra."

DANIEL ERMAN

Simons postdoctoral fellow Daniel Erman's work lies in the field of algebraic geometry, which concerns the qualitative properties of geometric objects defined by algebraic equations; for instance, the solutions to the familiar equation $x^2+y^2=1$ form a circle in the plane; and the solutions to the similar-looking equation $x^3+y^3=1$ can be 'added' to one another to derive new solutions. Questions about equations correspond to questions about geometry: for example, if you want to know whether two equations have any common solutions, you can check to see whether their corresponding geometric objects have any points of intersection, and vice versa.

For algebraic geometers, that fundamental question is just the start. Erman studies 'free resolutions': these can be thought of as ways of describing the solutions of linear equations that vary with time. Erman and other researchers study how complicated the free resolutions will be and, more generally, what sorts of free resolutions can even exist. "The free resolution is a central construction in modern algebra," Erman says.

After earning a Ph.D. at the University of California, Berkeley, Erman is visiting Stanford University for a year before commencing his Simons postdoctoral fellowship at the University of Michigan in fall 2011. "I feel really fortunate that I'm going to get to spend three years at Michigan," Erman says. "It's just about the best fit I could imagine for my interests."

Erman is excited about the fellowship's generous travel allowance. "If I spark an exciting collaboration with someone at a different institution, it's exciting to know that I can really throw myself into it," he says.

"So many people are coming and going, and so many new things are happening here."

KEREN CENSOR-HILLEL

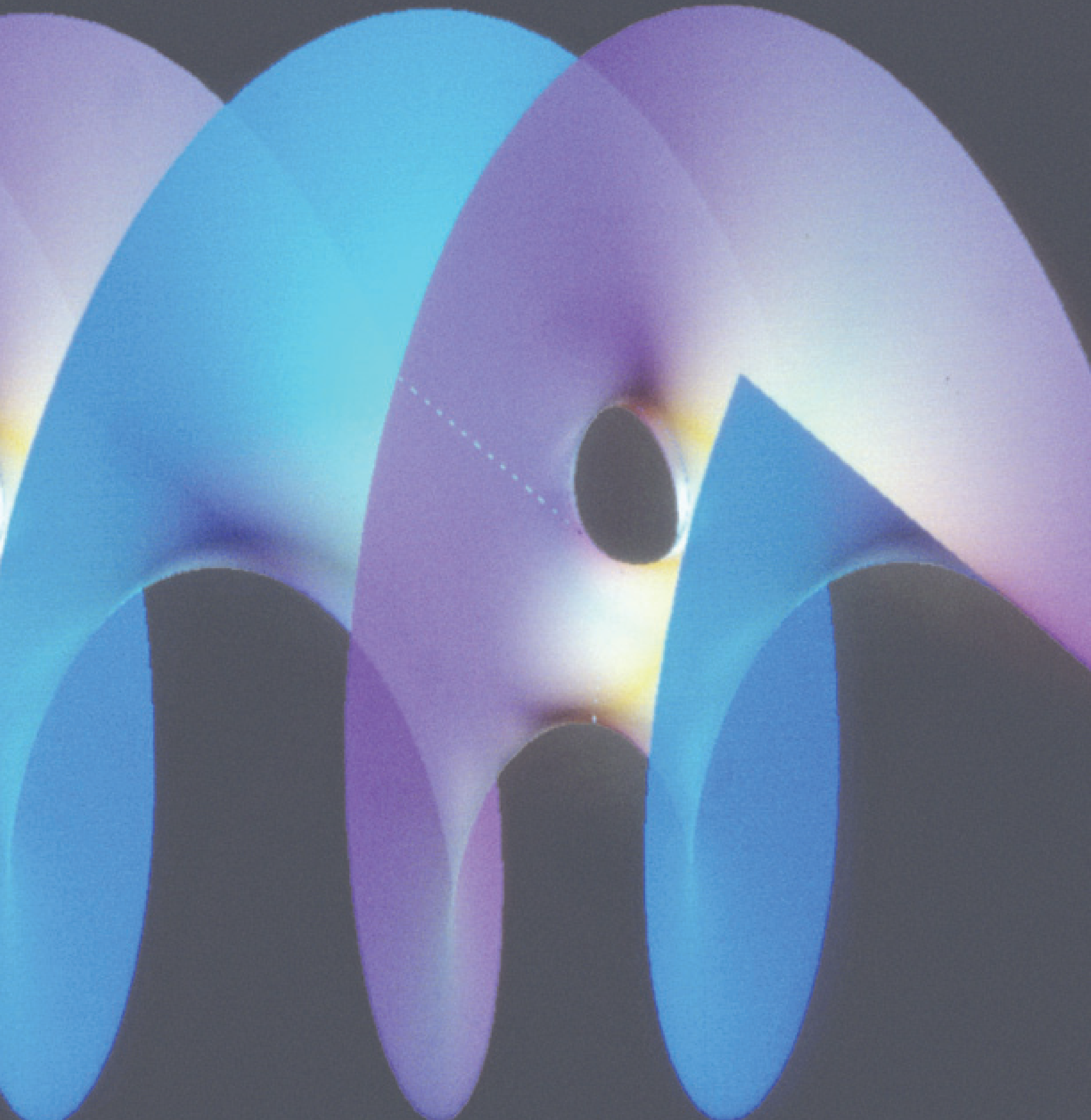
As computer components grow ever smaller and less expensive, distributed networks of computers and sensors are finding applications in everything from telecommunications to online games to environmental monitoring systems. Such networks, however, must contend with challenges a single computer doesn't face: how can the nodes of such a network coordinate with each other to make decisions without any centralized control to aggregate their information and tell them what to do?

This question is the focus of Simons postdoctoral fellow Keren Censor-Hillel's research. For her Ph.D. at the Technion in Haifa, Censor-Hillel studied the consensus problem—how a collection of processors reaches agreement about the value of a bit of information—in the case where the processors have access to a shared memory system. With her advisor, Hagit Attiya, Censor-Hillel came up with a new algorithm for this consensus problem and proved that it is the most efficient one possible.

Censor-Hillel is now studying the 'gossip problem': how information spreads through a network that constrains the way in which the nodes can interact. Her Simons postdoctoral fellowship has brought her to the Massachusetts Institute of Technology, which Censor-Hillel describes as "the place where everything happens" in her field. "So many people are coming and going, and so many new things are happening here," she says. "It advances my research in so many ways."

The singly periodic genus-one helicoid

It has been well over two centuries since the helicoid was identified as a minimal surface. Since then, minimal surface theory has advanced, enabling mathematicians to use modern methods from complex analysis and topology to understand the qualitative theory of these surfaces. In the 1980s, interest began to focus on the surfaces that divide space into two solid regions. Illustrated here is a surface that can be visually understood to be a helicoid into which 'handles' or holes have been added at regular intervals. 'Genus-one' refers to the handle. If you only consider a basic building block of the surface—one that would generate the surface by horizontal translations—you would have a surface that is topologically the same as the surface of a bagel, and it would have only one handle. The picture of this surface contains enough information to make a physical model of it, so the question "Does this surface exist?" does not seem to make sense. For a geometer, however, the question has serious content; it asks, "Is there a minimal surface with all the geometric properties that this one appears to have?" One cannot tell whether or not it is minimal by visual inspection. However, in 1993 a proof that there is such a minimal surface (and that this is an accurate depiction of it) was produced by David Hoffman, Hermann Karcher and Fusheng Wei.



GERALD D. FISCHBACH

Scientific Director

2010 was a productive year for the Simons Foundation Autism Research Initiative (SFARI). We moved to new quarters that have allowed expansion of the SFARI program, and that brought us into proximity with the mathematics and physical sciences components of the Simons Foundation. Altogether, we enjoy a stimulating intellectual community. Superb investigators have been attracted from many fields to the study of autism. New hypotheses have emerged and powerful experimental tools are available to test them. A few of the advances made by Simons Investigators in the past year are outlined in this report. We now fund approximately 100 scientists who, in the aggregate, span the entire spectrum of neuroscience. The complexity of autism demands nothing less, as important questions must be answered at the levels of human genetics, molecular, cell and developmental biology, neural circuits, cognition and behavior.

The Simons Simplex Collection (SSC) now includes more than 2,700 families. Two studies describing whole genome scans for copy number variants of the probands, their parents and their unaffected siblings have appeared in the journal *Neuron*. Several other searches for *de novo* and inherited genetic risk factors in the SSC population will be completed in the coming months. Quantitative studies of the autism phenotype within the SSC population have also been completed.

The value of the SSC will increase over time as it is accessed for new studies, and as existing studies add a longitudinal component. Autism cannot be fully understood through a snapshot at just one point in time.

A new approach to analysis of genetic risk factors, called the Simons Variation in Individuals Project, was launched this year. The project is aimed at individuals with the exact same genetic variant, who will be evaluated with standard clinical assessments, neurological exams and advanced imaging protocols. We are beginning with deletions or duplications at chromosome 16p11.2, the most common variant discovered to date. What is the constellation of symptoms and signs associated with a known variant? Can insights be gained that will lead to biomarkers and potential therapies?

We welcomed scientists at SFARI this year. Marian Carlson, a distinguished geneticist at Columbia University, and formerly at the Howard Hughes Medical Institute, joined as deputy director of life sciences. Dennis Choi, a distinguished neuroscientist with extensive experience in translational research and therapeutics, joined as executive vice president of the foundation.

This year, SFARI.org, an important vehicle for communication with the science community, leaped ahead. New content and timely, well-written reporting have led to a remarkable increase in the number of users each month. SFARI.org has become an engine for scientific discourse, and a valuable resource for research tools such as SFARI Gene and SFARI Base.

In the coming year, the site will relaunch with a new design and many new resources and opportunities for the community. We welcome your input as new articles appear and new forums emerge.

Gerald D. Fischbach, M.D.
Scientific Director

RICARDO DOLMETSCH

Simons Investigator

"There were lots of people who said, 'No, by the time you reprogram the cell, you will have lost everything.'"

Not too long ago, scientists could only dream of studying live human neurons. Today, they've learned how to take an ordinary cell and coax it into becoming all the different cells in the human body—including neurons.

Ricardo Dolmetsch is performing this cellular alchemy for individuals with autism. By exposing skin cells taken from a particular individual to various chemical compounds, he can reverse their development, turning them into so-called induced pluripotent stem cells, which in turn can differentiate into neurons.

"When you take these cells and start differentiating them, they really do form little brains—it's really bizarre," says Dolmetsch, assistant professor of neurobiology at Stanford University.

Dolmetsch is doing this with children who have Timothy syndrome. Only about 60 people in the world are diagnosed with the disease, which is caused by a single gene and leads to heart arrhythmias, high anxiety and, for about 80 percent of individuals, autism.

Dolmetsch has already successfully turned skin cells from people with the syndrome into neurons. His next challenge is to see whether these neurons are noticeably different than those from healthy people.

"There were lots of people who said, 'No, by the time you reprogram the cell, you will have lost everything,'" he says. To the contrary, he has discovered several ways in which Timothy syndrome cells are abnormal.

For example, there are about 30 different types of neurons, and they show up in different proportions among the Timothy syndrome cells than in controls. Timothy syndrome neurons also have fewer synapses—the junctions between neurons—and shorter dendrites, the branches that receive nerve signals.

One big promise of these cells is that they could be used to screen drug treatments.

For example, stem cell–derived heart cells from people with Timothy syndrome have shown that certain anti-arrhythmia medications are more effective than others in people with the disorder, Dolmetsch says. "We're now convinced that this is a very viable approach to studying autism and probably other psychiatric disorders."

RUTH O'HARA

Simons Investigator

"While it has really been apparent that sleep is dysregulated in autism, it's unclear which particular sleep disorders are most prevalent and result in the observed sleep disturbance."

Most people have experienced crankiness, weakness and mental sluggishness after a bad night's sleep. For many children with autism and their parents, though, this pattern is a recurring nightmare.

Ruth O'Hara is investigating the murky relationship between sleep disturbances and autism spectrum disorders. As many as 80 percent of children with autism have trouble falling asleep or tend to wake up in the middle of the night, according to parent reports. A few small studies measuring brain waves during sleep have confirmed that children with autism don't get enough shut-eye.

"While it has really been apparent that sleep is dysregulated in autism, it's unclear which particular sleep disorders are most prevalent and result in the observed sleep disturbance," notes O'Hara, associate professor of psychiatry and behavioral sciences at Stanford University.

It's not difficult to imagine how sleep deprivation might contribute to a child's social and communication problems. Because of the extensive equipment and practicalities needed, this kind of research has been difficult to carry out, and much of it has been limited to older children who come into a laboratory for a night of observation.

"For children with autism, who show resistance to change and have difficulties with new environments, we may get a much better assessment of sleep if we can conduct the assessment in their home," she says.

O'Hara has spent much of her career performing full at-home sleep assessments on older individuals with Parkinson's and Alzheimer's diseases. In the past three years, she has begun to apply the technologies used in these assessments to developmental disorders, including autism.

For her SFARI project, she is thoroughly characterizing sleep disturbances in 130 children with autism—double the size of the largest study to date. Participants fall asleep in their own beds with electrodes attached to their heads—to measure brain activity—and to their legs, to monitor nighttime movements.

The children also wear a tube in their nose so that researchers can measure their breathing, and an oximeter to measure their oxygen saturation levels throughout the night—a key factor in determining sleep apnea, or irregular breathing during sleep.

This rigorous analysis of sleep problems in autism could have immediate treatment implications. For example, melatonin—a naturally occurring hormone and over-the-counter supplement—helps many adults with insomnia, and small clinical trials have shown that it may also lengthen sleep time in children with autism.

Even after O'Hara's study is complete, it will be difficult to sort out whether sleep disturbances are a cause or consequence of living with autism. To get at that question, she plans to conduct long-term studies that track sleep over the course of a child's early development.

MATTHEW STATE

Simons Investigator

"Finding one extremely rare variant that points to a key biological process can be more powerful in my view than finding out a ton about 30 different alleles that contribute a tiny bit of risk."

Dedicated child psychiatrists are not a rarity, but Matthew State is among the few who can also lay claim to a career as a world-class scientist, delivering breakthroughs in autism genetics.

State's work in 2005 on the SLITRK1 gene, associated with some forms of Tourette's syndrome, and his 2010 finding with collaborator Murat Gunel on the role of the WDR62 gene in brain malformations, were both cited as top scientific breakthroughs by *Science* magazine.

In autism research, State is best known for identifying rare mutations in the genes CNTN4 and CNTNAP2. His team is one of two that are sequencing and analyzing samples and data from the Simons Simplex Collection, a repository of genetic samples and clinical profiles from more than 2,700 families that have only one child with autism and unaffected parents.

Early in his research career, State was a staunch believer in the importance of rare variants in genetic disorders. "I like rare variants because they have big effects," he says. "Finding one extremely rare variant that points to a key biological process can be more powerful in my view than finding out a ton about 30 different alleles that contribute a tiny bit of risk, which is what we're seeing with common alleles in many common disorders."

Despite his interest in the important role rare variants can play in generating biological insights, State nonetheless says no one approach is likely to identify all of the causes of autism.

The genetic architecture of autism is likely to include both common and rare variants, he points out. And interestingly, so-called 'rare' variants are not as uncommon as once believed. "Rare variants are extremely common in the genome," State says. "And they are not always pathogenic."

But identifying a rare variant that crops up over and over again in the same spot on the genome in families or individuals with autism is like striking gold. "That would give you a very strong sense that you are looking in the right spot," State says.

Still, State believes that genetics can only take autism research so far. "It's the biological mechanisms that are going to be a target for treatment," he says, "not a particular variation in one person versus someone else."

LI-HUEI TSAI

Simons Investigator

"There are a lot of cross-disciplinary interactions [in autism research]," she says. "It's a highly stimulating environment."

Thought is electric in the human brain. Information flows from one brain cell to another via electrical signals that leap across the gap between neurons.

But in people with autism the ability of synapses—the junctions between neurons—to regulate the strength of this electrical signal goes awry. Some scientists say this difficulty with what's called synaptic plasticity may underlie the problems with learning and memory seen in people on the autism spectrum.

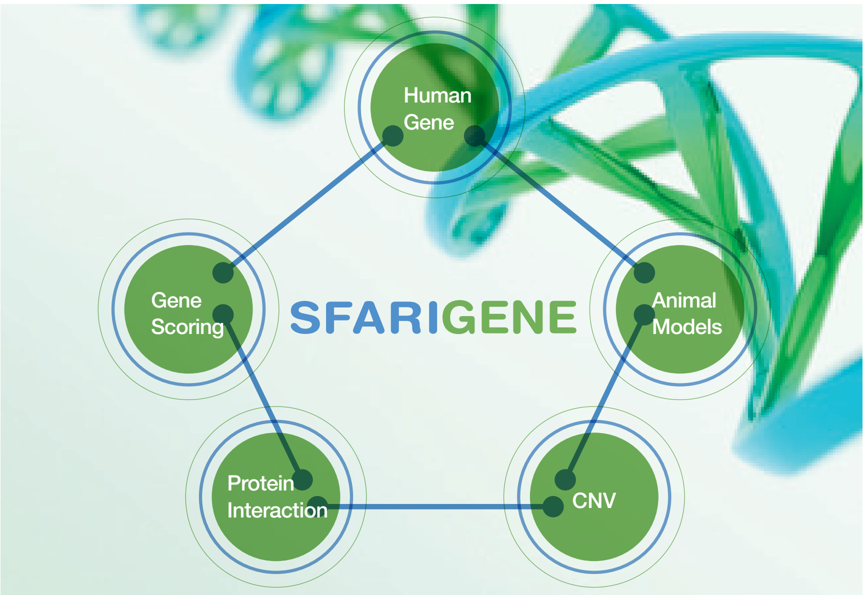
Li-Huei Tsai has been studying the neural pathways that control synaptic plasticity for more than 16 years. Born in Taiwan, she came to the United States to earn a Ph.D. at the University of Texas Southwestern Medical Center.

Following postdoctoral fellowships at Cold Spring Harbor Laboratory in New York and Massachusetts General Hospital, she joined the faculty at Harvard University in 1994. In 2006, she became the Picower Professor of Neuroscience at the Massachusetts Institute of Technology.

Tsai's research focuses on an important enzyme called cyclin-dependent kinase-5, or CDK5, which plays a major role in synaptic plasticity and is critical for learning and memory. Her lab is particularly interested in the maturation of dendrites—the spiny projections of neurons that help transmit electrical signals at the synapse. "Without CDK5, the spine remains in a very immature state," Tsai says.

She is set to examine how CDK5 regulates SHANK3, a gene implicated in autism. Mice lacking SHANK3 have trouble learning new tasks and interacting with other mice.

Tsai says she is new to translational research, which focuses on bringing results from the lab to the clinic more quickly. Unlike the more basic studies her lab has traditionally been involved in, "there are a lot of cross-disciplinary interactions [in autism research]," she says. "It's a highly stimulating environment."



SFARI GENE

http://gene.sfari.org/

A decade ago, researchers dreamed of finding the 'autism gene': a single major gene, or maybe a combination of a few genes that cause autism spectrum disorders. Today, the dream of one unified theory of autism has given way to a reality of more than 200 genes that have each been implicated in this complex disorder. New autism genes are constantly being identified by researchers at an ever-accelerating rate.

To help researchers sort through this large array of genes, in 2008 the Simons Foundation launched SFARI Gene, an evolving, expanding database of autism genes. The database currently lists about 250 genes, with detailed information about each. It also lists corresponding animal models when available, including links to the peer-reviewed literature.

A dedicated team of scientists headed by Sharmila Banerjee-Basu at Mindspec, Inc., a nonprofit bioinformatics organization based in McLean, Virginia, updates the database as new studies are published. Researchers using the site can edit the information on a particular gene or propose that a new gene be included (subject to approval by moderators).

"The site is really useful for people who aren't closely involved in the field, because there have been so many genes reported to be relevant to autism that it's hard for those researchers to have a grasp on it all," says Lauren Weiss, Ph.D., a Simons Investigator at the University of California, San Francisco.

At present, the project gives all autism genes equal emphasis. By summer 2011, however, the project's developers intend to incorporate a score for each gene that assesses the strength of the evidence linking that gene to autism. The scoring criteria, as well as the scores themselves, will be decided by an independent panel of experts: Lauren Weiss, Brett Abrahams of the Albert Einstein College of Medicine in New York, Dan Arking of Johns Hopkins University in Baltimore, Dan Campbell of the University of Southern California in Los Angeles, Heather Mefford of the University of Washington in Seattle, and Eric Morrow of Brown University in Providence, Rhode Island.

The scoring process has turned up some surprises even for the experts, Weiss says. "Sometimes there was a gene I had previously brushed off that turned out to have more evidence than I had realized, and sometimes it was the reverse," she says. "In some cases it became clear that there was a gap in the evidence about a particular gene, which suggests what the next study should be."

The site's developers also plan to release two other new modules in 2011: a list of copy number variants—portions of the genome that have been deleted or duplicated—that are linked to autism, and an 'interactome' that gives information about which cellular proteins interact with the protein produced by an autism gene.

SFARI MEETINGS

Simons Investigator
Guoping Feng,
SFARI Annual Meeting

A core mission of SFARI is to create a community of scientists and scholars galvanized by a single goal: to advance autism science. In 2010, several important meetings brought together top minds in autism research to collaborate and cross-pollinate ideas.

At a SFARI workshop held in February in New York, a distinguished panel of scientists met to discuss the link between autism and fever, an intriguing new research area.

Dominick P. Purpura, M.D., vice president for medical affairs at the Albert Einstein College of Medicine and one of the pioneering researchers in this area, said parents consistently report that during episodes of fever some of their children's autism symptoms improve, only to return when the fever subsides. Preliminary data from the Simons Simplex Collection, a repository of genetic samples from families with one child on the autism spectrum and unaffected parents, indicate that about 30 to 40 percent of families report improvement during febrile episodes.

This ebb and flow of symptoms suggests that the area of the brain in question, the locus coeruleus—a bundle of neurons in the brain stem that control many complex cognitive tasks—may be structurally normal but improperly regulated in those with autism, and therefore a potential target for treatment. A clear consensus from the meeting was that a deeper investigation of the locus coeruleus is required.

A one-day workshop that SFARI held in New York in May delved into the role of neural circuitry in autism.

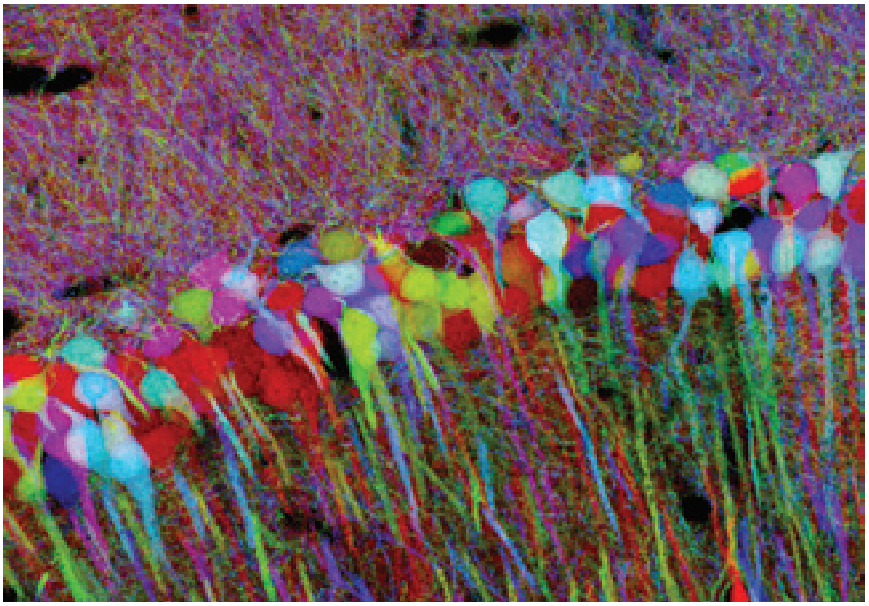
Many recent advances in autism research have centered on genetic and behavioral dysfunction, but less is known about how neural circuitry is altered. Researcher Tom Jessell of Columbia University proposes that autism may be, at least in part, a disorder of the synapses, the junctions between neurons.

Participants concluded that day that research on neural circuitry dysfunction in autism must range from the study in mouse models of individual synapses and neurons, to the study of cortical columns—vertical structures that are basic functional units for sensory processing—as well as large, inter-regional networks of the brain.

They said that rigorous measurement of physiological properties such as synaptic function and network synchronization are the first step toward achieving a better understanding of the neural circuitry underlying autism.

To further its goal of bringing together the best minds in autism research to share research progress, SFARI held its second annual meeting in Washington, D.C., in September. More than 130 Simons Investigators attended the three-day event in which they spoke about their work in cognition and behavior, gene discovery and expression, and molecular mechanisms or synaptic biology.

SFARI scientific director Gerry Fischbach said, “The meeting was exciting in that new, important advances were described in the areas of human genetics, nerve cell biology, systems neuroscience and animal models of autism. These advances move us closer to meaningful biomarkers for all aspects of the autism spectrum.”



A 'brainbow' image of the hippocampus of a transgenic mouse

RECENT ADVANCES

Over the past five years, the Simons Foundation Autism Research Initiative (SFARI) has lured a cohort of top-notch scientists into autism research in an effort to push the field past its infancy. That investment is bearing fruit as important new findings and publications have begun to manifest. SFARI-supported researchers are making discoveries using a wide range of approaches in autism research, from discovering new autism risk genes to testing the function of these genes in mice and studying higher-level cognition and behavior. The following represents a cross-section of recent publications by, or including, SFARI investigators.

The first study described below shows a relationship between copy number variants and autism spectrum disorders; the following two papers explore the functions of known genetic risk factors for autism in mice; and the final two reveal ways in which the human brain is affected by risk factors for autism.

Autism copy number variants

The genomes of people with autism contain a higher-than-typical number of deletions or duplications of stretches of DNA in protein-coding regions of the genome, reported a large, multi-author study in the 15 July 2010 issue of *Nature*[1]. Using high-resolution microarrays to scan genomes, the researchers found more than 200 different duplications or deletions, called copy number variants (CNVs), that occur in people with autism but not in controls. They also identified more than 100 new candidate risk genes for autism.

The researchers, among them several Simons Investigators, used bioinformatic analysis to study how these risk genes fit together into biochemical pathways. Some of the pathways they identified had already been implicated in autism. Others, such as a pathway involved in neural responses to external stimuli, had not previously been considered in connection with autism.

Each individual with autism may have a unique fingerprint of CNVs, but the affected genes appear to cluster into these connected pathways, says lead investigator Stephen Scherer, senior scientist at the Hospital for Sick Children in Toronto, Canada.

Genes underlying Angelman syndrome

A new mouse model sheds light on the genetic basis for the more severe forms of Angelman syndrome, a disorder marked by stunted language and cognitive development.

The main culprit in Angelman syndrome is believed to be a deletion in the UBE3A gene, which is also an autism risk gene. In the new study, reported in the August 2010 issue of *PLoS ONE* [2], SFARI Investigator Arthur Beaudet of Baylor College of Medicine in Houston and his colleagues produced a more debilitating form of Angelman syndrome in mice, with seizures and more severe motor and learning problems, by inactivating two genes near UBE3A, as well as UBE3A itself.

One of these two genes, GABRB3, is involved in controlling inhibitory signals in the brain, and has previously been linked to autism. The role of the other gene, ATP10A, in Angelman syndrome is unknown. The researchers plan to create mice that lack this gene alone in order to test its function.

Rett syndrome brain messenger

A single brain messenger may underlie nearly all of the characteristics of Rett syndrome, a disorder closely linked to autism, researchers reported in the 11 November issue of *Nature*[3].

A team led by Simons Investigator Huda Zoghbi at Baylor College of Medicine in Houston bred genetically-engineered mice in which the neurons that release an inhibitory neurotransmitter called gamma-aminobutyric acid (GABA) lack MeCP2, the gene that is mutated in Rett syndrome. In normal mice, this gene's product plays an important role in producing GABA.

In contrast with mice that lack MeCP2 in other subgroups of neurons, the new mice show nearly the full suite of social behaviors, compulsive paw-clasping and breathing difficulties that mark the disorder in mice. The study underscores the importance of inhibitory neurons for compulsive behaviors, Zoghbi says. She plans to study how restoring GABA signaling in mice lacking MeCP2 affects their symptoms.

Connectivity theory of autism

Children who carry a variant of the gene CNTNAP2, which has been linked to autism, show fewer long-range connections between language-processing regions of the brain and more connections between nearby regions compared with controls, according to a study in the 3 November issue of *Science Translational Medicine*[4]. The study provides evidence for the long-standing 'connectivity theory' of autism, which proposes that the disorder results from disrupted long-range connections and too many local connections.

The CNTNAP2 variant in question is found in about one-third of the population. It has been linked to higher risk for both autism and a disorder called specific language impairment.

SFARI investigator Daniel Geschwind of the University of California, Los Angeles, and his colleagues scanned the brains of children with autism, healthy children with the CNTNAP2 risk variant and controls as they performed learning tasks. Children with autism and the children with the risk variant both display highly similar brain connectivity patterns.

Families with autism genes

Children with autism and their typically developing siblings share certain patterns of brain activity that are different from those seen in the general population, researchers announced in the 7 December issue of the *Proceedings of the National Academy of Sciences*[5].

Simons Investigator Kevin Pelphrey of Yale University and his colleagues scanned the brains of children as they watched animations either of people walking, or of scrambled movement. As expected, children with autism show less activity than their typically developing siblings and a control group in a brain region specifically sensitive to biological motion.

Surprisingly, however, children with autism and their siblings both show lower activity than the control group in face-processing regions of the brain. This phenomenon represents an 'endophenotype'—a trait that appears in people who carry autism risk genes but do not have the disorder.

Intriguingly, typically developing siblings show higher activity than both their siblings with autism and the control group in a third brain region—possibly a form of compensatory brain activity, Pelphrey suggests. Stimulating these compensatory regions in high-risk children at an early age might help them avoid developing autism, he suggests.

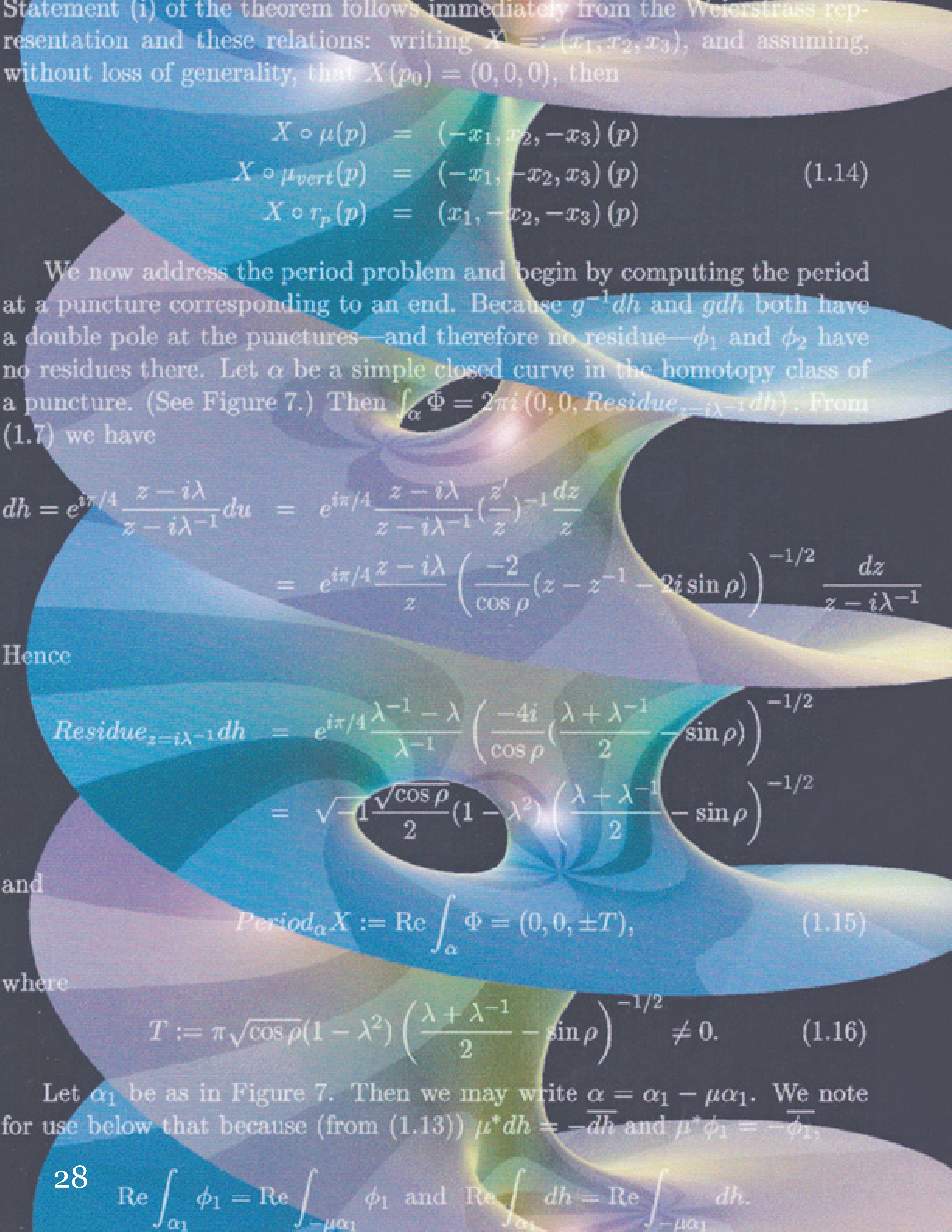
[1] Pinto D. *et al. Nature* **466**, 368–372 (2010)

[2] Jiang Y.H. *et al. PLoS ONE* **5**, e12278 (2010)

[3] Chao H. T. *et al. Nature* **468**, 263–269 (2010)

[4] Scott-Van Zeeland A. *et al*. *Sci. Transl. Med.* **2**, 56–80 (2010)

[5] Kaiser M.D. *et al. Proc. Natl. Acad. Sci. U. S. A.* **107**, 21223–21228 (2010)



Statement (i) of the theorem follows immediately from the Weierstrass representation and these relations: writing $X =: (x_1, x_2, x_3)$, and assuming, without loss of generality, that $X(p_0) = (0,0,0)$, then

$$\begin{aligned} X \circ \mu(p) &= (-x_1, x_2, -x_3)(p) \\ X \circ \mu_{vert}(p) &= (-x_1, -x_2, x_3)(p) \\ X \circ r_p(p) &= (x_1, -x_2, -x_3)(p) \end{aligned} \tag{1.14}$$

We now address the period problem and begin by computing the period at a puncture corresponding to an end. Because $g^{-1}dh$ and gdh both have a double pole at the punctures—and therefore no residue—ϕ_1 and ϕ_2 have no residues there. Let α be a simple closed curve in the homotopy class of a puncture. (See Figure 7.) Then $\int_\alpha \Phi = 2\pi i\,(0, 0, Residue_{z=i\lambda^{-1}} dh)$. From (1.7) we have

$$\begin{aligned} dh = e^{i\pi/4}\frac{z - i\lambda}{z - i\lambda^{-1}}du &= e^{i\pi/4}\frac{z - i\lambda}{z - i\lambda^{-1}}\left(\frac{z'}{z}\right)^{-1}\frac{dz}{z} \\ &= e^{i\pi/4}\frac{z - i\lambda}{z}\left(\frac{-2}{\cos\rho}(z - z^{-1} - 2i\sin\rho)\right)^{-1/2}\frac{dz}{z - i\lambda^{-1}} \end{aligned}$$

Hence

$$\begin{aligned} Residue_{z=i\lambda^{-1}} dh &= e^{i\pi/4}\frac{\lambda^{-1} - \lambda}{\lambda^{-1}}\left(\frac{-4i}{\cos\rho}\left(\frac{\lambda + \lambda^{-1}}{2} - \sin\rho\right)\right)^{-1/2} \\ &= \sqrt{-1}\,\frac{\sqrt{\cos\rho}}{2}(1 - \lambda^2)\left(\frac{\lambda + \lambda^{-1}}{2} - \sin\rho\right)^{-1/2} \end{aligned}$$

and

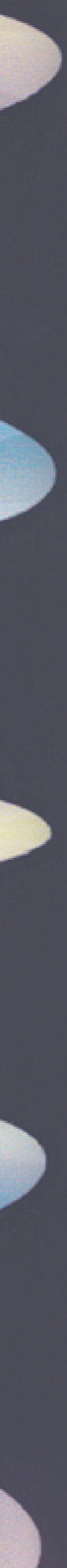
$$Period_\alpha X := \text{Re}\int_\alpha \Phi = (0, 0, \pm T), \tag{1.15}$$

where

$$T := \pi\sqrt{\cos\rho}(1 - \lambda^2)\left(\frac{\lambda + \lambda^{-1}}{2} - \sin\rho\right)^{-1/2} \neq 0. \tag{1.16}$$

Let α_1 be as in Figure 7. Then we may write $\alpha = \alpha_1 - \mu\alpha_1$. We note for use below that because (from (1.13)) $\mu^* dh = -\overline{dh}$ and $\mu^*\phi_1 = -\overline{\phi_1}$,

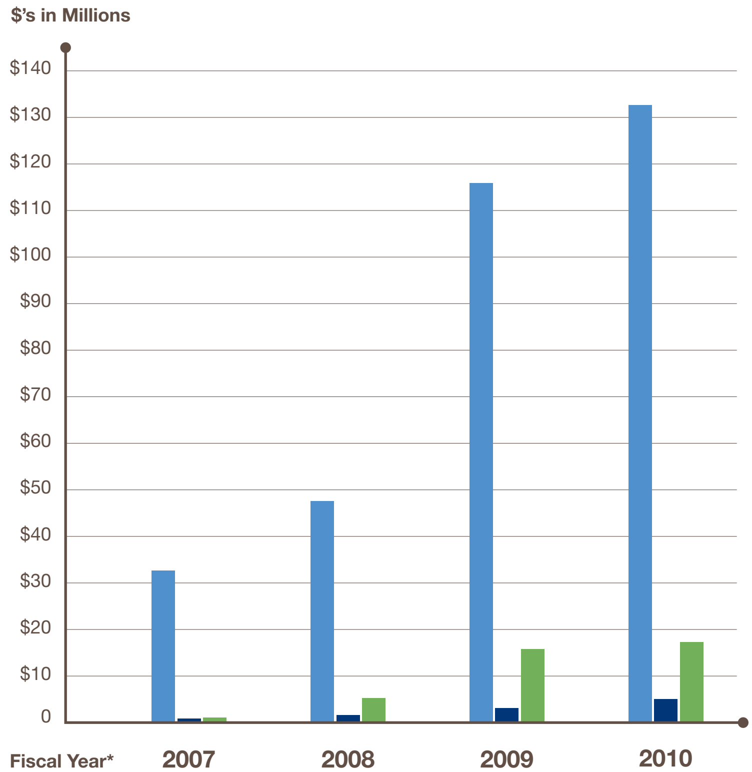
$$\text{Re}\int_{\alpha_1}\phi_1 = \text{Re}\int_{-\mu\alpha_1}\phi_1 \quad \text{and} \quad \text{Re}\int_{\alpha_1} dh = \text{Re}\int_{-\mu\alpha_1} dh.$$



A screw-motion-invariant genus-one helicoid

This surface with a ponderous name looks very much like the singly periodic genus-one helicoid with an overlay of mathematical text. The mathematics describes a surface very similar to the one illustrated here, from the paper by Hoffman, Karcher and Wei that proved its existence. As part of the research that led to its discovery, the surface was simulated by numerical approximation, and then, for several reasons, rendered graphically. First, it provided a test for the theoretical arguments that produced the formulae. Second, it verified that certain constants that had to be approximated were in fact computed correctly. Third, it exposed the geometry of the surface and allowed the researchers to produce a proof that the surface exists in a purely mathematical sense. If you look closely at the surface you may observe that the handles are more closely spaced than those in the singly periodic genus-one helicoid. You can also see that the periodicity of the surface requires not only a translation but also a slight twist around the central vertical axis. Mathematically, this is a great deal more difficult to handle than pure translation. In fact, even though the surface in this illustration exists, the proof of its existence came more than a decade after the image was made.

Proportions of Expenses

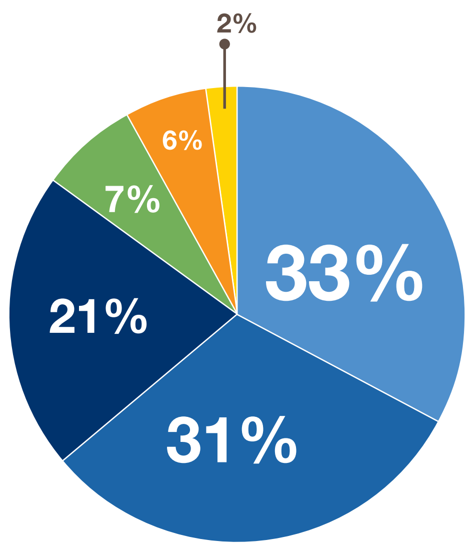


- Grant Payments
- General and Administrative Expenses
- Program Expenses

*2007 and 2008 figures reflect fiscal years ending June 30, 2007 and 2008; in 2009, the Simons Foundation changed its fiscal year to a December 31 year end. Therefore, the figures shown for 2009 and 2010 reflect grants and expenses for the calendar years 2009 and 2010.

Grant Payments by Category

Fiscal Year 2010



- Autism
- Math & Physical Science
- Life Science
- Misc. Education
- Math & Science Education
- Discretionary Giving

Balance Sheet

ASSETS	Dec 31, 2010	Dec 31, 2009
Cash and Cash Equivalents	33,126,253	46,878,441
Investment Portfolio	1,817,684,384	1,499,044,685
Property and Equipment, Net	11,177,137	1,174,199
Prepaid Excise Taxes	52,200	27,543
Other	148,807	190,094
Total	**1,862,188,781**	**1,547,314,962**

LIABILITIES	Dec 31, 2010	Dec 31, 2009
Grants Payable	257,627,652	243,928,115
Deferred Excise Tax Liability	8,694,983	8,694,983
Other	600,000	7,500
Total	**266,922,635**	**252,630,598**

NET ASSETS		
UNRESTRICTED NET ASSETS	**1,595,266,146**	**1,294,684,364**

Income Statement

REVENUE	Dec 31, 2010	Dec 31, 2009
Contributions	270,395,620	224,286,198
Investment Income	199,324,925	224,225,693
Total	**469,720,546**	**448,511,891**

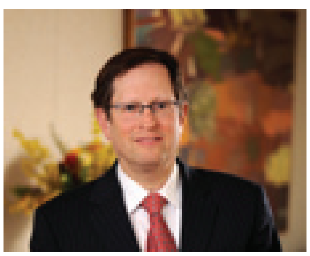
EXPENSES	Dec 31, 2010	Dec 31, 2009
Grant Payments	132,374,789	115,961,326
Change in Grants Payable	13,699,539	54,185,546
Program	17,056,217	15,789,493
General and Administrative	4,795,596	3,127,430
Depreciation and Amortization	579,743	274,235
Taxes	501,958	1,050,798
Other (Income) Losses	130,922	-
Total	**169,138,764**	**190,388,828**

NET INCOME	**300,581,781**	**258,123,063**

DIRECTORS

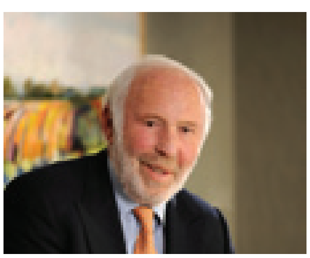
MARILYN H. SIMONS, PH.D.
PRESIDENT

Marilyn Hawrys Simons, Ph.D., has worked primarily in the nonprofit sector as a volunteer for the past 20 years, focusing on education. She has served as president of the Simons Foundation since 1994. Ms. Simons is currently president of the board of LearningSpring School, a school for children diagnosed with autism spectrum disorders, and is a member of the board of trustees of the East Harlem Tutorial Program. Ms. Simons is also a trustee of the Cold Spring Harbor Laboratory. She received a B.A. and a Ph.D. in economics from the State University of New York at Stony Brook.



MARK SILBER, J.D., M.B.A.
VICE PRESIDENT

Mark Silber is executive vice president and CFO of Renaissance Technologies LLC, a New York–based private investment adviser. Mr. Silber joined the company in 1983 and is responsible for the overall operations of its finance, administration and compliance departments. He was formerly a certified public accountant with the firm of Seidman & Seidman, now BDO USA. He holds a bachelor's degree from Brooklyn College, a J.D. and L.L.M. in tax law from New York University School of Law and an M.B.A. in finance from New York University Graduate School of Business Administration.



JAMES H. SIMONS, PH.D.
SECRETARY AND
TREASURER

James H. Simons, Ph.D., is secretary and treasurer of the Simons Foundation. Dr. Simons is also board chair and founder of Renaissance Technologies. Prior to his financial career, Dr. Simons served as chairman of the mathematics department at the State University of New York at Stony Brook, taught mathematics at the Massachusetts Institute of Technology and Harvard University, and was a cryptanalyst at the Institute for Defense Analyses in Princeton, New Jersey. Dr. Simons's scientific work was in geometry and topology; his most influential work involved the discovery and application of certain measurements, now called Chern-Simons invariants, which have had wide use, particularly in theoretical physics. Dr. Simons holds a B.S. from the Massachusetts Institute of Technology and a Ph.D. from the University of California, Berkeley and won the American Mathematical Society's Veblen Prize for his work in geometry in 1975. He is a trustee of the Stony Brook Foundation, Rockefeller University, Massachusetts Institute of Technology, Brookhaven National Laboratory, the Mathematical Sciences Research Institute and the Institute for Advanced Study and a member of the American Academy of Arts and Sciences and the American Philosophical Society.

SIMONS FOUNDATION STAFF

MARIA ADLER, M.B.A.
Chief Financial Officer

KATE AUGENBLICK, B.A.
Senior Executive Assistant

MARTA BENEDETTI, PH.D.
Associate Director for Research

LAWRENCE BIANCO, M.AC. C.P.A.
Finance Associate

ALEXANDRA BOWE, B.A.
Simons VIP Project Manager Assistant

MARIAN CARLSON, PH.D.
Deputy Director of Life Sciences

DENNIS CHOI, M.D., PH.D.
Executive Vice President

FRANK COLEMAN
Project Manager, SFARI.org

MEGHAN CRISWELL
Executive Assistant

KORI DEVLIN, B.A.
SFARI Research Administrative Assistant

MONIKA DYMEK, B.A.
Office Manager

DAVID EISENBUD, PH.D.
Director, Mathematics & the Physical Sciences

JAN FERNANDEZ, M.AC.
Accounts Payable Accountant

GERALD D. FISCHBACH, M.D.
Scientific Director

CHRIS FLEISCH, B.S.
IT Manager

ANDREA GALLEGO, B.A.
Program Associate, Family Giving

ANASTASIA GREENEBAUM, J.D., M.I.D.
Communications Director

MARION GREENUP, M.P.H., M.ED.
Vice President, Administration

FANG HAN, B.B.A, C.P.A.
Accounting Manager

LYDIA JUNG, B.A.
Administrative Assistant

STEPHEN JOHNSON, PH.D.
Director of Informatics

PEGGY KAPLIN, B.A.
Web Producer

PATTY KIM, B.A.
Administrative Assistant, Finance

APOORVA MANDAVILLI, M.S., M.A.
Director, SFARI.org

RICHARD MCFARLAND, M.P.A.
Grants Manager

AMY MILLETTE, B.A.
Manager, Conferences and Events

DAVID MOSHER, B.S., B.A.
Web Editor

DEBRA J. OLCHICK, B.A.
Manager, Conferences & Events

ALAN PACKER, PH.D.
Associate Director for Research

LAUREN RATH, B.A.
Grants Associate

ELIZABETH ROY, M.S.
Program Manager

DEBORAH RUDACILLE, M.A.
News Editor

ANNALIESE SHARKEY, B.A.
Executive Assistant

MARILYN SIMONS, PH.D.
President

JAMES H. SIMONS, PH.D.
Secretary and Treasurer

JOHN SPIRO, PH.D.
Senior Associate Director for Research

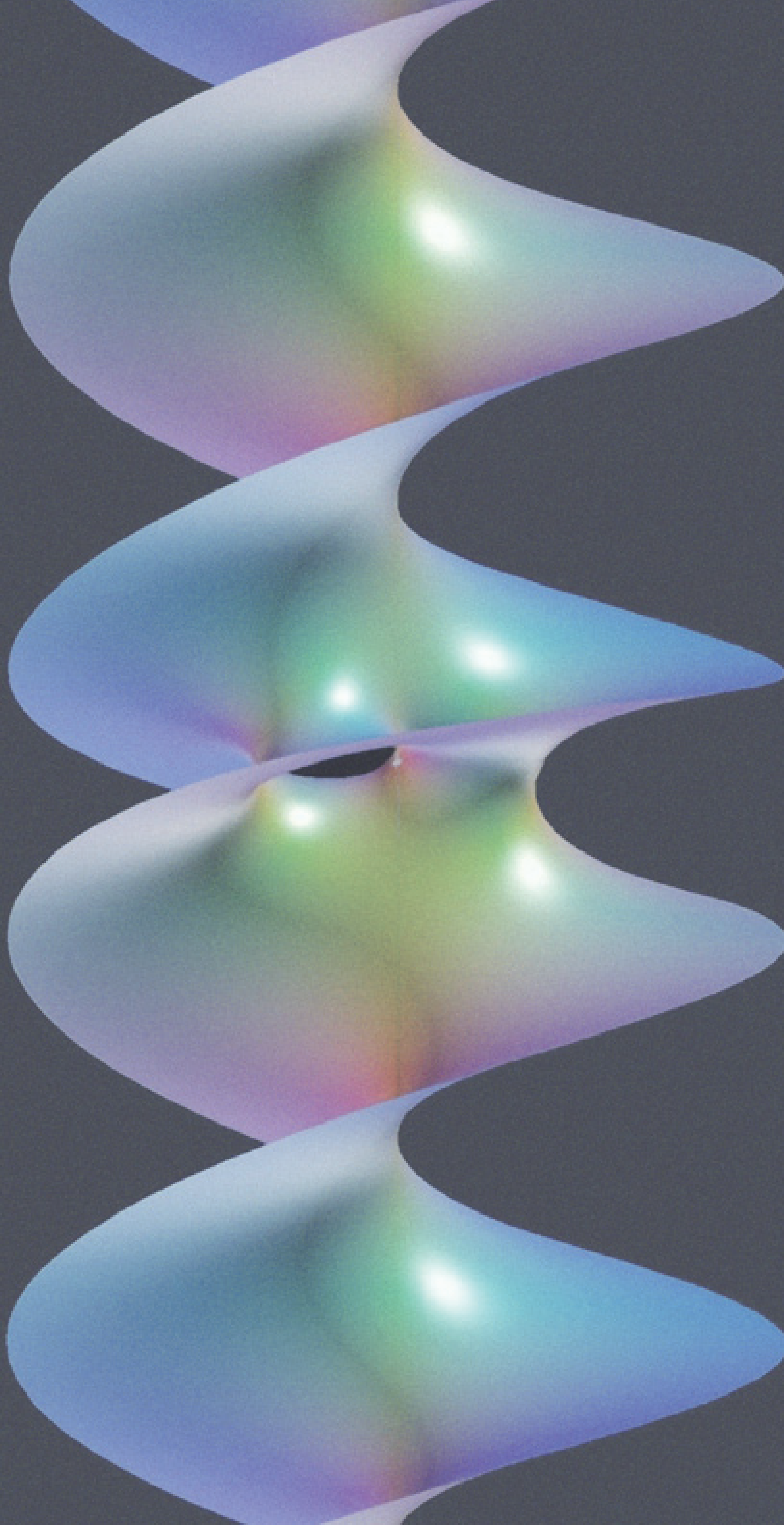
ADRIENNE TAURO-GREENBERG, B.S.
Business Manager

JENNIFER TJERNAGEL, M.S.
Simons VIP Project Manager

ZARA WATSON, B.A.
Receptionist

PATTY WEISENFELD, M.P.A.
Vice President, Family Giving

JESSICA WRIGHT, PH.D.
Research Editor



A genus-one helicoid

Though this surface looks simpler than its multi-handled relatives, its simplicity is deceptive: the lack of periodicity is a source of subtle complexity. There is only one handle, and the surface quickly becomes asymptotic to the helicoid. It was believed that it was impossible to have a minimal surface with these properties. The idea of how to make one can be easily described: take the periodic genus-one helicoid, and instead of screwing down the handles so they get closer together as in the preceding illustration, twist the other way so that they get farther apart. Remain near one handle and wait while the others disappear in the limit. Unfortunately, to make this into real mathematics requires a tremendous amount of machinery. Proof of its existence, by Hoffman, Michael Wolf and Matthias Weber, required several theoretical advances, computer simulation and the use of modern techniques in geometry related to such things as flat structures, gluing Riemann surfaces and the analysis of conical singularities with negative and infinite cone angles. However, the situation is still not satisfactory because the intuition developed in recent years indicates that this surface should be as natural as the helicoid. Indeed, Hoffman and Brian White have shown that such a surface exists based on intuitive geometric principles. But as of this writing no one has indicated a clear path to prove the existence or nonexistence of higher-genus helicoids. We can't even do two handles. What is missing from our arsenal of analytic techniques? What is it that we do not yet understand?

The Simons Foundation supports outstanding individual researchers and institutions seeking funding for advanced work in the basic sciences and mathematics, with a focus on innovative scientific projects where our involvement will play an essential role. In the course of this support, the foundation is interested in partnering with other entities, or providing matching support where appropriate.

Historically, the Simons Foundation has accepted only solicited grant proposals. All grant decisions are made by the directors of the foundation and the foundation staff. The foundation does not make awards to individuals, except through their institutions.

GRANTS TO INSTITUTIONS

Mathematics & the Physical Sciences

AMERICAN UNIVERSITY OF BEIRUT
Beirut, Lebanon

FRIENDS OF THE INSTITUT DES HAUTES ÉTUDES SCIENTIFIQUES
New York, New York

HARVARD UNIVERSITY
Cambridge, Massachusetts

MASSACHUSETTS INSTITUTE OF TECHNOLOGY
Cambridge, Massachusetts

MATHEMATICAL SCIENCES RESEARCH INSTITUTE
Berkeley, California

STONY BROOK UNIVERSITY
Stony Brook, New York

S.S. CHERN FOUNDATION FOR MATHEMATICAL RESEARCH
Houston, Texas

NATIONAL ACADEMY OF SCIENCES
Washington, D.C.

PEKING UNIVERSITY
Beijing, China

INSTITUTE FOR ADVANCED STUDY
Princeton, New Jersey

INSTITUTO DE MATEMÁTICA PURA E APLICADA
Rio de Janeiro, Brazil

Math and Science Education

AMERICAN ACADEMY OF ARTS AND SCIENCES
New York, New York

AMERICAN UNIVERSITY OF BEIRUT
Beirut, Lebanon

BROOKINGS INSTITUTION
Washington, D.C.

COLUMBIA UNIVERSITY
New York, New York

QUEENS COLLEGE/CUNY JOINTLY WITH RESEARCH FOUNDATION/CUNY
New York, New York

MATH FOR AMERICA
New York, New York

MATHEMATICAL SCIENCES RESEARCH INSTITUTE
Berkeley, California

MUSEUM OF MATHEMATICS
New York, New York

NEW YORK ACADEMY OF ARTS AND SCIENCES
New York, New York

ROCKEFELLER UNIVERSITY
New York, New York

SCIENCE FESTIVAL FOUNDATION
New York, New York

STONY BROOK UNIVERSITY
Stony Brook, New York

THIRTEEN WNET
New York, New York

UNIVERSITY OF MASSACHUSETTS, BOSTON
Boston, Massachusetts

Life Sciences

COLD SPRING HARBOR LABORATORY
Cold Spring Harbor, New York

INSTITUTE FOR ADVANCED STUDY
Princeton, New Jersey

MEMORIAL SLOAN-KETTERING CANCER CENTER
New York, New York

ROCKEFELLER UNIVERSITY
New York, New York

STONY BROOK UNIVERSITY
Stony Brook, New York

Autism

BAYLOR COLLEGE OF MEDICINE
Houston, Texas

BETH ISRAEL DEACONESS MEDICAL CENTER
Boston, Massachusetts

CALIFORNIA INSTITUTE OF TECHNOLOGY
Pasadena, California

CHILDREN'S HOSPITAL BOSTON
Boston, Massachusetts

CHILDREN'S HOSPITAL PHILADELPHIA
Philadelphia, Pennsylvania

COLD SPRING HARBOR LABORATORY
Cold Spring Harbor, New York

COLUMBIA UNIVERSITY
New York, New York

DUKE UNIVERSITY
Durham, North Carolina

EMORY UNIVERSITY
Atlanta, Georgia

FEINSTEIN INSTITUTE FOR MEDICAL RESEARCH
Manhasset, New York

GEORGETOWN UNIVERSITY
Washington, D.C.

HARVARD MEDICAL SCHOOL
Boston, Massachusetts

HARVARD UNIVERSITY
Cambridge, Massachusetts

HUGO W. MOSER RESEARCH INSTITUTE AT KENNEDY KRIEGER, INC.
Baltimore, Maryland

INTERNATIONAL SOCIETY FOR AUTISM RESEARCH
West Hartford, Connecticut

JOAN & SANFORD I. WEILL MEDICAL COLLEGE OF CORNELL UNIVERSITY
New York, New York

JOHNS HOPKINS UNIVERSITY SCHOOL OF MEDICINE
Baltimore, Maryland

MASSACHUSETTS GENERAL HOSPITAL
Boston, Massachusetts

MASSACHUSETTS INSTITUTE OF TECHNOLOGY
Cambridge, Massachusetts

MOUNT SINAI SCHOOL OF MEDICINE
New York, New York

NEW YORK UNIVERSITY
New York, New York

NEW YORK UNIVERSITY SCHOOL OF MEDICINE
New York, New York

OREGON HEALTH & SCIENCE UNIVERSITY
Portland, Oregon

PRINCETON UNIVERSITY
Princeton, New Jersey

RESEARCH FOUNDATION FOR MENTAL HYGIENE, INC. AT NEW YORK STATE PSYCHIATRIC INSTITUTE
New York, New York

RESEARCH INSTITUTE OF THE MCGILL UNIVERSITY HEALTH CENTRE
Montreal, Canada

ROCKEFELLER UNIVERSITY
New York, New York

RUTGERS, THE STATE UNIVERSITY OF NEW JERSEY
New Brunswick, New Jersey

SALK INSTITUTE FOR BIOLOGICAL STUDIES
La Jolla, California

STANFORD UNIVERSITY
Menlo Park, California

UNIVERSITY OF CALIFORNIA, LOS ANGELES
Los Angeles, California

UNIVERSITY OF CALIFORNIA, SAN DIEGO
San Diego, California

UNIVERSITY OF CALIFORNIA, SAN FRANCISCO
San Francisco, California

UNIVERSITY OF ILLINOIS AT CHICAGO
Chicago, Illinois

UNIVERSITY OF MASSACHUSETTS MEDICAL SCHOOL
Worcester, Massachusetts

UNIVERSITY OF MICHIGAN
Ann Arbor, Michigan

UNIVERSITY OF MISSOURI
Columbia, Missouri

UNIVERSITY OF NORTH CAROLINA AT CHAPEL HILL
Chapel Hill, North Carolina

UNIVERSITY OF OXFORD
Oxford, England

UNIVERSITY OF PENNSYLVANIA
Philadelphia, Pennsylvania

UNIVERSITY OF SOUTHERN CALIFORNIA
Los Angeles, California

UNIVERSITY OF TEXAS SOUTHWESTERN MEDICAL CENTER
Dallas, Texas

UNIVERSITY OF WASHINGTON
Seattle, Washington

VANDERBILT UNIVERSITY
Nashville, Tennessee

VANDERBILT UNIVERSITY MEDICAL CENTER
Nashville, Tennessee

WASHINGTON UNIVERSITY IN ST. LOUIS
St. Louis, Missouri

WHITEHEAD INSTITUTE FOR BIOMEDICAL RESEARCH
Cambridge, Massachusetts

YALE UNIVERSITY
New Haven, Connecticut

SFARI Scientific Advisory Board

CORI BARGMANN, PH.D.
Rockefeller University

THOMAS M. JESSELL, PH.D.
Columbia University

NANCY KANWISHER, PH.D.
Massachusetts Institute of Technology

DAVID LEWIS, M.D.
University of Pittsburgh

J. ANTHONY MOVSHON, PH.D.
New York University

STEVEN PAUL, M.D.
Cornell University

MARTIN RAFF, M.D.
University College London

ELIZABETH SPELKE, PH.D.
Harvard University

HUNTINGTON WILLARD, PH.D.
Duke University

Past Members

DENNIS W. CHOI, M.D., PH.D.
The Simons Foundation

WENDY CHUNG, M.D., PH.D.
Columbia University

CATHERINE E. LORD, PH.D.
University of Michigan Autism and Communication Disorders Center

RICHARD P. LIFTON, M.D., PH.D.
Yale University

Simons Investigators

RALPH ADOLPHS
California Institute of Technology

JOHN M. ALLMAN
California Institute of Technology

DAN ARKING
Johns Hopkins University School of Medicine

MARK BEAR
Massachusetts Institute of Technology

ARTHUR BEAUDET
Baylor College of Medicine

RAPHAEL BERNIER
University of Washington

MANZOOR BHAT
University of North Carolina

RANDY BUCKNER
Harvard University

JOSEPH BUXBAUM
Mount Sinai School of Medicine

ARAVINDA CHAKRAVARTI
Johns Hopkins University School of Medicine

ANDREW CHESS
Massachusetts General Hospital

WENDY CHUNG
Columbia University

JOHN CONSTANTINO
Washington University in St. Louis

EDWIN COOK, JR.
University of Illinois at Chicago

ERIC COURCHESNE
University of California, San Diego

MARK DALY
Massachusetts General Hospital

TED M. DAWSON
Johns Hopkins University School of Medicine

CURTIS DEUTSCH
University of Massachusetts Medical School

BETTY DIAMOND
The Feinstein Institute for Medical Research

RICARDO DOLMETSCH
Stanford University

MICHAEL D. EHLERS
Duke University

EVAN EICHLER
University of Washington

NOÉMIE ELHADAD
Columbia University

GUOPING FENG
Duke University

GORDON J. FISHELL
New York University School of Medicine

SIMON FISHER
University of Oxford

ERIC FOMBONNE
McGill University

JOHN GABRIELI
Massachusetts Institute of Technology

NICHOLAS GAIANO
Johns Hopkins University School of Medicine

DANIEL GESCHWIND
University of California, Los Angeles

JAY GINGRICH
Research Foundation for Mental Hygiene, Inc. at New York State Psychiatric Institute

JOSEPH GLEESON
University of California, San Diego

JOSEPH GOGOS
Columbia University

ANN GRAYBIEL
Massachusetts Institute of Technology

JAMES F. GUSELLA
Massachusetts General Hospital

ELLEN HANSON
Children's Hospital Boston

DAVID HEEGER
New York University

NATHANIEL HEINTZ
The Rockefeller University

BARBARA HEMPSTEAD
Weill Medical College of Cornell University

Z. JOSH HUANG
Cold Spring Harbor Laboratory

KIMBERLY HUBER
University of Texas Southwestern Medical Center

PENG JIN
Emory University

ERIC R. KANDEL
Columbia University

JOSHUA KAPLAN
Harvard University

MARIA KARAYIORGOU
Columbia University

DAVID KAUFMAN
Columbia University

RAYMOND KELLEHER
Massachusetts General Hospital

YOUNG-SHIN KIM
Yale University

AMI KLIN
Emory University

ROBIN KOCHEL
Baylor College of Medicine

RICHARD KRAUZLIS
Salk Institute for Biological Studies

ABBA KRIEGER
University of Pennsylvania

LOUIS KUNKEL
Children's Hospital Boston

PAUL LAW
Kennedy Krieger

DAVID LEDBETTER
Emory University

CHRISTA LESE MARTIN
Emory University

ARNOLD J. LEVINE
Institute for Advanced Study

PAT LEVITT
University of Southern California

J. TROY LITTLETON
Massachusetts Institute of Technology

DAN LITTMAN
New York University School of Medicine

CATHERINE E. LORD
University of Michigan

CHRISTA LESE MARTIN
Emory University

STEVEN MCKNIGHT
University of Texas Southwestern Medical Center

JUDITH MILES
University of Missouri

ALEA MILLS
Cold Spring Harbor Laboratory

ANTHONY MONACO
University of Oxford

CHARLES NELSON
Children's Hospital Boston

SASHA NELSON
Brandeis University

JOEL NIGG
Oregon Health and Science University

RUTH O'HARA
Stanford University

KAREN O'MALLEY
Washington University in St. Louis

PAVEL OSTEN
Cold Spring Harbor Laboratory

OPAL OUSLEY
Emory University

LUIS PARADA
University of Texas Southwestern Medical Center

KAREN PARKER
Stanford University

PAUL PATTERSON
California Institute of Technology

KEVIN PELPHREY
Yale University

STEVEN PETERSEN
Washington University in St. Louis

BRADLEY PETERSON
Columbia University

BEN PHILPOT
University of North Carolina at Chapel Hill

JOSEPH PIVEN
University of North Carolina at Chapel Hill

VIJAYA RAMESH
Massachusetts General Hospital

LOUIS REICHARDT
University of California, San Francisco

BERNARDO SABATINI
Harvard Medical School

REBECCA SAXE
Massachusetts Institute of Technology

ROBERT SCHULTZ
The Children's Hospital of Philadelphia

JONATHAN SEBAT
University of California, San Diego

MORGAN SHENG
Massachusetts Institute of Technology

ELLIOTT SHERR
University of California, San Francisco

MAGGIE SHIFFRAR
Rutgers, The State University of New Jersey

PAWAN SINHA
Massachusetts Institute of Technology

HAZEL SIVE
Whitehead Institute for Biomedical Research

JESSE SNEDEKER
Harvard University

MATTHEW STATE
Yale University

THOMAS SÜDHOF
Stanford University

Simons Investigators, continued

DAVID SULZER
Columbia University

MRIGANKA SUR
Massachusetts Institute of Technology

JIM SUTCLIFFE
Vanderbilt University

SUSUMU TONEGAWA
Massachusetts Institute of Technology

LI-HUEI TSAI
Massachusetts Institute of Technology

RICHARD TSIEN
Stanford University

MICHAEL ULLMAN
Georgetown University

FLORA VACCARINO
Yale University

ROGER VAUGHAN
Columbia University

CHRISTOPHER WALSH
Beth Israel Deaconess Medical Center

STEPHEN WARREN
Emory University

ZACHARY WARREN
Vanderbilt University

LAUREN WEISS
University of California, San Francisco

MICHAEL WIGLER
Cold Spring Harbor Laboratory

LARRY ZIPURSKY
University of California, Los Angeles

HUDA ZOGHBI
Baylor College of Medicine

For more information on the
Simons Foundation and SFARI,
please visit our websites:

www.simonsfoundation.org
www.sfari.org

The Simons Foundation is pleased to present you with these computer-generated images of minimal surfaces by mathematician David Hoffman and collaborators, including James T. Hoffman (no relation). These images illustrate ongoing contemporary mathematics research on a very classical subject. Minimal surface theory uses techniques from many areas of mathematics—topology, partial differential equations, measure theory, complex and geometric analysis, to name only a few. There are also deep connections with mathematical physics (cosmology, string theory) and with materials science and other areas of engineering. We have illustrated here just one of many threads in this ongoing research area.

David Hoffman is currently a consulting research professor in the Department of Mathematics at Stanford University. He studies differential geometry and its applications, and his research has incorporated computer simulation in the theory of minimal and constant-mean-curvature surfaces.

SIMONS FOUNDATION
160 Fifth Avenue
New York, NY 10010
Tel. 646 654 0066

www.simonsfoundation.org

SFARI
www.sfari.org

The catenoid

The study of minimal surfaces—mathematical idealizations of soap films—has been central to the development of modern geometry and partial differential equations. The minimal surface pictured here, called the catenoid, is the surface of rotation swept out by a catenary, the curve formed by a hanging chain. Leonhard Euler, the greatest mathematician of his age, inaugurated the study of minimal surfaces in 1744 by proving that, among all connected surfaces with the same pair of coaxial circular boundaries, the one with the least area must be part of a catenoid.