IAS
The Institute Letter
Spring 2009

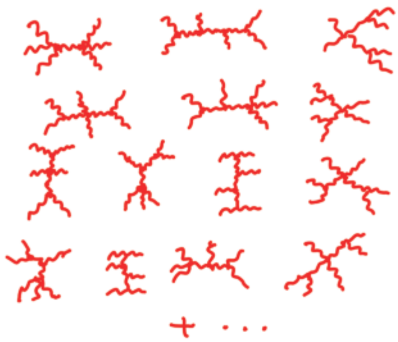

Figure 1

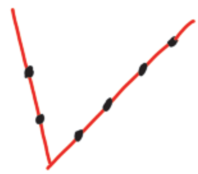

Figure 3

Figure 4

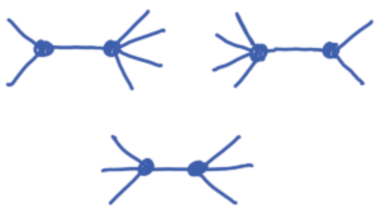

Figure 2

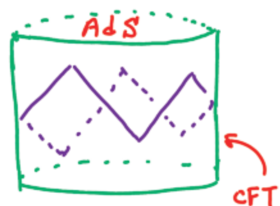

Figure 5

NIMA ARKANI-HAMED AND DONAL O'CONNELL

Feynman Diagrams and Beyond

Physicists have used Feynman diagrams as a tool for calculating scattering amplitudes that describe particle interactions for more than six decades (see article, page 4). Their broad utility was due initially in large part to the seminal work of Freeman Dyson, Professor Emeritus in the School of Natural Sciences. Feynman diagrams provide a way of calculating scattering amplitudes in a manner that is consistent with quantum mechanics and special relativity and more recently they have been used for increasingly complex calculations related to the physics being probed at high-energy particle accelerators, such as the Large Hadron Collider (LHC).

The many graphs depicted in Figure 1 represent a small sample of the Feynman diagrams necessary to compute the amplitude for producing four outgoing gluons from the collision of two incoming ones. This process will occur several hundred times a second at the LHC. Each Feynman diagram pictorially represents a specific way in which this process can happen, and is associated with a complicated mathematical expression. The amplitude is obtained by adding up a total of 220 diagrams.

Because the number of Feynman diagrams needed to calculate an amplitude can climb into the thousands, increasingly clever tricks have been developed to bypass their direct computation. Figure 2 represents the complete set of BCFW diagrams required to calculate the same process. These powerful new diagrams were developed at the Institute, and were made possible by the realization that the amplitudes possess remarkable properties when the gluons are associated with points in a geometric setting known as "twistor space," rather than ordinary space-time. For example, this six-gluon process is only not zero when the points in twistor space representing the six gluons lie along two intersecting lines (Figure 3). Recent work has revealed a direct relationship between BCFW terms and "twistor diagrams" (Figure 4), which reduce the calculation of amplitudes to simple multiplication rules. Scattering processes involving very strongly interacting gluons are impossible to calculate using Feynman diagrams. Instead, a "holographically dual" formulation of the problem has been developed (Figure 5), where the gluon scattering in a four-dimensional conformal field theory (CFT) is related to a tractable string theoretic calculation in a higher-dimensional anti–de Sitter (AdS) space.

IAS
The Institute Letter

Institute for Advanced Study — Spring 2009

New Faculty Appointed to School of Natural Sciences

Cosmologist Matias Zaldarriaga to Explore Connections between Astrophysics and Particle Physics

TAMAR DUJOVNE

Matias Zaldarriaga

Matias Zaldarriaga, who has made many influential and creative contributions to our understanding of the early universe, particle astrophysics, and cosmology as a probe of fundamental physics, will join the Faculty of the School of Natural Sciences at the Institute as of July. He will succeed astrophysicist Peter Goldreich, who joined the Faculty in 2004 and who will retire at the end of June.

"We are delighted that Matias Zaldarriaga will be joining the Faculty of the Institute," said Director Peter Goddard. "He has added greatly to our understanding of the microwave background, and he combines great breadth and depth in his research with the ability to find simple and elegant solutions to complicated problems, leading to results that are practically useful."

Much of Zaldarriaga's work centers on the recent remarkable discovery that the expansion of the universe is accelerating, rather than decelerating as would be expected if gravity were the dominant long-range force in the universe. Zaldarriaga, who is currently a Professor of Astronomy and Physics at Harvard University, first became known for the development of an extremely fast numerical technique for calculating the properties of small fluctuations in the Cosmic Microwave Background (CMB), which suggest the properties of the early universe. He developed this technique in 1996 while a first-year graduate student at the Massachusetts Insti-

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Stanislas Leibler to Expand Life Sciences at IAS

COURTESY OF THE ROCKEFELLER UNIVERSITY

Stanislas Leibler

Stanislas Leibler, a leading scientist working in theoretical and experimental biology, has been appointed to the Faculty of the Institute's School of Natural Sciences as part of a joint initiative with the Rockefeller University. Leibler, who joined the Institute as of April, will continue to hold his positions at Rockefeller as Gladys T. Perkin Professor and Head of the Laboratory of Living Matter.

"The quality and depth of Stan's research and his influential experimental and theoretical work will contribute greatly to our work in systems biology," said Director Peter Goddard. "This new initiative with the Rockefeller University will foster important and distinctive contributions to research in biology, and will enable us to expand greatly what we are doing in this field, helping the Institute to continue to train the next generation of life scientists."

Leibler's appointment engages the Institute and the Rockefeller University in a collaboration that will further quantitative and theoretical biology at both institutions. The initiative is being funded by a $10 million gift from the Simons Foundation that will be divided equally between the two institutions and will support biologists, mathematicians, physicists, and computer scientists exploring quantitative and theoretical approaches to biological problems. As part of this collaboration, the Institute and Rockefeller will jointly appoint visiting professors and graduate and postdoctoral fellows,

(Continued on page 9)

Major Gift to Establish the Shelby White and Leon Levy Archives Center

COURTESY OF THE INSTITUTE FOR ADVANCED STUDY ARCHIVES

A photograph from the Institute Archives of a symposium on differential topology held in 1963. Back row (left to right): Raoul Bott, Barry Mazur, G. A. Hedlund, T. T. Frankel, Stephen Smale, N. H. Kuiper, J. F. Adams, William Browder, J. W. Milnor, M. A. Kervaire. Front row: S. S. Chern, R. G. Pohrer, Atle Selberg, Marston Morse, Walter Leighton, Morris Hirsch, S. S. Cairns, Hassler Whitney

The creation of an archives center at the Institute for Advanced Study has been funded by a $3.5 million gift from the Leon Levy Foundation. The Shelby White and Leon Levy Archives Center will allow the Institute to formally organize and preserve important historical materials, and serve as a repository for papers, oral histories, photographs, and other essential source materials moving forward. The gift reflects the continuing, dedicated support of Institute Trustee Shelby White and the Leon Levy Foundation, a not-for-profit foundation formed after the death of White's husband Leon Levy, a leading financier who served as an Institute Trustee from 1988 to 2003.

"We are immensely grateful to Shelby White and the Leon Levy Foundation for providing us with the resources to meet a pressing and critically important need for the Institute," said Director Peter Goddard. "This donation will ensure the preservation of the Institute's Archives, a resource of great historical importance, and demonstrates the outstanding generosity and vision of Shelby and the foundation, from which the Institute has benefited enormously over the years."

The gift from the Leon Levy Foundation will cover initial capital costs for the Archives, and fund an endowment to support operating costs now and in future years. The gift has enabled the hiring of Christine Di Bella, most recently the archivist and project director for the Philadelphia Area Consortium of Special Collections Libraries' Consortial Survey Initiative based at the Historical Society of Pennsylvania, as the Institute's first full-time archivist. In addition, the gift will make possible the employment of support staff and oral historians, facilitate improvements to the existing archival space, and create additional space to house acquisitions projected over the next twenty years.

(Continued on page 12)

News of the Institute Community

DANIELLE ALLEN, UPS Foundation Professor in the School of Social Science, and NIMA ARKANI-HAMED, Professor in the School of Natural Sciences, have been elected Fellows of the American Academy of Arts & Sciences.

From Arabian Tribes to Islamic Empire: Army, State and Society in the Near East c. 600–850, a collection of articles that study the development of early Muslim society by PATRICIA CRONE, Andrew W. Mellon Professor in the School of Historical Studies, has been published by Ashgate.

NICOLA DI COSMO, Luce Foundation Professor in East Asian Studies in the School of Historical Studies, has edited two books. *Military Culture in Imperial China* (Harvard University Press, 2009) explores the relationship between culture and the military in Chinese society from early China to the Qing empire. *The Cambridge History of Inner Asia: The Chinggisid Age* (Cambridge University Press, 2009), coedited with Allen J. Frank and Peter B. Golden, centers on the history and legacy of the Mongol world empire founded by Chinggis Khan and his sons.

ERIC S. MASKIN, Albert O. Hirschman Professor in the School of Social Science, was named an honorary Professor of Shenzhen University in China in ceremonies held last November.

JOAN WALLACH SCOTT, Harold F. Linder Professor in the School of Social Science, has received the American Historical Association's Award for Scholarly Distinction. Previous awardees from the Institute include Felix Gilbert, George F. Kennan, and Kenneth M. Setton, former Professors in the School of Historical Studies. At the same meeting, ATINA GROSSMANN, former Member (1997–98) in the School of Social Science, received the AHA's George L. Mosse Prize for her book *Jews, Germans, and Allies: Close Encounters in Occupied Germany* (Princeton University Press, 2007).

Contents

Questions and comments regarding the *Institute Letter* should be directed to Kelly Devine Thomas, Senior Publications Officer, via email at kdthomas@ias.edu or by telephone at (609) 734-8091.

Harvard University Press has published a festschrift for GLEN W. BOWERSOCK, Professor Emeritus in the School of Historical Studies, as part of its Loeb Classical Monographs series. Former School of Historical Studies Members T. Corey Brennan (1998) and Harriet I. Flower (2001–02) edited the volume, *East & West: Papers in Ancient History Presented to Glen W. Bowersock*, which is based on a 2006 Princeton University symposium held in honor of Bowersock upon his retirement. The volume features contributions from eight scholars from France, Germany, Italy, the United Kingdom, and the United States, five of whom are past Members in the School. Also, the Oxford University Press has published Bowersock's new book, *From Gibbon to Auden: Essays on the Classical Tradition*, and he was recently elected a Foreign Member of the Royal Academy of Belgium.

PETER PARET, Professor Emeritus in the School of Historical Studies, presented a talk, "Barlach at the Princeton University Art Museum," on February 21 to mark the opening of the Princeton University Art Museum exhibition "Myth and Modernity: Ernst Barlach's Images of the Nibelungen and Faust," on view until June 7. Paret also gave a lecture about Barlach's work for the Institute community and participated in a related symposium on March 28, where he spoke on the mythological aspect of the exhibition. This talk will be published in Germany in conjunction with an exhibition at the Ernst Barlach Foundation in Güstrow.

LUIS CAFFARELLI, former Faculty member (1986–96) and Member (2009) in the School of Mathematics, has been awarded the 2009 Leroy P. Steele Prize for Lifetime Achievement, which recognizes Caffarelli as "one of the world's greatest mathematicians studying nonlinear partial differential equations."

Institute Trustee DAVID A. HOLLINGER, Preston Hotchkis Professor in the Department of History at the University of California, Berkeley, has been elected President-Elect of the Organization of American Historians. In 2010, he will become President of the organization, a 9,000-member professional association for specialists in the history of the United States.

Music for Limón Dances, composed by the Institute's former Artist-in-Residence (2000–07) JON MAGNUSSEN, has been released by Albany Records. The CD includes *Psalm*, recorded in Princeton during Magnussen's final year at the Institute, and *The Winged*, recorded earlier by members of the Juilliard Orchestra.

The Strangest Man: The Hidden Life of Paul Dirac, Quantum Genius, by GRAHAM FARMELO, a former Director's Visitor, has been published in the United Kingdom by Faber and Faber. The book is scheduled for publication in the United States by Basic Books in August. Farmelo, Senior Research Fellow at the Science Museum in London, wrote much of the biography while at the Institute.

The Jordan Schnitzer Book Award of the Association for Jewish Studies was awarded to ELISHEVA BAUMGARTEN, Member (2008–09) in the School of Historical Studies for her book *Mothers and Children: Jewish Family Life in Medieval Europe* (Princeton University Press, 2004).

AURELIAN CRAIUTU, Member (2008–09) in the School of Social Science, has been named by the President of Romania to serve as Honorary Chair of the Presidential Committee for the Study of Romania's Political and Constitutional Regime.

BENCE KOCSIS, Member (2008–09) in the School of Natural Sciences, has received the Junior Prima Primissima Prize, awarded annually to recognize Hungarians under the age of thirty with exceptional accomplishments and potential. Kocsis was honored in the category of arts and sciences.

PANTELIS NIGDELIS, Member (2008–09) in the School of Historical Studies, has been awarded the G. Oicnomos Prize by the Academy of Athens for his book *Epigraphica Thessalonicensia: A Contribution to the Political and Social History of Ancient Thessaloniki* (University Studio Press, 2006). The prize is awarded for original scientific research devoted to the history, epigraphy, and archaeology of ancient Macedonia. Nigdelis's book illuminates the history of Thessalonika based on some 140 ancient Greek inscriptions.

NICHOLAS CANNY, former Member (1979–80) in the School of Historical Studies, was elected in March 2008 to serve for three years as President of the Royal Irish Academy. Canny is currently Academic Director of the Moore Institute for Research in the Humanities and Social Studies at the National University of Ireland, Galway.

The Leroy P. Steele Prize for a Seminal Contribution to Research was presented to former Member (1992–93) RICHARD HAMILTON for his paper "Three-manifolds with positive Ricci curvature," published in the *Journal of Differential Geometry* in 1982.

Former Member (1968–69, 1977–78) I. G. MACDONALD received the Leroy P. Steele Prize for Mathematical Exposition for his book *Symmetric Functions and Hall Polynomials* (second edition, Oxford University Press, 1995).

Former Member (1996–97) JOHN MORGAN was honored by the American Mathematical Society with the 2009 Levi L. Conant Prize for his article, "Recent Progress on the Poincaré Conjecture and the Classification of 3-Manifolds," published in the *Bulletin of the AMS* in 2005. The Conant Prize recognizes the best expository paper published in either the *Notices of the AMS* or the *Bulletin of the AMS* in the preceding five years. In September, Morgan will become Director of the new Simons Center for Geometry and Physics at Stony Brook University, the State University of New York.

Former Members ALAIN ROUET (1981–82) and RAYMOND STORA (1961–62) are among the winners of the 2009 Dannie Heineman Prize for Mathematical Physics, awarded by the American Institute of Physics and the American Physical Society. Rouet and Stora share the prize with Carlo Becchi of the University of Genoa and Igor Tyutin of the Lebedev Physical Institute in Moscow "for discovery and exploitation of the BRST symmetry for the quantization of gauge theories providing a fundamental and essential tool for subsequent developments."

VASUDEVAN SRINIVAS, former Member (1982–83) in the School of Mathematics, has been selected to receive the 2008 TWAS Prize in Mathematics. TWAS, the Academy of Sciences for the Developing World, will present the award at its annual meeting, which will be held in October in South Africa.

CORRECTION: The Fall 2008 issue of the *Institute Letter* incorrectly stated that Paul Dirac was still the youngest-ever theoretician to win the Nobel Prize in Physics. In 1957 this distinction passed to T. D. Lee, then a Member of the Institute.

Spiro J. Latsis Elected to the Board of Trustees

ARGYROPOULOS/SIPA

Spiro Latsis

Spiro J. Latsis, President of the Latsis Group, one of the largest privately owned firms in Europe, has been elected to the Board of Trustees of the Institute for Advanced Study.

The Latsis Group is active in more than twenty countries across five continents, with holdings in shipping, banking, aviation, oil refining, construction, and real estate. Latsis serves as Chairman of the Board of EFG Bank European Financial Group. He is an Honorary Fellow of the London School of Economics and a member of its Board of Governors. He also sits on the advisory board of the institution's Hellenic Observatory.

Latsis earned a B.S., M.S., and Ph.D. at the London School of Economics, where he later served as a Research Assistant and Instructor. He was a Visiting Professor at the Harvard University Graduate School of Education and at Boston University, where he taught courses in economics and in the methodology of social science.

Second Trip Into Space for Charles Simonyi

PETER GODDARD

Charles Simonyi, with hand raised, prepares for launch

Charles Simonyi, Chairman of the Institute's Board of Trustees and President and Chief Executive Officer of Intentional Software Corporation, has become the first civilian to travel into space for a second time. Simonyi was on board the Soyuz TMA-14 spacecraft that launched from the Baikonur Cosmodrome in Kazakhstan and docked with the International Space Station in March. He spent thirteen days in space, conducting experiments and communicating by HAM radio with students on Earth. His website, www.charlesinspace.com, features a blog about his trip, along with information about his training and the mission.

History in the Comic Mode, or Always Admitting That We May Be Wrong

Professor Caroline Walker Bynum describes the Institute's School of Historical Studies not as a history department in the traditional sense, but rather a school that "offers the study of phenomena from a historical perspective." In "Perspectives, Connections & Objects: What's Happening in History Now," an article in the Winter 2009 issue of *Dædalus*, Bynum writes about the application of theory to historical scholarship, particularly the great shift during the past four decades toward cultural history—a linguistic turn influenced by French intellectuals and American anthropologists, especially the late Clifford Geertz, founding Professor of the Institute's School of Social Science.

KATE ABLUTZ

Caroline Bynum discusses the future of historical scholarship with a roundtable of IAS Members.

"This cultural or linguistic, poststructuralist or postmodern turn is usually understood to hold that language does not reflect the world but precedes it and makes it intelligible by constructing it: in other words, there is no objective universe independent of language and no transparent relationship between social organization and individual self-understanding," according to Bynum. "Such awareness entails, for historians, the realization that the categories and periods they use are expository devices that need constant reformulation exactly because they are always based in political and social assumptions that may, because inherited, be very hard to detect."

Bynum's own work as a medieval historian has played a considerable role in this shift. She has influenced scholars by advocating a style of historical scholarship, which she calls "history in the comic mode," that acknowledges that evidence will always be partial and analysis inconclusive. First proposed in her book *Fragmentation and Redemption: Essays on Gender and the Human Body in Medieval Religion* (Zone Books, 1991), "a comic stance toward doing history is aware of contrivance, of risk," according to Bynum. "It always admits that we may be wrong. A comic stance knows that there is, in actuality, no ending (happy or otherwise)—that doing history is, for the historian, telling a story that could be told in another way."

A recent festschrift in honor of her work, *History in the Comic Mode: Medieval Communities and the Matter of Person* (Columbia University Press, 2007), was presented to Bynum by her students of the past thirty-five years, including a number of former Institute Members and Visitors, at a conference held at Princeton University in 2007. According to the volume's editors, Rachel Fulton and Bruce W. Holsinger, who were graduate students at Columbia where Bynum taught from 1998 until her appointment to the Faculty of the Institute in 2003, her most influential lessons extended beyond particular subjects, such as her work on women, the body, food, and religiosity, for which she is well known, to the larger arena of method. Her "comic mode," Fulton and Holsinger explain, has encouraged her students to "revel in the compromises, coincidences, and wild improbabilities of the past that we can in fact see, if all too provisionally, through our sources, while at the same [time] enjoying the contingency and plurality of the approaches we bring to our understanding of the past."

In her recent *Dædalus* article, Bynum evaluates the current state of historical writing against the anxiety voiced in the mid-1990s about the direction of scholarship in the field, articulated perhaps most acutely in the volume *What's Happened to the Humanities?* (Princeton University Press, 1997). What she finds today is history writing that is stronger and more sophisticated "exactly because the insights of the linguistic turn have been

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Sparking Cross-Disciplinary Conversations

Caroline Walker Bynum, who studies the social, cultural, and intellectual history of Europe from the early Middle Ages to the early modern period, has created the paradigm for the study of women's piety that dominates the field of medieval studies today and has helped propel the history of the body into a major area of premodern history.

The breadth of her influence was the topic of a panel discussion at a conference on women and religion at the Radcliffe Institute for Advanced Study in April 2008. The session was convened by Drew Gilpin Faust, the President of Harvard and a historian of the American South, who called Bynum's 1987 book *Holy Feast and Holy Fast* (University of California Press), a study of the religious lives of medieval women, "a touchstone" for younger scholars. Bynum's latest book, *Wonderful Blood* (University of Pennsylvania Press, 2007), which examines the religious significance of blood in late-medieval northern Germany, won the Award for Excellence in the historical-studies category from the American Academy of Religion in 2007.

According to Bynum, among the many ways that the Institute is exemplary is in the amount of free time it provides to scholars and the opportunities it enables for cross-disciplinary interactions. "There is a real need for people to have the opportunity to talk to each other," says Bynum. "At the Institute, there are surprising interactions and energy between fields."

Since February 2008, Bynum and Professor Piet Hut of the Program in Interdisciplinary Studies have organized a series of twice-weekly "After Hours Conversations," in which members of the Institute community gather to listen to a ten-minute presentation by an Institute scholar, followed by a period of questions and discussion. Recent topics have included human-rights precedents in Chinese tradition, the coevolution of human immunity and the flu virus, and the potential importance of the Large Hadron Collider for theoretical physics.

Feynman Diagrams and the Evolution of Particle Physics

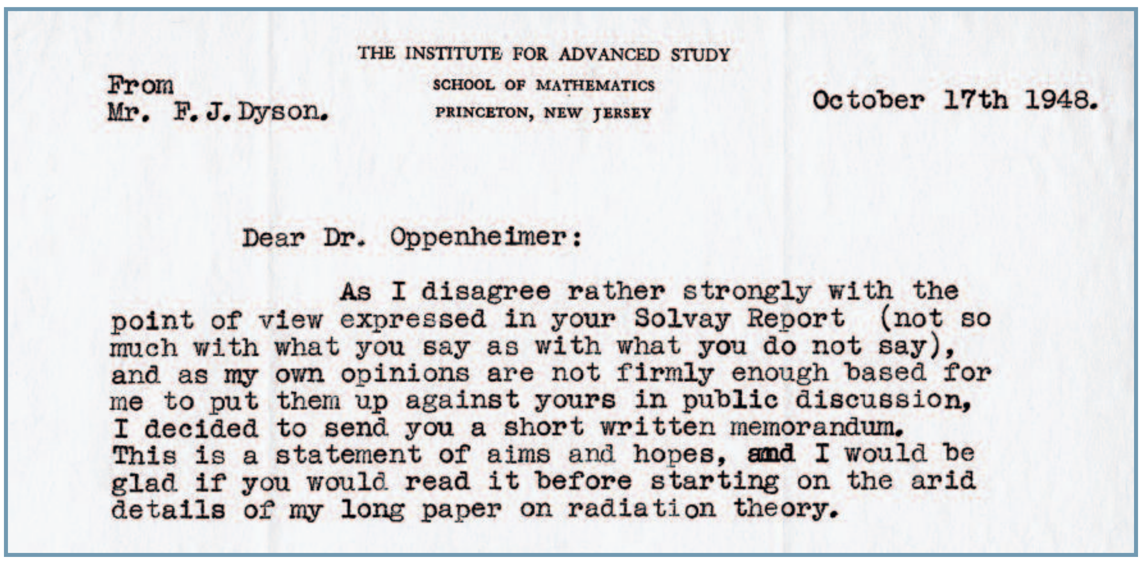
For sixty years, Feynman diagrams have been an essential calculational and conceptual tool for theoretical physicists striving to deepen our understanding of the fundamental forces and particles of nature. Members of the Institute have played leading roles in the development of their use, from Freeman Dyson in the late 1940s and early 1950s to the current generation of theoretical physicists in the School of Natural Sciences. Most recently, clues provided by Feynman diagrams have led to powerful new methods that are revolutionizing our ability to understand the fundamental particle collisions that will occur at the Large Hadron Collider (LHC). At the same time, these clues have motivated Institute theorists to pursue a radical transcription of our ordinary physics formulated in space and time in terms of a theory without explicit reference to space-time. The story of these developments connects one of the most pressing practical issues in theoretical particle physics with perhaps the most profound insight in string theory in the last decade—and at the same time provides a window into the history of physics at the Institute.

Surprising as it now seems, when Richard Feynman first introduced his diagrams at a meeting at a hotel in the Pocono Mountains in the spring of 1948, they were not immediately embraced by the physicists present, who included J. Robert Oppenheimer, then Director of the Institute and organizer of the meeting, and a number of then Members of the Institute, including Niels Bohr and Paul Dirac. The main event of the meeting, whose topic was how to calculate observable quantities in quantum electrodynamics, was an eight-hour talk by Julian Schwinger of Harvard, whose well-received analysis used calculations founded in an orthodox understanding of quantum mechanics. On the other hand, Feynman struggled to explain the rules and the origins of his diagrams, which used simple pictures instead of complicated equations to describe particle interactions, also known as scattering amplitudes.

Traveling on a Greyhound bus from San Francisco to Princeton at the end of the summer of 1948 to take up his appointment as a Member of the Institute, the twenty-four-year-old Dyson had an epiphany that would turn Feynman diagrams into the working language of particle physicists all over the world. Earlier, in June, Dyson had embarked on a four-day road trip to Albuquerque with Feynman, whom he had met at Cornell the previous year. Then he spent five weeks at a summer school at the University of Michigan in Ann Arbor where Schwinger presented detailed lectures about his theory. Dyson had taken these opportunities to speak at length with both Feynman and Schwinger and, as the bus was making its way across Nebraska, Dyson began to fit Feynman's pictures and Schwinger's equations together. "Feynman and Schwinger were just looking at the same set of ideas from two different sides," Dyson explains in his autobiographical book, *Disturbing the Universe*. "Putting their methods together, you would have a theory of quantum electrodynamics that combined the mathematical precision of Schwinger with the practical flexibility of Feynman." Dyson combined these ideas with those of a Japanese physicist, Shinichiro Tomonaga, whose paper Hans Bethe had passed on to him at Cornell, to map out the seminal paper, "The Radiation Theories of Tomonaga, Schwinger and Feynman," as the bus sped on through the Midwest. Published in the *Physical Review* in 1949, this work marked an epoch in physics.

While Feynman, Schwinger, and Tomonaga were awarded the Nobel Prize in Physics in 1965 for their contributions to developing an improved theory of quantum electrodynamics, it was Dyson who derived the rules and provided instructions about how the Feynman diagrams should be drawn and how they should be translated into their associated mathematical expressions. Moreover, he trained his peers to use the diagrams during the late 1940s and 1950s, turning the Institute into a hotbed of activity in this area. According to David Kaiser of the Massachusetts Institute of Technology, author of *Drawing Theories Apart: The Dispersion of Feynman Diagrams in Postwar Physics*, "Feynman diagrams spread throughout the U.S. by means of a postdoc cascade emanating from the Institute for Advanced Study."

Feynman diagrams are powerful tools because they provide a transparent picture for particle interactions in space-time and a set of rules for calculating the scattering amplitudes describing these interactions that are completely consistent with the laws of quantum mechanics and special relativity. These rules allow any process involving particle scattering to be converted into a collection of diagrams representing all the ways the collision can take place. Each of these diagrams corresponds to a particular mathematical expression that can be evaluated. The exact description of the scattering process involves summing an infinite number of diagrams. But in quantum electrodynamics, a simplification occurs: because the electric charge is a small number, the more interactions a diagram involves the smaller the contribution it makes to the sum. Thus, to describe a process to a given accuracy, one only has to sum up a finite number of diagrams.



THE INSTITUTE FOR ADVANCED STUDY
SCHOOL OF MATHEMATICS
PRINCETON, NEW JERSEY

From
Mr. F. J. Dyson.

October 17th 1948.

Dear Dr. Oppenheimer:

As I disagree rather strongly with the point of view expressed in your Solvay Report (not so much with what you say as with what you do not say), and as my own opinions are not firmly enough based for me to put them up against yours in public discussion, I decided to send you a short written memorandum. This is a statement of aims and hopes, and I would be glad if you would read it before starting on the arid details of my long paper on radiation theory.

COURTESY OF THE INSTITUTE FOR ADVANCED STUDY ARCHIVES

This excerpt is from a letter written to J. Robert Oppenheimer by Freeman Dyson shortly after his arrival at the Institute in 1948. Oppenheimer initially expressed deep resistance to Dyson's work on quantum electrodynamics, which drew on the ideas of Richard Feynman, Julian Schwinger, and Shinichiro Tomonaga. Oppenheimer eventually conceded his position with a small piece of paper left in Dyson's mailbox with the handwritten words, "Nolo contendere. R.O."

"Freeman was the person who realized that once you force the quantum mechanical answer to look like it is consistent with the laws of special relativity, then it is very natural to do the calculations in terms of Feynman diagrams," says Nima Arkani-Hamed, Professor in the School of Natural Sciences. "Almost nobody thinks about Feynman diagrams the way Feynman originally arrived at them. You open up any textbook and the derivation of these things uses this very beautiful, profound set of insights that Freeman came up with."

By the 1980s and 1990s, Feynman diagrams were being used to calculate increasingly complicated processes. These included not only collisions of the familiar electrons and photons, governed by quantum electrodynamics, but also the interaction of particles such as quarks and gluons, which are the basic constituents of protons and neutrons, and are governed by the theory known as quantum chromodynamics. These calculations are essential to understanding and interpreting the physics probed at modern high-energy particle accelerators. However, theorists found that using Feynman diagrams in this wider context led to an explosion in their number and complexity.

Increasingly clever tricks were developed in the late 1980s to calculate these more complicated processes without actually calculating the Feynman diagrams directly. This led to a surprising realization. While each step in the calculation was very complicated, involving a huge number of terms, cancellations between them led to a final answer that was often stunningly simple. "The answer seems to have all sorts of incredible properties in it that we are learning more and more about, which are not obvious when you draw Feynman diagrams. In fact, keeping space-time manifest is forcing the introduction of so much redundancy in how we talk about things that computing processes involving only a few gluons can require thousands of diagrams, while the final answer turns out to be given by a few simple terms," says Arkani-Hamed. "A big, overarching goal is to figure out some way of getting to that answer directly without going through this intermediary space-time description."

In 2003, Edward Witten, Charles Simonyi Professor in the School of Natural Sciences, came up with a proposal along these lines. He found a remarkable rewriting of the leading approximation to the interactions between gluons that led directly to the simple form of their scattering amplitudes, without using Feynman diagrams. This work immediately led to a major innovation: a new diagrammatic representation of amplitudes, called "CSW diagrams" (after Freddy Cachazo (then a Member), Witten's student Peter Svrcek, and Witten). This led to a number of new insights into amplitudes that, via a circuitous path, led to a second, apparently unrelated representation of the amplitudes known as "BCFW diagrams" (after former Members Ruth Britto and Bo Feng, as well as Cachazo and Witten). These powerful new diagrams highlight and exploit properties of the physics that are invisible in Feynman diagrams, and they provide a much more efficient route to the final answer.

These new methods have triggered a breakthrough in a critical area relevant to describing physics at the LHC. This enormous machine will experimentally probe our understanding of nature at extremely short distances, and could reveal major new physical principles, such as an extended quantum notion of space-time known as supersymmetry. In order to establish the discovery of new particles and forces, it is necessary to accurately understand the predictions from current theories. But these calculations had been hampered by the complexity of the relevant Feynman graphs. Many processes experimental physicists were interested in were considered to be impossible to calculate theoretically in practice. Now, this is no longer the case, and already computer code exploiting the BCFW technique is being developed for application to the data the LHC will produce.

In addition to their practical value, these new ideas have opened up a number of new frontiers of purely theoretical research, both in exploring further the inner workings of scattering amplitudes and in investigating their relationship with deeper theories of space and time. About a year and a half ago, Arkani-Hamed became intrigued by the BCFW formalism, and with his student Jared Kaplan he found a simple physical argument for why it is applicable to calculating scattering amplitudes for gluons and gravitons, not just in four dimensions of space-time as originally formulated, but in any number of dimensions. "This idea of BCFW is somehow a powerful and general fact about physics in any number of dimensions," says Arkani-Hamed. Their work also suggested that the amplitudes for the scattering of gravitons might be especially simple.

(Continued on page 5)

COURTESY OF THE INSTITUTE FOR ADVANCED STUDY ARCHIVES

COURTESY OF MELANIE JACKSON AGENCY AND CALTECH ARCHIVES

Freeman Dyson (left) and Richard Feynman, circa 1950

"Even the simplest processes for gravity involve ludicrously complicated Feynman diagrams, and yet not only are the amplitudes just as simple in this new language, there is even some indication that they might be simpler," says Arkani-Hamed. "Perhaps this is because the things that are the most complicated from the Feynman diagram perspective are the simplest from this other perspective that we are searching for."

Expressing amplitudes in terms of variables that encode directly only the physical properties of particles, such as their momentum and spin, is a key step in this program. This was achieved in the 1980s for four-dimensional theories. But if a general rewriting of basic interactions for particles like gluons and gravitons is sought, it must be possible to extend these successes to higher dimensions, especially since extra dimensions appear naturally in string theory. This year, Institute Member Donal O'Connell and one of Arkani-Hamed's students, Clifford Cheung, showed that this could also be achieved in six dimensions. Using their formalism, and BCFW diagrams in six dimensions, O'Connell and Cheung were able to discover very compact expressions for scattering gauge bosons and gravitons in higher dimensions, which also unify a multitude of four-dimensional expressions.

Witten's 2003 proposal used a set of ideas that Roger Penrose first suggested in the 1960s called twistor theory, which posits that instead of keeping track of points in space-time, physicists should look at the light rays that come out of those points and follow them out to infinity. Witten's method of calculating the scattering amplitudes suggested a new string theory that lives in twistor space rather than in ordinary space-time; the structure of this string theory is directly related to the CSW diagrammatic construction.

The BCFW diagrams arose from studying general properties of relativistic quantum theory formulated in space-time. However, in a recent collaboration, Arkani-Hamed, Cachazo, Cheung, and Kaplan, found to their surprise that the BCFW formalism is also most naturally expressed in twistor space. Their reasoning leads to a direct mapping of ordinary physics in space-time to a simpler description in twistor space. "What is extremely cool about this business is that we are trying to come up with an explanation for marvelous patterns found in theories describing our world," says Arkani-Hamed. "We have a lot of clues now, and I think there is a path towards a complete theory that will rewrite physics in a language that won't have space-time in it but will explain these patterns."

This line of thought has connections to the concepts of duality and holography, which grew out of developments in string theory in the 1990s and have dominated much of the activity in the field for the past decade. A "duality" is an exact quantum equivalence between two completely different classical theories. The first examples of this remarkable phenomenon were discovered in four-dimensional supersymmetric theories by Nathan Seiberg, Professor in the School of Natural Sciences, in collaboration with Witten. This led to the realization that all string theories are different manifestations of a single underlying theory. Holography is the most striking example of duality to date, relating a gravitational theory in a curved space-time to a non-gravitational particle theory in a lower-dimensional flat space. The analogy is to familiar holograms, which encode three-dimensional information on a two-dimensional surface. Juan Maldacena, also a Professor in the School of Natural Sciences, found the first example of a holographic duality, in which everything that happens in the bulk of space-time can be mapped to processes occurring on its boundary. Maldacena's conjecture is now known as the AdS/CFT correspondence, and provides a dictionary for translating the physics of anti–de Sitter space (AdS)—a negatively curved space with an extra fifth dimension, containing gravity and strings—to a conformal field theory (CFT), a four-dimensional particle theory that lives on the boundary of the space-time. "Things about gravity are mysterious; things about particle theories are much less mysterious. Incredibly, the AdS/CFT correspondence maps mysterious things about gravity to well-understood things about particle physics, giving us the first working example of what a theory with emergent space-time looks like," says Arkani-Hamed. "It encourages the thought that, even in a nearly flat space-time like our own, there is a picture of scattering processes, which takes incoming particles and converts them to outgoing particles with some very simple rules that bypass evolution through the intermediary space-time."

Exploitation of the AdS/CFT correspondence has led to many remarkable new developments. A key point is that the four-dimensional CFT involved in the correspondence is a close cousin of quantum chromodynamics, which is the theory relevant at the LHC. AdS/CFT thus provides a sort of theoretical laboratory for the exploration of phenomena related to the hadron collider. While the CFT is similar to the theories that describe nature, it is different in that it is far more symmetric. In fact, the theory enjoys so much symmetry that it has a property known as integrability, which has allowed, for the first time, the exact computation of a quantity relevant to scattering amplitudes. Already there is much progress in an area where a Feynman diagram computation is hopeless: when the coupling analogous to the electric charge is large, one would have to sum all possible diagrams. But via AdS/CFT, Maldacena and Member Fernando Alday have shown that in the large coupling regime, the scattering amplitude can be computed by turning it into a tractable calculation in a string theory living in AdS space. This work led to another major surprise: the scattering amplitudes were shown to have unexpected symmetries that were later sought and found in diagrammatic calculations at weak coupling. These symmetries are related to the integrability properties, and give new hope that scattering amplitudes in the CFT can be determined exactly.

Arkani-Hamed suspects that the key to further progress will be finding the analog for the AdS/CFT correspondence for flat space. An essential problem in gravity is the inability to precisely talk about physical observables that are localized in space and time. "The general rule seems to be that we can only describe gravitational systems when we're sitting at the boundary of space-time at infinity, because that is where notionally we can repeat experiments infinitely many times with an infinitely big apparatus to make infinitely precise measurements. None of these things are exactly possible with finite separations," says Arkani-Hamed. "The AdS/CFT correspondence already tells us how to formulate physics in this way for negatively curved space-times; we are trying to figure out if there is some analog of that picture for describing scattering amplitudes in flat space. Since a sufficiently small portion of any space-time is flat, figuring out how to talk about the physics of flat space holographically will likely represent a real step forward in theoretical physics."

Lecture on Public Policy: Mary Robinson Speaks on Human Rights

When Mary Robinson, the former President of Ireland, was the United Nations High Commissioner for Human Rights from 1997 to 2002, she oversaw the translation of the Universal Declaration of Human Rights into 236 languages, earning it a place in *Guinness World Records* as the most translated document in the world. The Declaration has since been translated into 337 languages. "It is most translated perhaps," Robinson noted in a lecture at the Institute last October, "but not necessarily most read, and certainly not most implemented or lived by."

Since completing her term as High Commissioner of Human Rights, Robinson has led Realizing Rights: The Ethical Globalization Initiative, an organization seeking wider implementation of the Universal Declaration. She has also become a member of "the Elders," a group of distinguished world leaders brought together by Nelson Mandela, Graça Machel, and Desmond Tutu to remind the "global village" of its values.

Although the General Assembly of the United Nations adopted the Declaration in 1948, Robinson noted that many countries still have not ratified its articles into law. The United States, for example, has given treaty status to the Declaration's political and civil rights, which are similar to those guaranteed by the Bill of Rights, but it has not ratified its articles addressing social and economic issues, such as entitlement to health care and shelter. Moreover, since the attacks of September 11, 2001, Robinson and others have been fighting against the temptation of governments to compromise civil rights in the name of security.

Robinson was the second speaker to participate in the Institute's Lectures on Public Policy, following Lakhdar Brahimi, former Special Adviser to the Secretary-General of the United Nations, a fellow Elder, and Director's Visitor at the Institute from 2006 to 2008. The next lecture in the series will be given on October 23 by David Cole, a Professor at the Georgetown University Law Center who specializes in civil rights and criminal justice.

RANDALL HAGADORN

Mary Robinson

Fourth Member of Bohr Family at IAS Pursues Quantum Theory of Gravity

"Scientific research in many domains of knowledge has time after time proved the necessity of abandoning or remoulding viewpoints which, due to their fruitfulness and apparently unrestricted applicability, were regarded as indispensable for rational explanation." —Niels Bohr

Since the advent of the theory of quantum mechanics, which governs motion and change in the subatomic realm, the question of how to deal with gravitational interaction on a quantum mechanical scale has been high on the scientific agenda. Although the understanding of gravitational interaction is still not complete, scientists are steadily learning more about its properties.

N. Emil J. Bjerrum-Bohr, a physicist and the fourth member of his family to be a Member at the Institute for Advanced Study, spent 2006–08 in the School of Natural Sciences studying the computation of amplitudes relevant to understanding physics and phenomenology in and beyond the Standard Model of physics as well as in quantum gravity.

"I have always had a great interest in understanding the necessary concepts for developing a theory for quantum gravity," says Bjerrum-Bohr. "I believe that in order to fully understand the fundamental concepts of space, time, and matter, a theory for gravitational interaction valid at the quantum level will be unavoidable."

The questions posed by a full quantization of gravity are linked to many of the famous exchanges that took place, many of them at the Institute, between former Institute Professor Albert Einstein and Bjerrum-Bohr's maternal great-grandfather Niels Henrik David Bohr (1885–1962), the Nobel Laureate and former Member who made the Institute his headquarters on visits to the United States between 1938–58. "It is very inspiring to work and think about such matters in a place such as the Institute," says Bjerrum-Bohr, "since many of these important discussions took place in these halls and offices."

The late School of Mathematics Professor Abraham Pais described the debates between Niels Bohr and Einstein as follows: "In a spirit of friendly and heroic antagonism, these two men argued about questions of principle." From Bohr's resistance to Einstein's idea of the photon to their debate on the foundations of quantum mechanics, "the intellectual resistance and opposition of one against the most basic views held by the other continued unabated until the end of Einstein's life," wrote Pais. "At issue were the criteria by which one should judge the completeness of the description of the physical world."

Yet theirs was a relationship marked by great respect and fondness. When Einstein was nearly seventy, he wrote, "That this insecure and contradictory foundation [of physics in the years from 1910 to 1920] was sufficient to enable a man of Bohr's unique instinct and tact to discover the major laws of the spectral lines and of the electron shells of the atoms together with their significance for chemistry appeared to me like a miracle—and appears to me as a miracle even today. This is the highest form of musicality in the sphere of thought." Of Einstein's influence on Bohr, Pais wrote, "Just as in many sports a player goes through warming-up exercises before entering the arena, so Bohr would relive the struggles which it took before the content of quantum mechanics was understood and accepted. I can say that in Bohr's mind this struggle started all over every single day. This, I am convinced, was Bohr's inexhaustible source of identity. Einstein appeared forever as his leading spiritual partner—even after the latter's death he would argue with him as if Einstein were still alive."

Niels, who won the Nobel Prize in Physics in 1922 for his exploration of the inner structure of atoms, first visited the Institute as a Member in 1938–39. He wrote to Oswald Veblen, then Professor in the School of Mathematics, in advance of his stay, "It shall be so great a pleasure to me to come into a still closer contact with you and the other eminent mathematicians of your group and to try, as far as I can, to stimulate discussions on the fundamental problems in atomic physics among the younger scientists."

Shortly before his arrival in Princeton, Niels learned that German scientists had succeeded in splitting uranium atoms. During his time at the Institute, he developed with John Wheeler, the late Professor Emeritus at Princeton University and a former Member of the Institute, a theory of nuclear fission that formed the basis for work in atomic energy. Wheeler recalled of their work together, "A work session might start with Bohr sitting or standing near the blackboard in my office. He would outline an idea based on his compound-nucleus model and sketch something on the board. Soon we would be trading a piece of chalk back and forth, drawing pictures and writing equations on the board."

The Bohr family maintained a close connection with the Institute over the span of its first three Directors. Letters in the Institute Archives show that as early as 1933, Niels's brother, the mathematician Harald Bohr, who was closely connected to the University of Göttingen, corresponded with founding Director Abraham Flexner in an effort to secure the safety and employment of German scholars, such as Richard Courant, and others threatened by the Nazi regime.

BJERRUM-BOHR PHOTO BY SAMEERA KHAN, ALL OTHER PHOTOS COURTESY OF NIELS BOHR ARCHIVE, COPENHAGEN

Clockwise from top left: Niels Bohr and Albert Einstein; Niels and Aage Bohr in 1954; N. Emil J. Bjerrum-Bohr at IAS; Harald Bohr, Luther P. Eisenhart, and Niels Bohr in Princeton in 1948

In 1943, Niels and his family fled from Nazi-occupied Denmark to Sweden in the cabin of a fishing boat. Soon Niels and his physicist son Aage Niels Bohr (b. 1922), who served as his assistant, became involved in the British and American war efforts, traveling to the United States and briefly visiting then Institute Director Frank Aydelotte, before traveling on to Los Alamos. Aage has recalled, "On our arrival in New York my father was requested to assume the pseudonym Nicholas Baker, while I became James Baker. We were issued with papers in these names, and at the beginning there was constantly an armed detective at our side. When we traveled around in the States, we were always accompanied by a bodyguard; over long distances the guard was changed, and the one who assumed responsibility for us had to sign a receipt for our delivery in good condition."

Despite a standing invitation, Niels did not formally return to the Institute until after the war in 1948. Harald and Aage, who were also Members that year, accompanied him to the Institute. Like his father, Aage was awarded the Nobel Prize in Physics. He shared the Prize in 1975 with Ben R. Mottelson and James Rainwater for their work in determining the asymmetrical shapes of certain atomic nuclei. Harald was a distinguished mathematician whose main field of interest was analytic number theory. According to the late mathematician, historian, and former Member Otto Neugebauer, "The modern era of mathematics in England as well as in Denmark and Scandinavia will always be connected with the names of [G. H.] Hardy and [Harald] Bohr respectively."

In letters in the Institute Archives, J. Robert Oppenheimer, Institute Director from 1947 to 1966, addressed Niels as "Uncle Nick," a nickname referencing Niels's wartime alias. "There is almost no end to the things I would wish to talk with you about, and I fear that if you come I shall be a burden with all my questions and stories," Oppenheimer wrote to Niels in 1953. Niels returned to the Institute in 1954, when he gave a series of lectures at the Institute on the implications of modern physics for objective description in various domains of knowledge. He visited as a Member for the last time in 1958.

Growing up, Bjerrum-Bohr was well aware of the physics questions that fascinated his great-grandfather and Einstein. It was his great-uncle Aage who persuaded Bjerrum-Bohr to study physics rather than chemistry, the field of the noted Danish chemist Niels Janniksen Bjerrum, who was Bjerrum-Bohr's paternal great-grandfather and a close friend of Niels Bohr. He is most well known for his work on the dissociation of strong electrolytes.

At the Institute, Bjerrum-Bohr worked on problems related to the incompatibility of Einstein's theory of general relativity with basic quantum mechanical ideas. In particular, his research concerned the analytic structure of amplitudes, which provide a measure for the probability of particle interactions in quantum physical theories.

For many years, Feynman diagrams (see article, page 4) have been the standard tool for computing amplitudes. However, recent computations of quantum amplitudes for Yang-Mills theories and gravity by Edward Witten, Charles Simonyi Professor in the School of Natural Sciences, have inspired much more efficient ways of doing amplitude computations with high precision. Progress has come through combining input from string theory, extended supersymmetry, twistor variables, and the clever use of unitarity methods. Consequently, many amplitudes in Yang-Mills theories that are relevant for quantum chromodynamics and were previously considered unattainable are now readily available. Such results are important for the comparison of theoretical and experimental data in scattering experiments, like those being conducted at the Large Hadron Collider in Switzerland. "This research has the potential to revolutionize the way we think about physical theories such as particle physics and string theory," says Bjerrum-Bohr. "It might lead to new insights in how to formulate a fundamental theory of quantum gravity."

In addition to relishing the freedom to explore many ideas important to his research and becoming acquainted with scientists from all over the world, Bjerrum-Bohr felt a strong connection to the Institute's natural surroundings. "There is nothing that compares to walking in the Institute Woods or sitting on the benches next to the Institute Pond," says Bjerrum-Bohr. "The walking trails through the sunlit forest of the woods bring me back to summer vacations in the Tisvilde forests of northern Zealand where my great-grandfather's beloved summer cottage is located. I believe that when visiting Einstein at the Institute my great-grandfather must have felt very at home walking through the Institute Woods, pondering questions in the field of physics, smoking his pipe."

Institute Visit Inspired Creation of the Institute of Mathematical Sciences in Madras

Alladi Ramakrishnan (1923–2008)

by Krishnaswami Alladi

My father Alladi Ramakrishnan, who made significant contributions to stochastic processes, elementary particle physics, matrix algebra, and the special theory of relativity, passed away at my home in Gainesville, Florida, last June, at the age of eighty-four. Inspired by his visit to the Institute for Advanced Study, where he was a Member in 1957–58, he later founded and directed the Institute of Mathematical Sciences (MATSCIENCE), in Madras, India.

Initially attracted to law—my paternal grandfather Sir Alladi Krishnaswami Iyer was a prominent Indian lawyer who helped draft the Constitution of India—my father decided to pursue a career in science after he heard Homi Bhabha give a lecture on Meson Theory at the Presidency College in Madras in 1943.

COURTESY OF KRISHNASWAMI ALLADI

Alladi Ramakrishnan as a Member at the Institute in the 1950s

In 1947, my father joined Bhabha's fledgling Tata Institute of Fundamental Research in Bombay. Bhabha introduced my father to cascade theory and the problem of cosmic radiation, the study of which required the probabilistic analysis of the distribution of a discrete number of particles in continuous energy space. In attacking this problem, my father introduced a new technique, which he called the method of product densities. In 1949, my father left the Tata Institute and sailed to England to complete his Ph.D. under Professor M. S. Bartlett of the University of Manchester. My father's thesis work on product densities, which extended the earlier work of D. G. Kendall, appeared in the *Proceedings of the Cambridge Philosophical Society*, and is considered among his major contributions.

After his Ph.D., my father returned to India and joined the University of Madras first as a Reader, then as Professor of Physics. During the fifties, he developed the theory of product densities and its applications in collaboration with his students. He came into contact with the astrophysicist Subramanyam Chandrasekhar, who provided the *Astrophysical Journal* with eight of my father's papers, some of which dealt with the fluctuation of brightness of the Milky Way. In 1955, my father was elected a Fellow of the Indian Academy of Sciences with the backing of Nobel Laureate Sir C. V. Raman.

In 1956, at a high-energy physics conference at the University of Rochester, my father met J. Robert Oppenheimer, then Director of the Institute. Oppenheimer inquired about my father's plans for the future, and my father replied that he would like to visit the Institute. Within a few months, my father received an invitation to come for the academic year 1957–58.

The visit was a turning point in his career. At the Institute my father had the opportunity to listen to the lectures of leading physicists of his generation. T. D. Lee and C. N. Yang had just completed their famous work on nonconservation of parity in weak interactions. They were in residence at the Institute that year and everyone was excited about the possibility of a Nobel Prize, which they received shortly thereafter. In those eight months, my father heard over one hundred seminars—Bengt Strömgren on astrophysics, Marvin Goldberger on dispersion theory, Rudolf Haag on scattering, Abraham Pais and Sam Treiman on weak interactions. Oppenheimer was an active participant in the seminars. My father wrote in his diary, "Oppenheimer's very presence stimulated creative thought and invited impartial criticism." As a result of these lectures, my father shifted his research to elementary particle physics in the next decade.

After his year at the Institute, my father returned to India filled with a desire to induct talented students into theoretical physics and expose them to the latest advances in the field. Not satisfied with the curriculum at the University of Madras, he conducted theoretical physics seminars at our family home between 1958–61. Eager students gathered at the seminar and he invited well-known scientists from abroad to address them. My mother graciously hosted the visitors and the students.

When Nobel Laureate Niels Bohr, a former Member of the Institute (see article, page 6), came to India in 1960 as the guest of Prime Minister Jawaharlal Nehru, he lectured in my father's seminar. Upon his return to Delhi, Bohr was asked for his opinion about science in India. He said that two things impressed him the most—the massive Tata Institute in Bombay, and the small group of students trained by my father in Madras. Bohr's statement, which was reported in newspapers like the *Hindu*, prompted Nehru to meet with my father and his students. At their meeting, Nehru asked my father what he wanted. My father asked for an institute for advanced fundamental research like the Institute for Advanced Study in Princeton. MATSCIENCE was created on January 3, 1962.

My father served as the Director of MATSCIENCE for twenty-one years until his retirement in 1983. During his tenure, hundreds of important mathematicians and physicists visited MATSCIENCE. After I moved to Florida permanently in 1987, he and my mother made extended annual visits to Gainesville. Even in his retirement, his spirit of inquiry remained unabated, and he published papers on the special theory of relativity. I close with a dictum that he had inscribed on the walls of MATSCIENCE:

The pursuit of science is at its best
when it is a part of a way of life.

Krishnaswami Alladi, Professor of Mathematics at the University of Florida, is a former Member (1981–82) of the School of Mathematics. He is the founder and editor-in-chief of the Ramanujan Journal *(Springer), which is devoted to all areas of mathematics influenced by the Indian mathematician Srinivasa Ramanujan.*

ZALDARRIAGA *(Continued from page 1)*

tute of Technology (MIT), working with Uros Seljak, who was then a postdoctoral student at Harvard. Their method, called CMBFAST, accelerated calculations of CMB fluctuations by some two orders of magnitude, making all previous codes obsolete.

"Matias combines great creativity, formidable technical power, and a deep understanding of the experimental landscape and data analysis," said Scott Tremaine, Richard Black Professor in the School of Natural Sciences. "He is uniquely able to exploit the growing connections between astrophysics and particle physics and to link the ongoing research efforts in these two disciplines at the Institute."

Zaldarriaga's recent research has focused on intergalactic hydrogen gas in the early universe, before galaxy and star formation was underway. He is one of the leading theorists developing machinery to study this gas using the spectral line from neutral hydrogen at 21-centimeter wavelength. While the idea of using 21-cm radiation to probe the history of the universe dates back some two decades, Zaldarriaga's work has emphasized the strong analogy between 21-cm fluctuations and CMB fluctuations, and the importance of using statistical techniques to study these fluctuations. His insights have been largely responsible for igniting the enthusiasm of the large community of CMB theorists and experimentalists who are now working with this challenging but potentially transformative new technique.

In his study of the early universe, Zaldarriaga has proposed qualitatively new ways of driving inflation and generating density perturbations. He has also investigated more formal issues in cosmology, including a proposed alternative to inflation, the "bouncing cyclic universe." Working with Paolo Creminelli and Alberto Nicolis, he showed that it is possible to make predictions for density perturbations that are independent of the details of the bouncing phase.

Born in Argentina, Zaldarriaga earned his undergraduate degree in physical science from the University of Buenos Aires in 1994. In 1998, he obtained a Ph.D. in physics from MIT. He served as W. M. Keck Visiting Associate in Cosmology at the Institute from 2001 to 2002. He moved to New York University in 2003 as an Assistant Professor, and the following year he joined Harvard University as Associate Professor. In 2004, he became Professor of Astronomy and Physics at Harvard.

Zaldarriaga has maintained a close relationship with the Institute since his postdoctoral days. He was a long-term Member from 1998 to 2001 and spent additional time as a Visitor in the School of Natural Sciences in 2004, 2005, and 2008. "The very strong astrophysics and particle physics efforts at the Institute provide the ideal environment for my research," said Zaldarriaga. "I am eager to join the Institute this July and look forward to many exciting years on the Faculty."

Zaldarriaga is the recipient of a 2006 MacArthur Fellowship. In 2005, he was awarded the Gribov Medal, which is presented every two years by the European Physical Society to recognize a young physicist for outstanding work performed in the field of theoretical particle physics or field theory. The American Astronomical Society awarded him its 2003 Helen B. Warner Prize for Astronomy, and he received a David and Lucile Packard Fellowship in 2001 and a Hubble Fellowship in 1998. While a student at MIT, he was awarded the Barrett Prize for originality in astrophysics research.

Conference Celebrates Phillip Griffiths's Achievements and Example

A conference on algebraic and differential geometry was held last fall in celebration of the seventieth birthday of former Institute Director (1991–2003) Phillip A. Griffiths, a Professor in the School of Mathematics, who will retire at the end of June. In the following passages, three conference participants comment on his influence and work, which has been central to the development of complex analysis, algebraic geometry, differential equations, and other areas.

ROBERT L. BRYANT, Director of the Mathematical Sciences Research Institute (MSRI), Director of the IAS/Park City Mathematics Institute (PCMI), and former Director's Visitor (1996) and School of Mathematics Member (1979–80):

It is a pleasure to write about my own experiences with Phillip, both as collaborator and as one who has benefited immeasurably from Phillip's advice and encouragement throughout his career.

Of course, I had known of Phillip's reputation, both as a mathematician and as a teacher, since my graduate school days. His great book with Joe Harris, *Principles of Algebraic Geometry*, had made a deep impression on me and, though I had not gotten beyond Chapter 1 by the time I finished graduate school, I still regarded it as one of the most important books in my library.

Shiing-Shen Chern, who organized a meeting on exterior differential systems in geometry in Berkeley in December 1979, introduced me mathematically to Phillip. Phillip and I were both invited to speak, and during the course of that meeting we discovered that we had quite a few interests in common. Our discussions began in earnest that spring. Phillip was interested in problems that were a considerable level above what I had been working on—specific questions about the integrals of the differential system that describes the Griffiths infinitesimal period relations and the exterior differential system that governed the overdetermined isometric embedding problem. Our paper on 3-folds with trivial canonical bundle was a result of those early conversations, as was the work on the overdetermined and determined cases of isometric embedding, which we did with Deane Yang and Eric Berger. Phillip always impressed me with his determination to follow a problem wherever it led, no matter what tools had to be learned and applied in the chase. As his students will tell you, seeing Phillip learning a new subject alongside you is a strong and inspiring motivator.

Our conversations and collaborations drew me into the Griffiths family, both mathematical and personal, and for this I am eternally grateful. The explorations of the geometry of differential equations that formed the basis of our long collaboration taught me an incredible amount about an enormous range of subjects: Lie groups and symmetry reduction of constrained variational problems, the role of homology and cohomology theories in the geometry of partial differential equations (PDE) (which formed the basis of our series of papers on characteristic cohomology), the geometry of characteristics and methods of integrability (always with an eye toward understanding the nature of integrability for PDE itself), the method of equivalence, and the geometry of the Poincaré-Cartan form.

CLIFF MOORE

Phillip Griffiths listens to a presentation during a conference on algebraic and differential geometry in his honor.

I count myself lucky indeed to have this mathematical connection with Phillip, but it would be remiss of me to end this without mentioning his deeply inspiring example of service to the mathematical community, the academic community, and the world at large. That Phillip was willing, in the early 1980s, to undertake the Provostship at Duke and, over the following decades, give ever more of his time and talent to issues in education and training, not just in the United States, but worldwide, has motivated so many of us also to give back to our communities and to society at large. His bread cast upon the waters has yielded a great harvest indeed, one that continues to enrich us all.

HERB CLEMENS, Professor of Mathematics at the Ohio State University, former Director of PCMI, and former Member (1968–70, 2001–02) in the School of Mathematics:

We came together in mid-October to celebrate the seventieth birthday of Phillip Griffiths, one of the world's leading mathematicians over the past forty-five years and a long-time advocate for and contributor to mathematics and mathematics teaching in the developing world. It reminded many of us of how our mathematical and professional lives were influenced by Phillip—in some cases, even formed under the umbrella of Phillip's influence.

In the gathering, we also saw reflected once again the mathematical truism that great problems generate great mathematics. A great problem is like a giant compass that orients the mathematical lives of those that choose to pursue it. The great problem in Phillip's case is the Hodge problem. It poses the challenge of proof or counterexample to the assertion that, in an algebraically defined object, topological classes that could come from algebraic sub-objects actually do come from algebraic sub-objects. The problem was posed more than fifty years ago, almost at the outset of the modern age of topology. The invisible, elusive but still beguiling guest at the October gathering at IAS was that problem, "the problem." She has grown older now, made more beautiful and perhaps even more elusive by the half century of beautiful mathematics that surrounds and enhances her. Phillip has led, and continues to lead, by example and by achievement, in our advancing understanding of her mysteries.

Phillip has also led, and continues to lead, by example and by achievement, in his contributions to the institutions that cultivate and maintain mathematics and its teaching. And his attention has extended, and continues to extend, not only the institutions that formed and nourished all of us who gathered to honor him, but also institutions only now being born and beginning to take hold in the far corners of the world, corners that seem improbable or impossible to many in the mathematics community. However, Phillip's impeccable intuitive understanding of things tells him something else, namely that these are shining opportunities for the future of mathematics, and for the shared purpose and shared sense of fulfillment that mathematics offers.

MARK L. GREEN (conference organizer), Director Emeritus of the Institute for Pure and Applied Mathematics (IPAM) and Professor of Mathematics at the University of California, Los Angeles:

A remarkable feature of Phillip's career is reflected in his students. They have collectively made an impressive contribution to mathematics—one is a member of the National Academy of Sciences and many hold positions at some of the nation's finest universities. Four have led national institutes (MSRI, IPAM, the Clay Mathematics Foundation, and PCMI) and many others have played important roles as chairs of major departments, in professional societies, and on deliberative bodies. At a festive dinner held in conjunction with the conference, Phillip's students reflected on their experiences. What was striking was that, universally, Phillip had played a pivotal role in their professional development, and meeting him was a turning point in their careers and in their lives.

I cannot resist saying a few words about Phillip himself. What an extraordinary collection of qualities to find all in the same person—an intellect of the very highest order, a set of values and an instinct for fairness that have brought him the trust of numerous institutions and indeed of entire professions, modesty, toughness when needed combined with an instinctive sense of generosity and optimism, an ability to bring out the best in people and to rally them to a higher purpose, a nose for the central issue involved in any problem, and enormous energy coupled with unstoppable determination. All of this harmonizes beautifully with his remarkable warmth and loyalty as a friend, a quality that has led to many deep and enduring friendships that have now lasted for multiple decades.

ARLEN HASTINGS

Nurturing Science in the Developing World

The Institute for Advanced Study welcomes the best scholars from all over the globe, but with few exceptions Members and Visitors come from North America, Europe, and parts of Asia. The Institute has been expanding its international reach with programs to identify and nurture excellence in science in the developing world, where financial resources are scarce but human potential is enormous.

During his time as Institute Director, Phillip A. Griffiths helped establish the Science Initiative Group (SIG), which was created in 1998 to provide scientific guidance for the Millennium Science Initiative. The project was inspired by the vision of James D. Wolfensohn, then Chairman of the Institute's Board of Trustees, and developed jointly with the World Bank to support centers of scientific excellence in the developing world. A recent SIG initiative, the Carnegie–IAS Regional Initiative in Science and Education (RISE), which supports university-based research and training networks to educate Ph.D.-level scientists in sub-Saharan Africa, has been enabled by Institute Trustee Vartan Gregorian, President of Carnegie Corporation of New York.

Griffiths, who chairs the SIG Board, and Arlen K. Hastings, SIG's Executive Director, spoke about their efforts at a Friends Forum in December. Griffiths will speak about the context for and evolution of SIG and RISE in a public lecture at 6:00 p.m. on May 1 in Wolfensohn Hall.

IAS Celebrates Fiftieth Anniversary of IHÉS

The Institute for Advanced Study celebrated the fiftieth anniversary of the founding of the Institut des Hautes Études Scientifiques (IHÉS), located at Bures-sur-Yvette, France, with an event at IAS last November. Attendees included IHÉS Director Jean-Pierre Bourguignon (a former Member in the School of Mathematics, 1979–80), IHÉS President Philippe Lagayette, IHÉS Professor Thibault Damour, IHÉS alumni, and Institute Faculty and Members.

The Institute's association with IHÉS predates its founding in 1958. Institute Director (1947–66) J. Robert Oppenheimer played a significant role in the establishment of IHÉS, one of the first major European institutions modeled on the Institute and on founding Director Abraham Flexner's view that the research that has the most profound impact on knowledge and understanding is that driven by curiosity rather than the prospect of immediate application.

Oppenheimer's papers, which are available for consultation at the Library of Congress, contain voluminous correspondence relating to IHÉS and, in particular, with founding Director Léon Motchane, who visited IAS in 1948. There are dozens of detailed letters from Motchane seeking advice, particularly in relation to appointments. Oppenheimer was, from the earliest days, a member of the Scientific Committee of IHÉS and served on its American fundraising committee when it was formed in 1964.

With the help of Oppenheimer and with financial support from several large companies, Motchane succeeded in launching a European counterpart of IAS in 1958. Until his death in 1967, Oppenheimer was an important adviser to Motchane in its development. On September 20, 1959, the *New York Times* reported Oppenheimer's efforts under the headline "Oppenheimer to Assist New French Institute." Oppenheimer's own education included advanced study in Europe, and he was keen to facilitate scholarly exchange of the type he had benefited from before World War I and World War II resulted in the influx of eminent scientists to the United States. In a December 17, 1959, letter to M. E. Bauer of the Cabinet du Ministre de L'Éducation Nationale, in which he suggested that the French government should support IHÉS (the French Ministry of Higher Education and Research has been supporting IHÉS since 1964), Oppenheimer wrote:

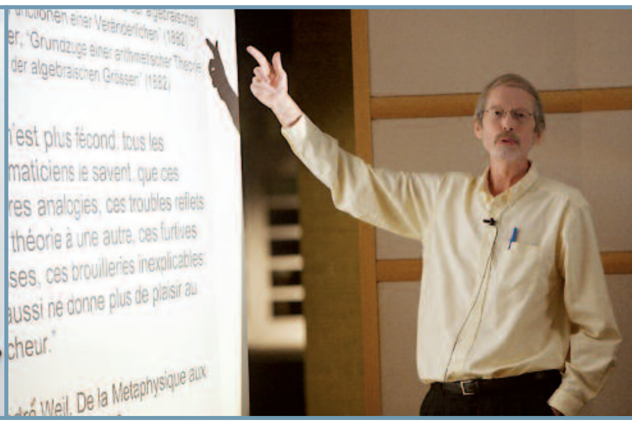
"With the increasing magnitude, complexity, and busyness of scientific progress in all fields, and with the growth of educational systems which corresponds to a new development in the world's history, university chairs no longer necessarily offer that opportunity for seclusion, and for the most difficult and intensive intellectual effort, which was once their special hallmark. For this reason, places of retreat, which are in effect places for advance, have been brought into being, as has our Institute. These serve multiple functions, but basic to them all is an opportunity for much more intensive concentration on study and research than is elsewhere possible. It is for me a common remark to be told by a member, 'I think about mathematical problems two or three times as many hours a week than I do anywhere else.' It needs hardly to be stressed that these experiences are helpful to the universities and institutions of learning to which our visitors return; and that they are passed on in appropriate form to the students whom they are teaching and training. For these reasons, and because in the experimental studies of nature adequate provision is made by other means, institutes for advanced study modeled in some measure or another along the lines of the Princeton Institute are and will multiply throughout the western world."

Oppenheimer's view was prescient. "The great growth in the number of institutes for advanced study accelerating now, particularly in the last couple of decades, all over the world is a powerful testimony to their perceived value," Institute Director Peter Goddard said at the event. "But our two institutes will always be linked because of our distinguished history and achievements, because of the excellence of our permanent faculty, and because of the tranquility and the true intellectual freedom that we are able to offer."

The last letter in Oppenheimer's file is one in which he expressed his regret that his health would prevent him from attending the meeting of the IHÉS fundraising committee held on January 23, 1967.

Oppenheimer died less than a month later. Earlier, Motchane had written to Oppenheimer about visiting the United States: "There is no doubt that I come principally to see you, and, like every year, have two or three good conversations with you. By discussing with you the problems that we share, by talking in all friendliness of things and men—because the Institute is a human affair—by listening to you, I succeed in finding my course."

The celebration included an exhibit of photographs related to the fiftieth anniversary of IHÉS, which was on view in the hallway directly off the Common Room in Fuld Hall.



Robert MacPherson, Hermann Weyl Professor in the Institute's School of Mathematics, spoke about connections between the two institutes concerning research in geometry.

Thibault Damour, a permanent Professor at IHÉS since 1989, spoke about the constants of nature, an important topic in physics that has been explored by scientists at IHÉS and IAS.

PHOTOS ANDREA KANE

LEIBLER *(Continued from page 1)*

fund early stage high-risk projects, and develop joint seminars, workshops, and lectures, as well as a series of annual conferences.

"This unique initiative, which draws on the strength of both Rockefeller and the Institute, will open new doors to studying complex biological problems," said Paul Nurse, President of the Rockefeller University. "By combining techniques from several different scientific disciplines, the effort will be well positioned to make breakthroughs in how we understand key processes of life and disease."

Interested in the quantitative description of microbial systems, both on cellular and population levels, Leibler is developing the theoretical and experimental methods necessary for studying the collective behavior of biomolecules, cells, and organisms. Even the simplest of organisms, such as bacteria, are capable of processing information in a highly sophisticated manner, adapting to varying environments and evolving new functions. By selecting a number of basic questions about how simple genetic and biochemical networks function in bacteria, he and his laboratory colleagues are beginning to understand how individual components can give rise to complex, collective phenomena.

"I am delighted to join the Faculty of the School of Natural Sciences at the Institute," said Leibler. "Both the Institute and the Rockefeller University are known for their scientific excellence and their deep attachment to academic freedom. I feel privileged to be given the opportunity to continue my research in these institutions and to participate in their new interdisciplinary initiative."

Leibler studied physics first at the University of Warsaw and then at the University of Paris, where he earned a Ph.D. in theoretical physics in 1981 and a second doctorate in physics in 1984. He became a tenured Research Fellow at the Centre d'Etudes de Saclay in 1984, where he remained until 1992, and was a Visiting Research Associate at Cornell University from 1985 to 1987. Leibler moved to Princeton University in 1992 as a Professor in the Department of Physics, becoming a Professor in the Department of Molecular Biology in 1993. He was a Visiting Scientist at the European Molecular Biological Laboratories in Heidelberg, Germany, in 1997–98. From 2000 to 2001, Leibler was a Howard Hughes Medical Institute Investigator, and he came to Rockefeller in 2001, becoming a Tri-Institutional Professor at Weill Medical College of Cornell University and the Sloan-Kettering Institute for Cancer Research in 2003.

In addition to funding this initiative, the Simons Foundation has given a $10 million challenge grant to add to the permanent endowment of the Simons Center for Systems Biology at the Institute, established in 2004 and named in recognition of major support from the foundation. Institute Trustee James H. Simons, Founder and President of Renaissance Technologies Corporation, and his wife Marilyn Hawrys Simons created the Simons Foundation in 1994 to support advanced research in science and mathematics. The Charles Simonyi Fund for Arts and Sciences, founded in 2003 by Charles Simonyi, Chairman of the Institute's Board of Trustees, has provided $1 million, the first gift to match the challenge. The challenge grant and matching gifts will enable the permanent endowment of the Simons Center for Systems Biology. Led by Arnold J. Levine, Professor in the School of Natural Sciences, the Simons Center fosters original theoretical research in systems biology as well as collaboration and interaction in the field. Major areas of study in the center include the genomic evolution and behavior of RNA viruses such as influenza, herpes, and human immunodeficiency viruses, and the molecular and cellular origins of cancer, autism, and other diseases.

Derek Bermel Appointed Artist-in-Residence

Derek Bermel, a composer, clarinetist, conductor, and jazz and rock musician, will join the Institute as its new Artist-in-Residence as of July. The position will afford him the opportunity to pursue his scholarly and creative interests, while arranging the Institute's annual Edward T. Cone Concert Series. "I am thrilled to join a community of scholars that I've long held in the highest esteem," said Bermel. "I look forward to drawing inspiration and contributing creative energy during my residency."

Bermel comes to the Institute from a three-year position as the American Composers Orchestra's Music Alive Composer-in-Residence. In that position, he played a central role in programming, serving as curator and artistic adviser to the organization's Orchestra Underground series.

"We are delighted that Derek is joining the Institute as our new Artist-in-Residence," said Director Peter Goddard. "The breadth of his musical influences and the wide range of his musical experience and achievement will add greatly to the cultural life of our community."

Bermel made his Carnegie Hall debut in 1998 as a soloist performing his own critically acclaimed clarinet concerto, *Voices*. He has received commissions from such organizations as the Pittsburgh Symphony, the National Symphony, the Los Angeles Philharmonic, the St. Louis Symphony, the New Jersey Symphony, the Chamber Music Society of Lincoln Center, the Aspen Music Festival, the Tanglewood Music Center, and WNYC Radio. Works from Bermel have also been commissioned by individuals and groups, including Music from China, Jazz Xchange (U.K.), Figura (Denmark), eighth blackbird, violinist Midori, cellist Fred Sherry, and pianist Chris Taylor. The London Philharmonia performed an all-Bermel concert as part of their Music of Today series in 2006, and his music has been featured at festivals around the world. A 2002 disc of his chamber work, *Soul Garden*, has received great acclaim, and the Boston Modern Orchestra Project released a CD of his orchestral music, *Voices*, in February 2009. Next year, a CD of several of his larger works will be released by the group Alarm Will Sound.

Last season, Bermel performed as a soloist alongside Wynton Marsalis in *Migration Series*, a composition by Bermel commissioned by the Lincoln Center Jazz Orchestra and the American Composers Orchestra. He also appeared as a clarinet soloist with the Los Angeles Philharmonic in composer John Adams's *Gnarly Buttons*, with Adams conducting, and as a soloist in his own concerto at the Beijing Modern Music Festival. Highlights during this season include the Pittsburgh Symphony's premiere of Bermel's composition for chorus and orchestra *The Good Life*, and a return to Carnegie Hall for two premieres: a performance of a Koussevitzky Commission for American Composers Orchestra, conducted by Maestro Dennis Russell Davies, and the world premiere of Fang Man's clarinet concerto *Resurrection*, in which Bermel will perform as a soloist. This September, Bermel will begin an affiliation as a guest composer with the Los Angeles Chamber Orchestra.

JAMES POMERANTZ

Derek Bermel

Bermel's awards include the Alpert Award in the Arts, Guggenheim and Fulbright fellowships, the Trailblazer Award from the American Music Center, the Academy Award from the American Academy of Arts and Letters, the Paul Boylan Award from the University of Michigan, and a Rome Prize Fellowship from the American Academy in Rome. He has also been granted commissions from the Fromm and Greenwall Foundations, Meet the Composer, and the Cary Trust, as well as residencies at Yaddo, Tanglewood, Aspen, Banff, Bellagio, Copland House, Sacatar, and Civitella Ranieri.

Bermel has collaborated with a wide variety of artists, including playwright Will Eno, filmmaker Kevin Jerome Everson, installation artist Shimon Attie, landscape architect Andy Cao, choreographer Sheron Wray, performance artist Kim Jones, composer and sound designer David Reid, and poets Wendy S. Walters, Mark Halliday, Naomi Shihab Nye, and Albert Bermel. As an educator, he founded the Making Score program for young composers at the New York Youth Symphony and regularly leads master classes at universities, conservatories, and concert venues worldwide.

Born in New York, Bermel began composing music at the age of eight. He obtained a B.A. from Yale University in 1989 and a D.M.A. from the University of Michigan in 1998, studying composition with William Bolcom, Michael Tenzer, William Albright, Henri Dutilleux, and Louis Andriessen. Bermel also studied ethnomusicology and orchestration in Jerusalem with André Hajdu, later traveling to Bulgaria to study Thracian folk style with Nikola Iliev, to Brazil to learn caxixi with Julio Góes, and to Ghana to study Dagara xylophone with Ngmen Baaru.

Bermel's music is published by Peermusic Classical in the Americas and Asia and by Faber Music in Europe and Australia.

The Artist-in-Residence program was established at the Institute for Advanced Study in 1994 to create a musical presence within the Institute community and to have in residence a person whose work could be experienced and appreciated by scholars from all disciplines. Pianist Robert Taub was the first Artist-in-Residence from 1994 to 2001, followed by Jon Magnussen from 2000 to 2007 and Paul Moravec from 2007 to 2008, after which Moravec became Artistic Consultant at the Institute from 2008 to 2009.

Paul Moravec's Prolific Residency

During his time at the Institute, composer Paul Moravec, who served as the Institute's Artist-in-Residence in 2007–08 and Artistic Consultant in 2008–09, has been remarkably prolific. His work *Brandenburg Gate*, a concerto grosso commissioned by the Orpheus Chamber Orchestra, was performed by the ensemble in Wolfensohn Hall last October. Five days later, the piece received its official world premiere when Orpheus presented it at Carnegie Hall. The composition was part of Orpheus's project to commission six composers to write works inspired by Bach's Brandenburg Concertos. The *New York Times* called Moravec's twenty-minute composition a "restless interplay and feisty competition between the chamber orchestra and a solo group. [His] compositional

(Continued on page 11)

RANDALL HAGADORN

Paul Moravec, at right, with the Orpheus Chamber Orchestra in Wolfensohn Hall

A Community of Imagination

Every public musical performance is a collaboration between the performer and the audience, because music is received and, in a sense, recreated in the mind of the listener. On some level then, a composition is only as interesting as the imagination of the individual listening to it. Walt Whitman said, "To have great poets, there must be great audiences too." While in residence at the Institute over the past two years, I have been delighted to present concerts to great audiences indeed. A musician naturally senses the extent to which an audience is paying attention to—and thinking about—a particular performance. Many of the artists who have performed recently for the Institute community have remarked to me on the high quality and degree of attention that the audiences here give to their performances. To perform for someone who really *listens* is a privilege for a musical artist.

It has been a privilege for me to participate in the community of the Institute during my time in Princeton. There are few venues in the contemporary world where the work of an artist is taken seriously as a viable mode of human understanding. Unlike in some other intellectual professions, the musical artist does not attempt to explain the mysteries and paradoxes of human experience, but rather makes them audibly sensible in forms of the most ordered and integrative beauty. In my time here, I have been granted the opportunity to complete several such endeavors, including my first opera, my first oratorio, a clarinet concerto, a concerto grosso, and a song cycle. My work has been especially encouraged and energized by the spirit of imagination and *possibility* that so generously pervades the Institute community. Just as important have been the warm friendships my wife, Wendy, and I have formed among so many in this most congenial community and which we will cherish for the rest of our lives.

—Paul Moravec

Membership Funding Ensures Freedom to Pursue Knowledge

Some two hundred Members come each year to the Institute, where they are afforded the freedom to pursue long-term goals. The Institute relies on the generosity of a range of donors, from foundations to Friends and former Members of the Institute, whose support ensures that research endeavors at the Institute are free of the pressure for immediate results.

In the 2008–09 academic year, the Ambrose Monell Foundation has supported Visiting Professor **Noga Alon** in his work in combinatorics, discrete mathematics, and theoretical computer science; former School of Mathematics Faculty member **Luis Caffarelli**, an expert on nonlinear problems in analysis and applied mathematics; **Mark Goresky**, who works on mathematics geometry and automorphic forms; astrophysicist **Ari Laor**, who studies massive black holes; **Burt Alan Ovrut**, who conducts research in string theory and particle cosmology; **Gary Shiu**, who studies string theory, particle physics, and cosmology; and string theorist and quantum field theorist **Charles B. Thorn**. For the 2009–10 academic year, the foundation has renewed its annual support for Members in the Schools of Mathematics and Natural Sciences and has directed additional funding to the Simons Center for Systems Biology.

The Gladys Krieble Delmas Foundation has provided support to medieval historian **Elisheva Baumgarten**, who has been studying Jewish communities in Germany and northern France during the High Middle Ages, and to **Martin J. Powers**, who has been examining the role of the arts in relation to political action and social justice in China. The foundation also has renewed its support for the 2009–10 academic year and will provide funding for two Members in the School of Historical Studies.

The Minerva Research Foundation is providing funding for **Alice Chang**, whose research as a Distinguished Visiting Professor in the School of Mathematics is focused on conformal invariants of high orders and classification results of manifolds according to the sign and size of conformal invariants. The foundation has renewed its support with a two-year grant for senior Members in mathematics.

Friends of the Institute for Advanced Study are also partners in the advancement of the highest levels of scholarship at the Institute. Contributions from individual Friends are extremely important, providing the largest source of unrestricted income and enabling the research of four Members in each School every year. In 2008–09, Friends' contributions have funded research by **Matthew Gursky**, a mathematician who has worked in variational problems from mathematical physics and spectral theory; **Darrel Moellendorf**, a philosopher pursuing research on moral matters relating to anthropogenic climate change; **Aristotle Socrates**, an astrophysicist interested in the physical processes that underlie accretion onto black holes and neutron stars; and **Zoltan Szombathy**, a specialist in Arabic studies who has been examining how the deliberate flouting of dominant norms and values by many individuals in medieval Arabic literature was not only tolerated but also highly prized.

Friends who join the Founders' Circle make a tangible connection to the intellectual work of the Institute by sponsoring a Membership in a School of their choice for one year. **Prashanth AK**, whose work has focused on how DNA structural properties determine fundamental biological mechanisms, is the Lynn and Robert Johnston Founders' Circle Member. Also in biology, **Alexei Vazquez**, the Helen and Martin Chooljian Founders' Circle Member, has worked to understand the organization of biological systems and to develop statistical frameworks to analyze large biological datasets. Physicist **Michelle Girvan**, the Ginny and Robert Loughlin Founders' Circle Member, studies the influence of network structure on phenomena (see article, below). **Richard Shweder**, the Rosanna and Charles Jaffin Founders' Circle Member, explores the ethical and legal foundations of tolerance for diversity and has been examining conflicts between mainstream populations and cultural minority groups.

In addition to providing funding support for the work of Mark Goresky in the School of Mathematics, in 2008–09 the Association of Members of the Institute for Advanced Study (AMIAS) has supported **Pantelis Nigdelis**, a scholar of ancient history and Greek epigraphy in the School of Historical Studies.

Applying Physics to Complex Social Systems

Michelle Girvan, the Ginny and Robert Loughlin Founders' Circle Member in the School of Social Science during the 2008–09 academic year, is one of many physicists who have been drawn in recent years to study complex systems beyond the purely physical. Using graph theory, statistical physics, algorithms, and nonlinear dynamics, these researchers can describe phenomena such as the connection of Internet sites and the spread of rumors and disease in mathematical terms, yielding some surprising results.

While at the Institute, Girvan, an Assistant Professor in the Department of Physics at the University of Maryland, has been examining how individuals' social networks and opinions develop in concert, as they seek to be like their neighbors and connect to other people like themselves, while still forming some opinions based on independent reflection.

COURTESY OF MICHELLE GIRVAN

Michelle Girvan

"We see that there is a tipping point in the parameters of this model, in which the system goes from one that is built from closely knit groups between which there are only looser connections to one in which there is only one group with a single opinion," Girvan explains.

Girvan is also looking for algorithms that will identify overlapping community structures in networks, helping to explain, for example, how business, social, and family ties interact. If one of these communities is disrupted, what will happen to the others? This is a question Girvan began looking into some years ago, at one point collaborating with a group of researchers studying primates in a project that demonstrates how mathematical modeling can reveal social forces.

In primate societies, a few older males often serve as a sort of police, intervening in conflicts when they arise and preventing others by their mere presence. Following a typical method of zoological observation, researchers removed these policing individuals from a group of captive pigtailed macaques, a type of monkey native to Southeast Asia, and observed the results. But before the observations were made, Girvan added another step: she constructed a topological model of what could be expected when these males were removed based on the network structure of their relationships, in which the policing males serve as nodes in a web of connections.

In a paper published in *Nature* in January 2006, the team reported the results. Simple observation of the macaques revealed the disruptiveness of removing the policing males. In their absence, the other macaques played with, groomed, and sat with far fewer partners than they did when the dominant males were present. But the topological model projected a higher level of disruption—if equally important nodes were removed from a physical structure, the collapse would have been more significant. The comparison revealed that the remaining macaques were in fact compensating for the absence of the policing males to some degree, restructuring some of their relationships to withstand the removal of these central figures. Such dynamics can now be investigated further, both by primatologists and by complex-network theorists like Girvan.

MORAVEC *(Continued from page 10)*

skill is apparent throughout this well-made and agreeable score."

Born in Buffalo, New York, Moravec will return to his position as University Professor at Adelphi University in the fall. After earning his B.A. in music composition from Harvard University in 1980, he won a Rome Prize Fellowship from the American Academy in Rome. He received both his master's (1982) and doctorate (1987) degrees in music composition from Columbia University, then went on to teach at Columbia and later at Dartmouth and Hunter colleges. He was awarded the 2004 Pulitzer Prize in Music for *Tempest Fantasy*, a thirty-minute "musical meditation" on Shakespeare's play scored for clarinet, violin, cello, and piano.

His numerous distinctions include a Fellowship in Music Composition from the National Endowment for the Arts, a Rockefeller Foundation Fellowship in Italy, a Camargo Foundation Residency Fellowship in France, and two fellowships from the American Academy of Arts and Letters.

While at the Institute, Moravec also composed *The Blizzard Voices*, an evening-length oratorio premiered by Opera Omaha in September 2008, a Concerto for Clarinet and Orchestra, premiered by the Princeton Symphony Orchestra in January 2009, and two pieces composed for Board Chairman Charles Simonyi and Vice Chairman Martin Leibowitz on the occasion of a transition in leadership in October 2008.

His major musical accomplishment during his stay in Princeton was a commission from the Santa Fe Opera, for which he collaborated with librettist Terry Teachout. Both Moravec and Teachout are making their operatic debuts with *The Letter*, an opera noir based on the short story by W. Somerset Maugham, which will premiere at the Santa Fe Opera in July. *The Letter* will feature soprano Patricia Racette and baritone Anthony Michaels-Moore in a production directed by the British theater and opera director Jonathan Kent. It will be conducted by Patrick Summers of the Houston Grand Opera, and the sets will be designed by Hildegard Bechtler. Fashion designer Tom Ford will design the costumes, making his debut as a stage designer with this production.

The League of Nations at IAS

by Patricia Clavin

On September 29, 1940, a small band of League of Nations employees and their families arrived at the Institute for Advanced Study, where they would base the civilian operations of the League's Economic and Financial Organization for the next five years. Led by Scotsman Alexander Loveday, the cosmopolitan group with members from Ireland, Sweden, Estonia, Canada, the Netherlands, Belgium, Czechoslovakia, Romania, Switzerland, France, and New Zealand comprised some of the leading experts in economics, finance, and demography. But why were they in Princeton?

COURTESY OF THE INSTITUTE FOR ADVANCED STUDY ARCHIVES

A meeting of the Economic and Financial secretariat of the League of Nations in Fuld Hall

The answer to this question lies in a mix of the personal, the political, and the circumstantial. At the time, the circumstances seemed the most important and were certainly the most dramatic factor. In 1940, the Economic and Financial Organization was the largest and most important agency of the League of Nations, the international body that preceded the United Nations. Its secretariat, a civil-servant section of economists and statisticians from around the world, came to the United States to escape a Nazi-occupied Europe that left the League isolated and at risk of Axis domination. When Loveday, the Director of the agency, put out his first call for help to the Institute in early May 1940, what remained of democratic Europe was on the brink of collapse.

By the time Loveday and his colleagues arrived at the Institute, Belgium and France had fallen to the Axis powers, British forces had been pushed back across the English Channel, and the only route out of Europe was across a hostile Spain and an unpredictable Portugal. (The League officials shared a fairly typical, if not fortunate, tale of flight: on their way from Geneva they survived a serious bus crash in which three members of the party were injured, then endured a three-week wait, huddled together on a shared mattress in a public room in Lisbon, before securing safe passage on board the *Exeter*.)

Aside from affording sanctuary, there were also constructive, political reasons why a League presence in Princeton was important. Moving the Economic and Financial secretariat to the Institute preserved the League's invaluable expertise and made it readily accessible to the United States government, which placed economic and financial reconstruction at the heart of its plans for a new world order. Between 1940 and 1945, the number of League officials based at Princeton grew from eleven to thirty-five. They helped establish the United Nations Relief and Reconstruction Administration in 1943, drafted plans for the new monetary order agreed to at the Bretton Woods Conference in 1944, and advanced the trade liberalization that resulted in the General Agreement on Tariffs and Trade in 1947. The League group in Princeton also provided essential practical support for the creation of the United Nations, established in 1945.

None of this would have been possible without the pivotal role played by the Institute. Its intervention in the summer of 1940 was crucial, as Director Frank Aydelotte explained to the Institute Trustees, "for the League was unlikely to approach the United States, a non-Member, and the United States would hardly approach the League." Moving the League's secretariat to the United States touched political sensitivities that ran deep, especially in 1940, an election year in which President Roosevelt bid for a controversial third term and the nation, though divided on issues of foreign engagement, began to prepare for war.

In a series of deft moves, Aydelotte, who had served as President of his local League of Nations Association for many years, quickly put together a tripartite response to Loveday's plea that included the Rockefeller Foundation (which helped to bankroll the move) and Princeton University, which made great play of "Wilson's University" saving the League in its hour of need. But it was Aydelotte who undertook the lion's share of the work, including the sensitive political task of negotiating with Secretary of State Cordell Hull to ensure that the State Department and the White House privately supported the Institute initiative. They endorsed the Director's efforts with alacrity.

The League's arrival in Princeton put considerable pressure on the Institute's resources: the new dining room in Fuld Hall was given over to the League while Faculty members were asked to share offices and secretaries to work in corridors. But the sacrifices demanded of Faculty and support staff alike were seen as a central contribution to the "mobilization of the scholarly resources of the nation" and were understood as part of the nation's "mobilization against the threat of war," as Aydelotte described it in an October 1940 report. Much of this history remains untold, as does the Institute's role in efforts to persuade the United States as a whole to assume global leadership during World War II. Undoubtedly, Aydelotte would be delighted at the inauguration of the new Shelby White and Leon Levy Archives Center, which will help to recover these and other forgotten histories of the Institute.

Patricia Clavin, Fellow and Tutor in Modern History at Jesus College, University of Oxford, was a Visitor in the School of Historical Studies during the second term of 2008–09. Her research at the Institute was funded by the Thank-Offering to Britain Fellowship of the British Academy. Her book, Bread and Butter Internationalism: The League of Nations and the World Economy, 1919–1946*, will be published by Oxford University Press in 2010. She can be reached at patricia.clavin@jesus.ox.ac.uk.*

LEVY ARCHIVES *(Continued from page 1)*

White, founding Trustee of the Leon Levy Foundation, said her interest in creating the center was sparked by an anecdote about John von Neumann, the renowned mathematician who came to the Institute in 1933 as one its first Professors and worked there until his death in 1957. "When his daughter, Marina Whitman, told me that she did not give the Institute his papers because it did not have an archive center," White said, "I knew that the Institute needed one to help ensure that the valuable papers of its distinguished Faculty be preserved."

White and the Leon Levy Foundation have supported the Institute in a range of significant ways. During his fifteen years on the Institute Board, Leon Levy contributed considerable talents in his role as Vice Chairman and President of the Corporation (1995–2003), and shared an intellectual vitality that greatly benefited the Institute. The New Initiatives Fund established by Levy and White in 1998 has promoted progress in new and important programs such as systems biology and theoretical computer science, and has supported emerging research in mathematics and astrophysics. Since the 2005–06 academic year, the foundation has funded a Leon Levy Member in the School of Social Science.

Since the Institute's Archives were formally established in 1986, they have existed as an informal adjunct to the Historical Studies–Social Science Library, through the part-time efforts of Library staff. Primarily a paper-based collection dating from the 1930s onward, the Archives currently include official correspondence of the Director's Office, minutes of meetings of the Faculty and Board of Trustees, correspondence and files concerning past Faculty members, records of the Electronic Computer Project, and other documents. In addition, the Archives house the papers of the late John Bahcall, Professor in the School of Natural Sciences from 1971–2005, and copies of the lecture notes of the late Ernst Kantorowicz, Professor in the School of Historical Studies from 1951–63. The Archives also contain the Institute's oral-history tapes and transcripts and a collection of photographs of the Institute's buildings and grounds, the Electronic Computer Project, Faculty, Directors, and others affiliated with the Institute.

BYNUM *(Continued from page 3)*

absorbed and utilized." She discerns new emphases on connectivity, transitions, material culture, objects, and "deep structures," but sees them as owing "more to the absorption than to the rejecting of the so-called linguistic or cultural turn."

Of greater threat to historical scholarship than the "culture wars" of the 1990s, according to Bynum, are the crushing expectations for over-production at most American universities. In her essay "The P Word," published by the American Historical Association's *Perspectives* in October 2007, she laments the increasing use of the word "project" by historians and suggests its abolishment. "'Scholarship,' 'research,' 'work' are open-ended activities; they are something one is, almost by definition, always in the middle of. When one does research or engages in scholarship, one meanders, following the sources where they lead," she notes. "A project, on the other hand, has a beginning and an end. It comes with its conclusions already drawn and its chapters outlined."

Addressing the increasing demands to produce in academia, Bynum proposes in *Dædalus* that historians extend the perspective inherent in the "comic mode" to their professional practices. "If we could really understand what we undertake as historians to be by definition partial and discontinuous, forever redone and in need of redoing because of our own cultural situated-ness, we—all of us, young scholars and old—would be able to slow down," Bynum suggests. "If there is no goal at the end of the race—that is, if the point is the running not the goal—why sprint instead of stroll (especially if sprinting damages our knees forever)? No longer pressured to read everything, consider everything, account for every new turn and twist of scholarship, we would recognize that each of us is—and can be—only one perspective. Accepting the fragmentary and necessarily partial nature of our own contribution, we might become more truly collaborative—that is, more open to using, even seeking out, work different from our own."

The Metropolitan Opera Hosts Centennial Council

Members of the Centennial Council, which includes the Institute's most active and involved donors, attended a performance at the Metropolitan Opera of *Doctor Atomic*, John Adams's exploration of J. Robert Oppenheimer's role as Technical Director of the Los Alamos Laboratory and Chief Scientific Officer of the atomic bomb project. Oppenheimer was the Institute's third and longest-serving Director (1947–66) and simultaneously served as Chairman of the General Advisory Committee of the Atomic Energy Commission from 1947 through 1952.

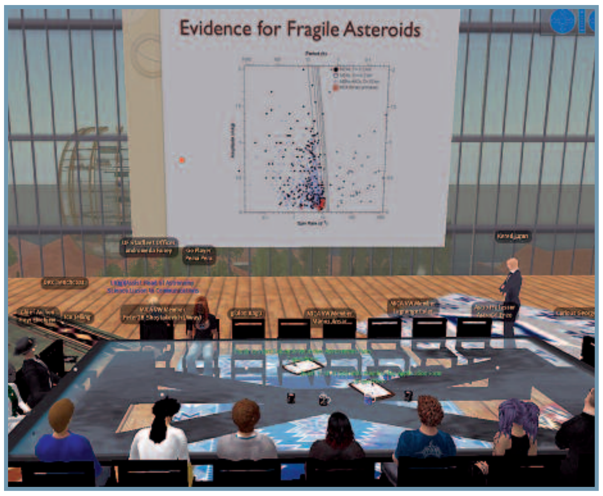
The performance, which took place in the fall, was preceded by a reception and talks on *Doctor Atomic* and Oppenheimer in the Met's boardroom. The General Manager of the Met, Peter Gelb, spoke about his efforts to revitalize the Met by making opera more appealing and accessible to a broader audience, maintaining its high standard of excellence, and making bold artistic choices, such as the decision to produce *Doctor Atomic* and the selection of Penny Woolcock, a British filmmaker, as its director. Peter Galison, Institute Trustee and Joseph Pellegrino University Professor at Harvard University, followed with a scientific perspective on the bomb, focusing on Oppenheimer's integral role in its development.

COREY WEAVER

Institute Trustee Peter Galison provides scientific background on J. Robert Oppenheimer and the atomic bomb prior to a performance of Doctor Atomic.

For more information about the Centennial Council, including ways in which donors can become more deeply involved in the work of the Institute by providing major operating, endowment, and Membership support, please contact Catie Newcombe, Senior Development Officer, at (609) 951-4542 or cnewcombe@ias.edu.

Exploring the Idea of a Second Life Virtual Campus



COURTESY OF PIET HUT

Professional astronomers from around the world gathered at a virtual colloquium (depicted above) given by Derek Richardson, Associate Professor and Director, Center for Theory and Computation, University of Maryland, in the virtual astronomy department at the Meta Institute for Computational Astrophysics.

Second Life is an online three-dimensional virtual world. Initially, it looks like a video game, but the participants are called "residents," and there is no game and no goal. Instead, Second Life residents spend their time in activities that mirror what people do in the normal world (called Real Life in contrast to Second Life). In Second Life, they meet and talk with each other, build houses, landscape gardens, make clothes, play chess, watch movies, and even make their own movies.

At any given moment, there are some 60,000 active residents. In total, a few hundred thousand individuals spend a few hours each day in Second Life, where a flourishing economy based on its own currency, the Linden dollar (L$), has a floating exchange rate with Real Life currencies.

Visiting Second Life is like entering a medium-sized city with a population of a few hundred thousand inhabitants, most of whom are energetic and creative and form many interwoven networks. This city, with a total surface area about the size of Manhattan, exists purely in cyberspace, made up of bits and bytes in data banks, represented by pixels on the screens of anyone interested in opening a free Second Life account.

Over the last few years, many universities and government organizations have opened branches in Second Life, including Harvard, the Massachusetts Institute of Technology, Princeton, and NASA. They have campuses and areas for meetings and exhibitions, along with spaces for educational and research activities. The advantages are interactivity, immediacy, and the size of the group that can be accommodated.

It would be possible to construct a virtual Institute campus with a virtual Fuld Hall and virtual teatime. Those interested should contact me at piet@ias.edu.

—Piet Hut, Professor, Program in Interdisciplinary Studies

The focus of Piet Hut's research is computational astrophysics, in particular multiscale multiphysics simulations of dense stellar systems. In addition, he is actively involved in interdisciplinary explorations in the areas of cognitive science and philosophy of science centered around questions involving the nature of knowledge.

Philanthropy as Legacy

The current economy and volatility in the marketplace make financial planning more important than ever. Philanthropy, as a part of one's legacy, need not fall by the wayside, even in these challenging times. A charitable life-income gift, for example, which creates a fixed, lifetime stream of income for an individual and/or a loved one, may be a worthwhile component of a wealth strategy. And, as always, the Institute is grateful to be remembered in a will or trust, which is a simple way to be philanthropic while maintaining lifetime control of one's assets.

The Institute has formed a Planned Giving Advisory Council, which offers advice and perspective on planned-giving issues. Current members of the Advisory Council are Ann Reichelderfer (Stevens & Lee); Nina L. Cohen (The Glenmede Trust Company, N.A.); John F. McCarthy III (McCarthy Law Firm); T. Randolph Harris (McLaughlin & Stern, LLP); and Barbara A. Sloan (McLaughlin & Stern, LLP).

Recently, the Advisory Council hosted a breakfast for the local financial, advisory, and trusts and estate community whose practices specialize in financial and estate planning. The featured speaker was Ashvin B. Chhabra, Chief Investment Officer at the Institute, who spoke on the subject of an article he coauthored, "Creating a Goal-Based Wealth Allocation Process," which appeared in the Winter 2008 *Journal of Wealth Management*.

Chhabra reviewed traditional financial models and then spoke about a more comprehensive wealth diversification strategy that incorporates a fuller picture of one's wealth—one that includes not only investible assets, but non-investment assets and liabilities as well. Viewing wealth allocation within this broader framework allows individuals to think about financial goals—the preservation of capital and lifestyle, the desire to retire, and the establishment of a legacy.

On May 21, the Einstein Legacy Society, which recognizes those who have included the Institute in their estate plans, will host a talk, "Dreams Deferred? Rebuilding Your Retirement Strategy," by Brett Hammond, Managing Director and Chief Investment Strategist of TIAA-CREF. For further information on planned giving, please contact Catie Newcombe, Senior Development Officer, at (609) 951-4542 or cnewcombe@ias.edu.

KATE ABLUTZ

Teatime Discussions More Fruitful: *Each weekday afternoon Faculty, scholars, and staff gather in the Common Room of Fuld Hall for tea and conversation, a tradition that dates back to the Institute's beginnings. Elizabeth Veblen, the wife of the late Oswald Veblen, Professor in the School of Mathematics, introduced the tradition of teatime to the Institute community when the Institute initially was housed in Fine Hall on the campus of Princeton University. When the Institute moved to Fuld Hall in 1939, the custom continued. This year, fresh fruit was added to the assortment of fresh-baked cookies and cakes traditionally served at the afternoon tea.*