2006 Fields Medals Awarded

On August 22, 2006, four Fields Medals were awarded at the opening ceremonies of the International Congress of Mathematicians (ICM) in Madrid, Spain. The medalists are Andrei Okounkov, Grigory Perelman, Terence Tao, and Wendelin Werner. [Editors Note: During the award ceremony, John Ball, president of the International Mathematical Union, announced that Perelman declined to accept the Fields Medal.]

The Fields Medals are given every four years by the International Mathematical Union (IMU). Although there is no formal age limit for recipients, the medals have traditionally been presented to mathematicians not older than forty years of age, as an encouragement for future achievement. The medal is named after the Canadian mathematician John Charles Fields (1863–1932), who organized the 1924 ICM in Toronto. At a 1931 meeting of the Committee of the International Congress, chaired by Fields, it was decided that funds left over from the Toronto ICM "should be set apart for two medals to be awarded in connection with successive International Mathematical Congresses." In outlining the rules for awarding the medals, Fields specified that the medals "should be of a character as purely international and impersonal as possible." During the 1960s, in light of the great expansion of mathematics research, the possible number of medals to be awarded was increased from two to four. Today the Fields Medal is recognized as the world's highest honor in mathematics.

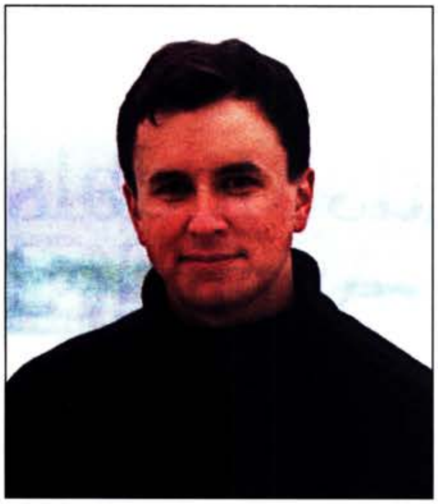
Previous recipients of the Fields Medal are: Lars V. Ahlfors and Jesse Douglas (1936); Laurent Schwartz and Atle Selberg (1950); Kunihiko Kodaira and Jean-Pierre Serre (1954); Klaus F. Roth and René Thom (1958); Lars Hörmander and John W. Milnor (1962); Michael F. Atiyah, Paul J. Cohen, Alexandre Grothendieck, and Stephen Smale (1966); Alan Baker, Heisuke Hironaka, Sergei P. Novikov, and John G. Thompson (1970); Enrico Bombieri and David B. Mumford (1974); Pierre R. Deligne, Charles L. Fefferman, Grigorii A. Margulis, and Daniel G. Quillen (1978); Alain Connes, William P. Thurston, and Shing-Tung Yau (1982); Simon K. Donaldson, Gerd Faltings, and Michael H. Freedman (1986); Vladimir Drinfeld, Vaughan F. R. Jones, Shigefumi Mori, and Edward Witten (1990); Jean Bourgain, Pierre-Louis Lions, Jean-Christoph Yoccoz, and Efim Zelmanov (1994); Richard Borcherds, William Timothy Gowers, Maxim Kontsevich, and Curtis T. McMullen (1998); Laurent Lafforgue and Vladimir Voevodsky (2002).

Andrei Okounkov

Citation: "for his contributions bridging probability, representation theory and algebraic geometry".

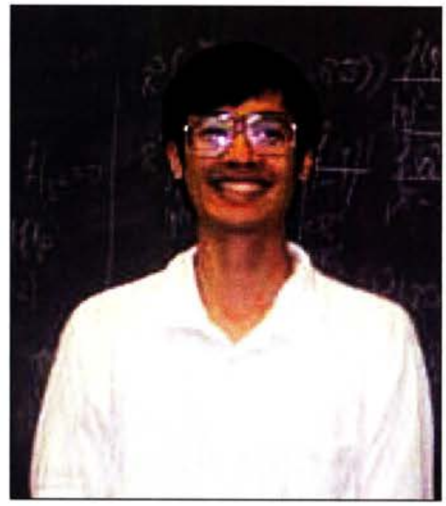
The work of Andrei Okounkov has revealed profound new connections between different areas of mathematics and has brought new insights into problems arising in physics. Although his work is difficult to classify because it touches on such a variety of areas, two clear themes are the use of notions of randomness and of classical ideas from representation theory. This combination has proven powerful in attacking problems from algebraic geometry and statistical mechanics.

One of the basic objects of study in representation theory is the "symmetric group", whose elements are permutations of objects. For example, if the objects are the letters {C, G, J, M, N, O, Q, Z}, then a permutation is an ordering of the letters, such as GOQZMNJC or JZOQCGNM. The number of



Andrei Okounkov

Grigory Perelman



Terence Tao

Wendelin Werner

possible permutations grows quickly as the number of objects grows; for 8 objects, there are already 40,320 different permutations. If we consider an abstract set of n objects, then the "symmetric group on n letters" is the collection of all the different permutations of those n objects, together with rules for combining the permutations.

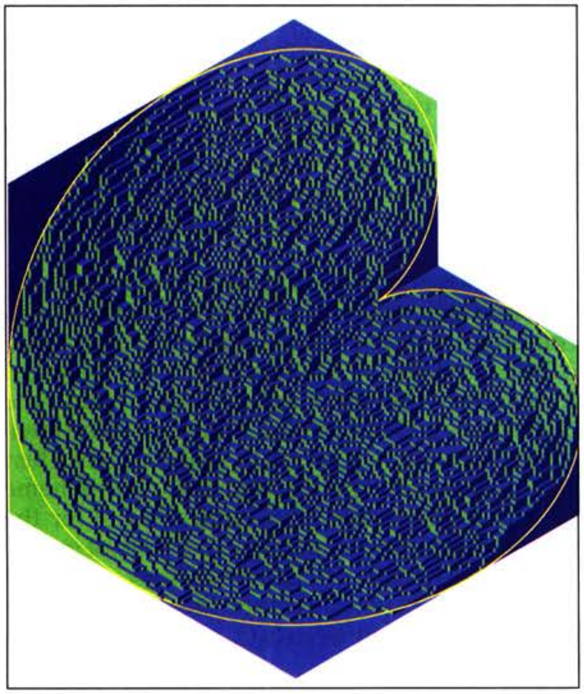
Representation theory allows one to study the symmetric group by representing it by other mathematical objects that provide insights into the group's salient features. The representation theory of the symmetric group is a well developed subfield that has important uses within mathematics itself and also in other scientific areas, such as quantum mechanics. It turns out that, for the symmetric group on n letters, the building blocks for all of its representations are indexed by the "partitions" of n. A partition of a number n is just a sequence of positive numbers that add up to n; for example $2 + 3 + 3 + 4 + 12$ is a partition of 24.

Through the language of partitions, representation theory connects to another branch of mathematics called "combinatorics", which is the study of objects that have discrete, distinct parts. Many continuous phenomena in mathematics are related by virtue of having a common discrete substructure, which then raises combinatorial questions. Continuous phenomena can also be discretized, making them amenable to the methods of combinatorics. Partitions are among the most basic combinatorial objects, and their study goes back at least to the 18th century.

Randomness enters into combinatorics when one considers very large combinatorial objects, such as the set of all partitions of a very large number. If one thinks of partitioning a number as randomly cutting it up into smaller numbers, one can ask, What is the probability of obtaining a particular partition? Questions of a similar nature arise in representation theory of large symmetric groups. Such links between probability and representation theory were considered by mathematicians in Russia during the 1970s and 1980s. The key to finding just the right tool from probability theory suited to this question derives from viewing partitions as representations of the symmetric group. A Russian who studied at Moscow State University, Andrei Okounkov absorbed this viewpoint and has deployed it with spectacular success to attack a wide range of problems.

One of his early outstanding results concerns "random matrices", which have been extensively studied in physics. A random matrix is a square array of numbers in which each number is chosen at random. Each random matrix has associated with it a set of characteristic numbers called the "eigenvalues" of the matrix. Starting in the 1950s, physicists studied the statistical properties of eigenvalues of random matrices to gain insight into the problem of the prediction and distribution of energy levels of nuclei. In recent years, random matrices have received renewed attention by mathematicians and physicists.

Okounkov has used ideas from quantum field theory to prove a surprising connection between random matrices and increasing subsequences in permutations of numbers. An increasing subsequence is just what it sounds like: For example, in a permutation of the numbers from 1 up to 8, say 71452638, two increasing subsequences are 14568 and 1238. There is a way to arrange these increasing subsequences into a hierarchy: the longest subsequence, followed by the second-longest, the third-longest, and so forth, down to the shortest.



This picture shows a random surface that can be thought of as the "melting" of a crystal. The heart-shaped curve forming the border between the melted and frozen regions is called a cardioid.

Image courtesy of Richard Kenyon and Andrei Okounkov.

Okounkov proved that, for very large n, the sequence of largest eigenvalues of an n-by-n random matrix behaves, from the probabilistic point of view, in the same way as the lengths of the longest increasing subsequences in permutations of the numbers from 1 to n. In his proof, Okounkov took a strikingly original approach by reformulating the question in a completely different context, namely, as a comparison of two different descriptions of a random surface. This work established a connection to algebraic geometry, providing a seed for some of his later work in that subject.

Random surfaces also arise in Okounkov's work in statistical mechanics. If one heats, say, a cubical crystal from a low temperature, one finds that the corners of the cube are eaten away as the crystal "melts". The geometry of this melting process can be visualized by imagining a corner to consist of a bunch of tiny blocks. The melting of the crystal corresponds to removing blocks at random. Thinking of the partitioning of the crystal into tiny blocks as analogous to partitioning integers, Okounkov brought his signature methods to bear on the analysis of the random surfaces that arise. In joint work with Richard Kenyon, Okounkov proved the surprising result that the melted part of the crystal, when projected onto two dimensions, has a very distinctive shape and is always encircled by an algebraic curve—that is, a curve that can be defined by polynomial equations. This is illustrated in the accompanying figure; here the curve is a heart-shaped curve called a cardioid. The connection with real algebraic geometry is quite unexpected.

Over the past several years, Okounkov has, together with Rahul Pandharipande and other collaborators, written a long series of papers on questions in enumerative algebraic geometry, an area with a long history that in recent years has been enriched by the exchange of ideas between mathematicians and physicists. A standard way of studying algebraic curves is to vary the coefficients in the polynomial equations that define the curves and then impose conditions—for example, that the curves pass through a specific collection of points. With too few conditions, the collection of curves remains infinite; with too many, the collection is empty. But with the right balance of conditions, one obtains a finite collection of curves. The problem of "counting curves" in this way—a longstanding problem in algebraic geometry that also arose in string theory—is the main concern of enumerative geometry. Okounkov and his collaborators have made substantial contributions to enumerative geometry, bringing in ideas from physics and deploying a wide range of tools from algebra, combinatorics, and geometry. Okounkov's ongoing research in this area represents a marvelous interplay of ideas from mathematics and physics.

Andrei Okounkov was born in 1969 in Moscow. He received his doctorate in mathematics from Moscow State University in 1995. He is a professor of mathematics at Princeton University. He has also held positions at the Russian Academy of Sciences, the Institute for Advanced Study in Princeton, the University of Chicago, and the University of California, Berkeley. His distinctions include a Sloan Research Fellowship (2000), a Packard Fellowship (2001), and the European Mathematical Society Prize (2004).

Grigory Perelman

Citation: "for his contributions to geometry and his revolutionary insights into the analytical and geometric structure of the Ricci flow".

The name of Grigory Perelman is practically a household word among the scientifically interested public. His work from 2002-2003 brought groundbreaking insights into the study of evolution equations and their singularities. Most significantly, his results provide a way of resolving two outstanding problems in topology: the Poincaré Conjecture and the Thurston Geometrization Conjecture. As of the summer of 2006 the mathematical community is still in the process of checking his work to ensure that it is entirely correct and that the conjectures have been proved. After more than three years of intense scrutiny, top experts have encountered no serious problems in the work.

For decades the Poincaré Conjecture has been considered one of the most important problems in mathematics. The conjecture received increased attention from the general public when it was named as one of the seven Millennium Prize Problems established by the Clay Mathematics Institute in 2000. The institute has pledged to award a prize of US$1 million for the solution of each problem. The work of Perelman on the Poincaré Conjecture is the first serious contender for one of these prizes.

The Poincaré Conjecture arises in topology, which studies fundamental properties of shapes that remain unchanged when the shapes are deformed—that is, stretched, warped, or molded, but not torn. A simple example of such a shape is the 2-sphere, which is the 2-dimensional surface of a ball in 3-dimensional space. Another way to visualize the 2-sphere is to take a disk lying in the 2-dimensional plane and identify the disk's boundary points to a single point; this point can be thought of as the north pole of the 2-sphere. Although globally the 2-sphere looks very different from the plane, every point on the sphere sits in a region that looks like the plane. This property of looking locally like the plane is the defining property of a 2-dimensional manifold, or 2-manifold. Another example of a 2-manifold is the "torus", which is the surface of a doughnut.

Although locally the 2-sphere and the torus look the same, globally their topologies are distinct: Without tearing a hole in the 2-sphere, there is no way to deform it into the torus. Here is another way of seeing this distinction. Consider a loop lying on the 2-sphere. No matter where it is situated on the 2-sphere, the loop can be shrunk down to a point, with the shrinking done entirely within the sphere. Now imagine a loop lying on the torus: If the loop goes around the hole, the loop cannot be shrunk to a point. If loops can be shrunk to a point in a manifold, the manifold is called "simply connected". The 2-sphere is simply connected, while the torus is not. The analogue of the Poincaré Conjecture in 2 dimensions would be the assertion that any simply connected 2-manifold of finite size can be deformed into the 2-sphere, and this assertion is correct. It is natural then to ask, What can be said about non-simply-connected 2-manifolds? It turns out that they can all be classified according to the number of holes: They are all deformations of the torus, or of the double-torus (with 2 holes), or of the triple torus (the surface of a pretzel), etc. (One actually needs two other technical assumptions in this discussion, compactness and orientability.)

Geometry offers another way of classifying 2-manifolds. When one views manifolds topologically, there is no notion of measured distance. Endowing a manifold with a metric provides a way of measuring distance between points in the manifold and leads to the geometric notion of curvature. 2-manifolds can be classified by their geometry: A 2-manifold with positive curvature can be deformed into a 2-sphere; one with zero curvature can be deformed into a torus; and one with negative curvature can be deformed into a torus with more than one hole.

The Poincaré Conjecture, which originated with the French mathematician Henri Poincaré in 1904, concerns 3-dimensional manifolds, or 3-manifolds. A basic example of a 3-manifold is the 3-sphere: In analogy with the 2-sphere, one obtains the 3-sphere by taking a ball in 3-dimensions and identifying its boundary points to a single point. (Just as 3-dimensional space is the most natural home for the 2-sphere, the most natural home for the 3-sphere is 4-dimensional space—which of course is harder to visualize.) Can every simply connected 3-manifold be deformed into the 3-sphere? The Poincaré Conjecture asserts that the answer to this question is yes.

Just as with 2-manifolds, one could also hope for a classification of 3-manifolds. In the 1970s Fields Medalist William Thurston made a new conjecture, which came to be called the Thurston Geometrization Conjecture and which gives a way to classify all 3-manifolds. The Thurston Geometrization Conjecture provides a sweeping vision of 3-manifolds and actually includes the Poincaré Conjecture as a special case. Thurston proposed that, in a way analogous to the case of 2-manifolds, 3-manifolds can be classified using geometry. But the analogy does not extend very far: 3-manifolds are much more diverse and complex than 2-manifolds.

Thurston identified and analyzed 8 geometric structures and conjectured that they provide a means for classifying 3-manifolds. His work revolutionized the study of geometry and topology. The 8 geometric structures were intensively investigated, and the Geometrization Conjecture was verified in many cases; Thurston himself proved it for a large class of manifolds. But hopes for a proof of the conjecture in full generality remained unfulfilled.

In 1982 Richard Hamilton identified a particular evolution equation, which he called the Ricci flow, as the key to resolving the Poincaré and Thurston Geometrization Conjectures. The Ricci flow is similar to the heat equation, which describes how heat flows from the hot part of an object to the cold part, eventually homogenizing the temperature to be uniform throughout the object. Hamilton's idea was to use the Ricci flow to homogenize the geometry of 3-manifolds to show that their geometry fits into Thurston's classification. Over more than twenty years, Hamilton and other geometric analysts made great progress in understanding the Ricci flow. But they were stymied in figuring out how to handle "singularities", which are regions where the geometry, instead of getting homogenized, suddenly exhibits uncontrolled changes.

That was where things stood when Perelman's work burst onto the scene. In a series of papers posted on a preprint archive starting in late 2002, Perelman established ground-breaking results about the Ricci flow and its singularities. He provided new ways of analyzing the structure of the singularities and showed how they relate to the topology of the manifolds. Perelman broke the impasse in the program that Hamilton had established and validated the vision of using the Ricci flow to prove the Poincaré and Thurston Geometrization Conjectures. Although Perelman's work appears to provide a definitive endpoint in proving the conjectures, his contributions do not stop there. The techniques Perelman introduced for handling singularities in the Ricci flow have generated great excitement in geometric analysis and are beginning to be deployed to solve other problems in that area.

Perelman's combination of deep insights and technical brilliance mark him as an outstanding mathematician. In illuminating a path towards answering two fundamental questions in 3-dimensional topology, he has had a profound impact on mathematics.

Grigory Perelman was born in 1966 in what was then the Soviet Union. He received his doctorate from St. Petersburg State University. During the 1990s he spent time in the United States, including as a Miller Fellow at the University of California, Berkeley. He was for some years a researcher in the St. Petersburg Department of the Steklov Institute of Mathematics. In 1994 he was an invited speaker at the International Congress of Mathematicians in Zurich.

Terence Tao

Citation: "for his contributions to partial differential equations, combinatorics, harmonic analysis and additive number theory".

Terence Tao is a supreme problem-solver whose spectacular work has had an impact across several mathematical areas. He combines sheer technical power, an other-worldly ingenuity for hitting upon new ideas, and a startlingly natural point of view that leaves other mathematicians wondering, "Why didn't anyone see that before?"

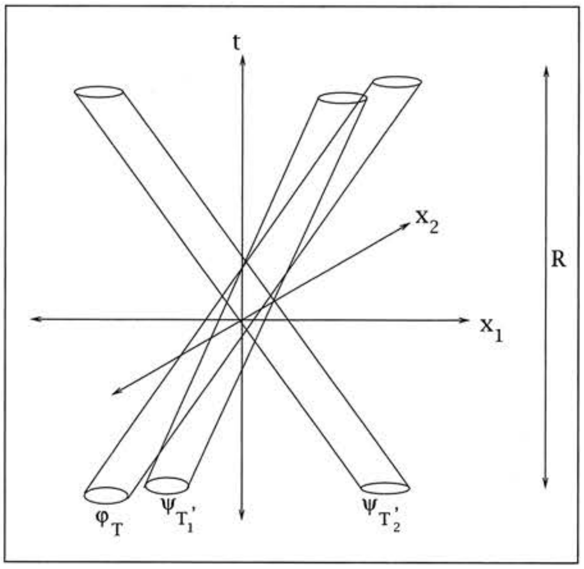
At 31 years of age, Tao has written over eighty research papers, with over thirty collaborators, and his interests range over a wide swath of mathematics, including harmonic analysis, nonlinear partial differential equations, and combinatorics. "I work in a number of areas, but I don't view them as being disconnected," he said in an interview published in the Clay Mathematics Institute Annual Report. "I tend to view mathematics as a unified subject and am particularly happy when I get the opportunity to work on a project that involves several fields at once."

Because of the wide range of his accomplishments, it is difficult to give a brief summary of Tao's oeuvre. A few highlights can give an inkling of the breadth and depth of the work of this extraordinary mathematician.

The first highlight is Tao's work with Ben Green, a dramatic new result about the fundamental building blocks of mathematics, the prime numbers. Green and Tao tackled a classical question that was probably first asked a couple of centuries ago: Does the set of prime numbers contain arithmetic progressions of any length? An "arithmetic progression" is a sequence of whole numbers that differ by a fixed amount: 3, 5, 7 is an arithmetic progression of length 3, where the numbers differ by 2; 109, 219, 329, 439, 549 is a progression of length 5, where the numbers differ by 110. A big advance in understanding arithmetic progressions came in 1974, when the Hungarian mathematician Emre Szemeredi proved that any infinite set of numbers that has "positive density" contains arithmetic progressions of any length. A set has positive density if, for a sufficiently large number n, there is always a fixed percentage of elements of $1, 2, 3, \ldots n$ in the set. Szemeredi's theorem can be seen from different points of view, and there are now at least three different proofs of it, including Szemeredi's original proof and one by 1998 Fields Medalist Timothy Gowers. The primes do not have positive density, so Szemeredi's theorem does not apply to them; in fact, the primes get sparser and sparser as the integers stretch out towards infinity. Remarkably, Green and Tao proved that, despite this sparseness, the primes do contain arithmetic progressions of any length. Any result that sheds new light on properties of prime numbers marks a significant advance. This work shows great originality and insight and provides a solution to a deep, fundamental, and difficult problem.

Another highlight of Tao's research is his work on the Kakeya Problem, which in its original form can be described in the following way. Suppose you have a needle lying flat on a plane. Imagine the different possible shapes swept out when you rotate the needle 180 degrees. One possible shape is a half-disk; with a bit more care, you can perform the rotation within a quarter-disk. The Kakeya problem asks, What is the minimum area of the shape swept out in rotating the needle 180 degrees? The surprising answer is that the area can be made as small as you like, so in some sense the minimum area is zero. The fractal dimension of the shape swept out provides a finer kind of information about the size of the shape than you obtain in measuring its area. A fundamental result about the Kakeya problem says that the fractal dimension of the shape swept out by the needle is always 2.

Imagine now that the needle is not in a flat plane, but in n-dimensional space, where n is bigger than 2. The n-dimensional Kakeya problem asks, What is the minimum volume of an n-dimensional shape in which the needle can be turned in any direction? Analogously with the 2-dimensional case, this volume can be made as small as you like. But a more crucial question is, What can be said about the fractal dimension of this n-dimensional shape? No one knows the answer to that question. The technique of the proof that, in the 2-dimensional plane the fractal dimension is always 2, does not work in higher dimensions. The n-dimensional Kakeya problem is interesting in its own right and also has fundamental connections to other problems in mathematics in, for example, Fourier analysis and nonlinear waves. Terence Tao has been a major force in recent years in investigating the Kakeya problem in n dimensions and in



Tubes that are transverse can have smaller intersection, and thus larger union, than tubes that are nearly parallel. Recent progress on problems such as the Kakeya conjecture has been aided by a "bilinear" approach that excludes the latter case from consideration.

Image courtesy of Terence Tao.

elucidating its connections to other problems in the field.

Another problem Tao has worked on is understanding wave maps. This topic arises naturally in the study of Einstein's theory of general relativity, according to which gravity is a nonlinear wave. No one knows how to solve completely the equations of general relativity that describe gravity; they are simply beyond current understanding. However, the equations become far simpler if one considers a special case, in which the equations have cylindrical symmetry. One aspect of this simpler case is called the "wave maps" problem, and Tao has developed a program that would allow one to understand its solution. While this work has not reached a definitive endpoint, Tao's ideas have removed a major psychological obstacle by demonstrating that the equations are not intractable, thereby causing a resurgence of interest in this problem.

A fourth highlight of Tao's work centers on the nonlinear Schrödinger equations. One use of these equations is to describe the behavior of light in a fiber optic cable. Tao's work has brought new insights into the behavior of one particular Schrödinger equation and has produced definitive existence results for solutions. He did this work in collaboration with four other mathematicians, James Colliander, Markus Keel, Gigliola Staffilani, and Hideo Takaoka. Together they have become known as the "I-team", where "I" denotes many different things, including "interaction". The word refers to the way that light can interact with itself in a medium such as a fiber optic cable; this self-interaction is reflected in the nonlinear term in the Schrödinger equation that the team studied. The word "interaction" also refers to interactions among the team members, and indeed collaboration is a hallmark of Tao's work. "Collaboration is very important for me, as it allows me to learn about other fields, and, conversely, to share what I have learnt about my own fields with others," he said in the Clay Institute interview. "It broadens my experience, not just in a technical mathematical sense, but also in being exposed to other philosophies of research and exposition."

These highlights of Tao's work do not tell the whole story. For example, many mathematicians were startled when Tao and co-author Allen Knutson produced beautiful work on a problem known as Horn's conjecture, which arises in an area that one would expect to be very far from Tao's expertise. This is akin to a leading English-language novelist suddenly producing the definitive Russian novel. Tao's versatility, depth, and technical prowess ensure that he will remain a powerful force in mathematics in the decades to come.

Terence Tao was born in Adelaide, Australia, in 1975. He received his Ph.D. in mathematics in 1996 from Princeton University. He is a professor of mathematics at the University of California, Los Angeles. Among his distinctions are a Sloan Foundation Fellowship, a Packard Foundation Fellowship, and a Clay Mathematics Institute Prize Fellowship. He was awarded the Salem Prize (2000), AMS Bôcher Prize (2002), and the AMS Conant Prize (2005, jointly with Allen Knutson).

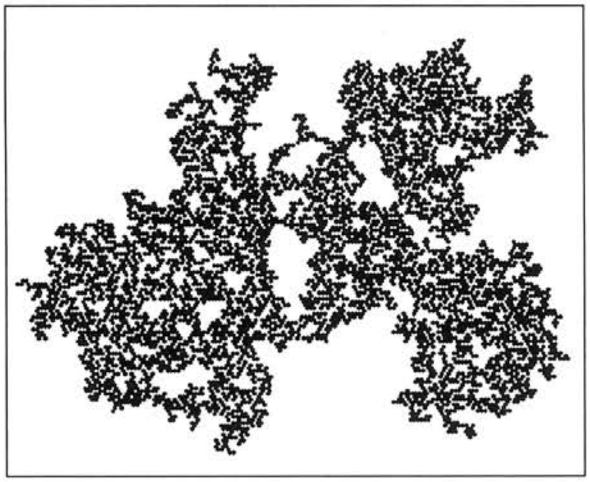
Wendelin Werner

Citation: "for his contributions to the development of stochastic Loewner evolution, the geometry of two-dimensional Brownian motion, and conformal field theory".

The work of Wendelin Werner and his collaborators represents one of the most exciting and fruitful interactions between mathematics and physics in recent times. Werner's research has developed a new conceptual framework for understanding critical phenomena arising in physical systems and has brought new geometric insights that were missing before. The theoretical ideas arising in this work, which combines probability theory and ideas from classical complex analysis, have had an important impact in both mathematics and physics and have potential connections to a wide variety of applications.

A motivation for Wendelin Werner's work is found in statistical physics, where probability theory is used to analyze the large-scale behavior of complex, many-particle systems. A standard example of such a system is that of a gas: Although it would be impossible to know the position of every molecule of air in the room you are sitting in, statistical physics tells you it is extremely unlikely that all the air molecules will end up in one corner of the room. Such systems can exhibit phase transitions that mark a sudden change in their macroscopic behavior. For example, when water is boiled, it undergoes a phase transition from being a liquid to being a gas. Another classical example of a phase transition is the spontaneous magnetization of iron, which depends on temperature. At such phase transition points, the systems can exhibit so-called critical phenomena. They can appear to be random at any scale (and in particular at the macroscopic level) and become "scale-invariant", meaning that their general behavior appears statistically the same at all scales. Such critical phenomena are remarkably complicated and are far from completely understood.

In 1982 physicist Kenneth G. Wilson received the Nobel Prize for his study of critical phenomena, which helped explain "universality": Many different physical systems behave in the same way as they get near critical points. This behavior is described by functions in which a quantity (for instance the difference between the actual temperature and the critical one) is raised to an exponent, called a "critical exponent" of the system. Physicists have conjectured that these exponents are universal in the sense that they depend only on some qualitative features of the system and not on its microscopic details. Although the systems that Wilson was interested in were mainly three- and four-dimensional, the same phenomena also arise in two-dimensional systems. During the 1980s and 1990s physicists made big strides in developing conformal

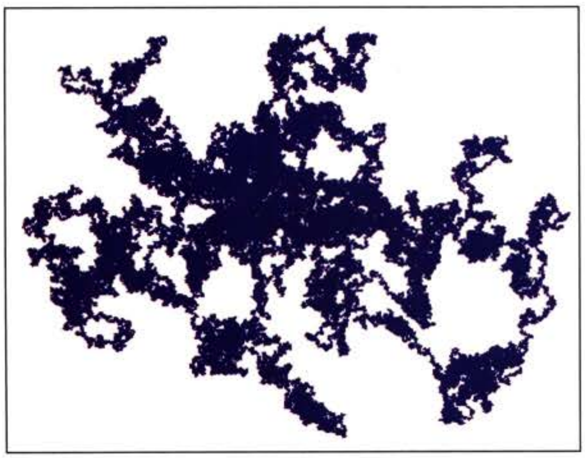


A percolation cluster.
Image courtesy of Wendelin Werner.

field theory, which provides an approach to studying two-dimensional critical phenomena. However, this approach was difficult to understand in a rigorous mathematical way, and it provided no geometric picture of how the systems behaved. One great accomplishment of Wendelin Werner, together with his collaborators Gregory Lawler and Oded Schramm, has been to develop a new approach to critical phenomena in two dimensions that is mathematically rigorous and that provides a direct geometric picture of systems at and near their critical points.

Percolation is a model that captures the basic behavior of, for example, a gas percolating through a random medium. This medium could be a horizontal network of pipes where, with a certain probability, each pipe is open or blocked. Another example is the behavior of pollutants in an aquifer. One would like to answer questions such as, What does the set of polluted sites look like? Physicists and mathematicians study schematic models of percolation such as the following. First, imagine a plane tiled with hexagons. A toss of a (possibly biased) coin decides whether a hexagon is colored white or black, so that for any given hexagon the probability that it gets colored black is p and the probability that it gets colored white is then $1 - p$. If we designate one point in the plane as the origin, we can ask, Which parts of the plane are connected to the origin via monochromatic black paths? This set is called the "cluster" containing the origin. If p is smaller than $1/2$, there will be fewer black hexagons than white ones, and the cluster containing the origin will be finite. Conversely, if p is larger than $1/2$, there is a positive chance that the cluster containing the origin is infinite. The system undergoes a phase transition at the critical value $p = 1/2$. This critical value corresponds to the case where one tosses a fair coin to choose the color for each hexagon. In this case, one can prove that all clusters are finite and that whatever large portion of the lattice one chooses to look at, one will find (with high probability) clusters of size comparable to that portion. The accompanying picture represents a sample of a fairly large cluster.

The percolation model has drawn the interest of theoretical physicists, who used various nonrigorous techniques to predict aspects of its critical behavior. In particular, about fifteen years ago, the physicist John Cardy used conformal field theory to predict some large-scale properties of percolation at its critical point. Werner and his collaborators Lawler and Schramm studied the continuous object that appears when one takes the large-scale limit—that is, when one allows the hexagon size to get smaller and smaller. They derived many of the properties of this object, such as, for instance, the fractal dimension of the boundaries of the clusters. Combined with Stanislav Smirnov's 2001 results on the percolation model and earlier results by Harry Kesten, this work led to a complete derivation of the critical exponents for this particular model.



The path of Brownian motion.
Image courtesy of Wendelin Werner.

Another two-dimensional model is planar Brownian motion, which can be viewed as the large-scale limit of the discrete random walk. The discrete random walk describes the trajectory of a particle that chooses at random a new direction at every unit of time. The geometry of planar Brownian paths is quite complicated. In 1982, Benoit Mandelbrot conjectured that the fractal dimension of the outer boundary of the trajectory of a Brownian path (the outer boundary of the blue set in the accompanying picture) is 4/3. Resolving this conjecture seemed out of reach of classical probabilistic techniques. Lawler, Schramm, and Werner proved this conjecture first by showing that the outer frontier of Brownian paths and the outer boundaries of the continuous percolation clusters are similar, and then by computing their common dimension using a dynamical construction of the continuous percolation clusters. Using the same strategy, they also derived the values of the closely related "intersection exponents" for Brownian motion and simple random walks that had been conjectured by physicists B. Duplantier and K.-H. Kwon (one of these intersection exponents describes the probability that the paths of two long walkers remain disjoint up to some very large time). Further work of Werner exhibited additional symmetries of these outer boundaries of Brownian loops.

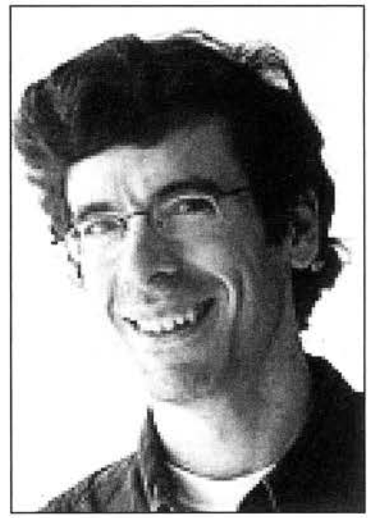
Another result of Wendelin Werner and his coworkers is the proof of the "conformal invariance" of some two-dimensional models. Conformal invariance is a property similar to, but more subtle and more general than, scale invariance and lies at the roots of the definition of the continuous objects that Werner has been studying. Roughly speaking, one says that a random two-dimensional object is conformally invariant if its distortion by angle-preserving transformations (these are called conformal maps and are basic objects in complex analysis) have the same law as the object itself. The assumption that many critical two-dimensional systems are conformally invariant is one of the starting points of conformal field theory. Smirnov's above-mentioned result proved conformal invariance for percolation. Werner and his collaborators proved conformal invariance for two classical two-dimensional models, the loop-erased random walk and the closely related uniform spanning tree, and described their scaling limits. A big challenge in this area now is to prove conformal invariance results for other two-dimensional systems.

Mathematicians and physicists had developed very different approaches to understanding two-dimensional critical phenomena. The work of Wendelin Werner has helped to bridge the chasm between these approaches, enriching both fields and opening up fruitful new areas of inquiry. His spectacular work will continue to influence both mathematics and physics in the decades to come.

Born in 1968 in Germany, Wendelin Werner is of French nationality. He received his Ph.D. at the University of Paris VI in 1993. He has been professor of mathematics at the University of Paris-Sud in Orsay since 1997. From 2001 to 2006, he was also a member of the Institut Universitaire de France, and since 2005 he has been seconded part-time to the Ecole Normale Supérieure in Paris. Among his distinctions are the Rollo Davidson Prize (1998), the European Mathematical Society Prize (2000), the Fermat Prize (2001), the Jacques Herbrand Prize (2003), the Loève Prize (2005) and the Pólya Prize (2006).

—From IMU news releases

2006 Nevanlinna Prize Awarded



Jon Kleinberg

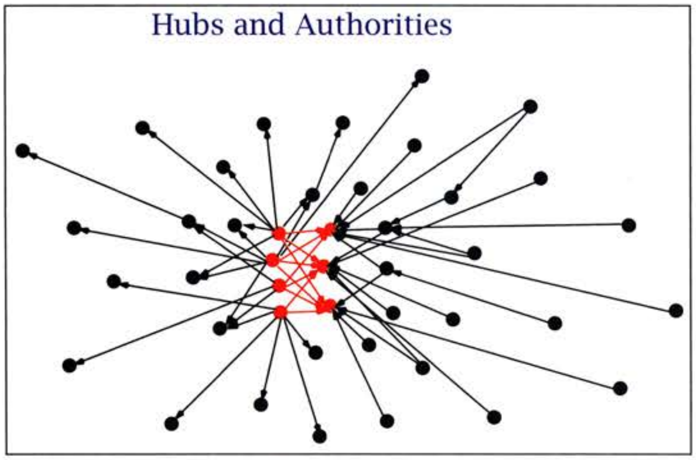
On August 22, 2006, the Rolf Nevanlinna Prize was awarded at the opening ceremonies of the International Congress of Mathematicians (ICM) in Madrid, Spain. The prizewinner is Jon Kleinberg.

In 1982 the University of Helsinki granted funds to award the Nevanlinna Prize, which honors the work of a young mathematician (less than forty years of age) in the mathematical aspects of information science. The prize is presented every four years by the International Mathematical Union (IMU). Previous recipients of the Nevanlinna Prize are: Robert Tarjan (1982), Leslie Valiant (1986), Alexander Razborov (1990), Avi Wigderson (1994), Peter Shor (1998), and Madhu Sudan (2002).

Jon Kleinberg's work has brought theoretical insights to bear on important practical questions that have become central to understanding and managing our increasingly networked world. He has worked in a wide range of areas, from network analysis and routing, to data mining, to comparative genomics and protein structure analysis. In addition to making fundamental contributions to research, Kleinberg has thought deeply about the impact of technology in social, economic, and political spheres.

One of Kleinberg's most important research achievements focuses on the network structure of the World Wide Web. His insights have greatly influenced how all of today's major search engines operate. While individual webpages have a degree of structure imposed by the creators of those pages, the structure of the World Wide Web as a whole is completely unplanned; the structure is continually emerging as new content and links are added. As a result, it is a challenging problem to design effective ways of selecting relevant webpages to offer to search-engine users. Prior to Kleinberg's work, search engines focused only on the content of webpages, not on the link structure. In 1996, Kleinberg introduced the idea of "authorities" and "hubs": An authority is a webpage that contains information on a particular topic, and a hub is a page that contains links to many authorities. For example, consider the search query "digital camera". A website offering guides and reviews of digital cameras would be a hub, and the website of a manufacturer of digital cameras would be an authority. Although the idea of hubs and authorities is clear intuitively, defining these notions mathematically is difficult because of the circularity that arises: A hub is a site that points to many authorities; an authority is a site with links from many hubs. Kleinberg's key contribution was to figure out a way to break this circularity, thereby opening the way for a mathematical analysis of the link structure of networks. He developed algorithmic tools for this problem and demonstrated their effectiveness by testing them on the World Wide Web.

Another area in which Kleinberg has made fundamental advances is in that of "small-world" networks. These networks were first noticed in experiments carried out in the 1960s by the psychologist Stanley Milgram and became the focus of a series of mathematical models based on work



The red dots represent "hubs" and the black dots represent "authorities". *Image courtesy of Jon Kleinberg.*

of Duncan Watts and Steve Strogatz in the 1990s. In Milgram's experiments, a person A would be asked to forward a letter to person B, whom A does not know personally, in as few steps as possible. Each person in the chain could forward the letter only to someone he or she knew personally. Milgram observed that on average the letter would reach B after being forwarded by 6 people (this is the origin of the phrase "six degrees of separation"). The number 6 is surprisingly small, given the size of the population overall, and given that each person operated on the basis only of local information about the social network. Up through the 1990s, there was a good deal of research in the social science literature about the existence of short paths between individuals in social networks. But there was little consideration of how to find short paths given only local information. How do people who know only their immediate friends and do not have a a global view of the whole network find shortest paths? It is this question that Kleinberg addressed, and he found some surprising things.

The nodes of a social network are the people in it; two nodes are connected if the two people know each other. Kleinberg observed that in small-world networks the probability two nodes will be connected decreases as the geographical distance between them increases. And he showed that, if the probability of a connection between two nodes in a network decreases with the square of the distance between them, then there are efficient algorithms for finding the shortest path between the two nodes. Most surprisingly, he showed that if the decrease is faster or slower than the square of the distance, no efficient algorithm exists. In addition to elucidating theoretical aspects of small-world networks, Kleinberg's work has proven useful in designing peer-to-peer file sharing systems, where information has to be located without a central index.

One of Kleinberg's early results also concerned efficient algorithms, this time for the problem of finding "nearest neighbors" in high-dimensional data sets. This problem arises in the following kind of setting. Suppose you have a set of documents and a dictionary of n words. For each document, you count the number of times the first word in the dictionary appears, the number of times the second word appears, the number of times the third word appears, and so on. In this way you obtain n counts, and they can be thought of as an n-dimensional vector that represents the document. For any particular document A, how can you identify its nearest neighbor—that is, the document B that is the most similar to A of all the documents in the set? Thinking of A and B as vectors, you want to find B such that the distance from A to B is as small as possible. One solution is of course to simply compute the distance between A and every other vector and then see which distance is smallest. But if n—the number of words in the dictionary—is very large, then one is dealing with a very high-dimensional space. In high-dimensional spaces the brute-force technique of simply checking all the possibilities runs quickly into the "curse of dimensionality" and becomes time-consuming and expensive. Kleinberg broke this impasse by developing an ingenious new approach to the nearest neighbor problem, by randomly combining one-dimensional projections of the vectors.

Another highlight of Kleinberg's work is his development of a mathematical model to recognize "bursts" in data streams. One way of analyzing the structure of information contained in a text data stream is to look for bursts of activity that appear suddenly and are sustained for a period of time. For example, even if you did not speak English, if you observed the sudden and frequent appearance of the word "Katrina" in news wire data from August 2005, you would know that something significant was happening. Kleinberg began studying bursts for a very practical reason: He wanted a better way of organizing the huge archive of personal email that he was accumulating. While the idea of a burst of information activity is intuitively clear, defining the notion rigorously is not easy, because of the difficulty of distinguishing bursts from statistical fluctuations in a sea of random information. Kleinberg's key contribution was to supply such a rigorous definition of bursts, using the mathematical concept of Markov models. He tested his ideas on a range of different data sets, such as the titles of research papers spanning several decades of research in a given area. In this case, the bursts correspond to the appearance of and attention paid to new topics in that research area.

The interplay between understanding networks theoretically and observing actual networks in action has informed Kleinberg's research and brought new perspectives about the role of technology in society. "[T]he Internet and the Web force us to think about the social consequences of a world in which information is more plentiful and travels more widely than ever before, and in which anyone has the potential, through new kinds of media and at very little cost, to become an author with a global audience," Kleinberg wrote in an email interview conducted with *Technology Research News* online magazine. "But there are a number of fundamental challenges here. We know that on-line discourse can be highly polarized; is it the case that the on-line tools we've created are contributing to a rising level of polarization in civic dialogue more generally? How might we accurately assess this phenomenon, and how might we think about designing new tools that make on-line discourse more productive?"

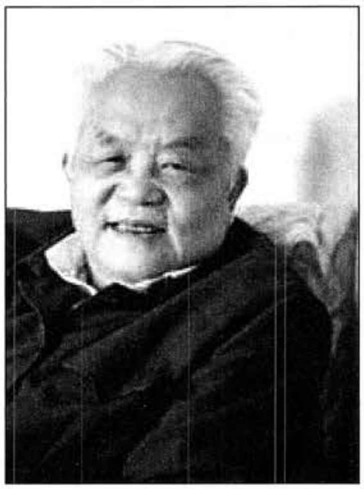
Kleinberg's work is distinguished by its richness and diversity, and also by his ability to use theoretical insights and deep understanding to address practical problems. This powerful combination ensures Kleinberg's status as one of the leading thinkers in theoretical computer science in the years to come.

Jon Kleinberg was born in 1971 in Boston, Massachusetts, USA. He received his Ph.D. in 1996 from the Massachusetts Institute of Technology. He is a professor of computer science at Cornell University. Among his distinctions are a Sloan Foundation Fellowship (1997), a Packard Foundation Fellowship (1999), and the Initiatives in Research Award of the U.S. National Academy of Sciences (2001). In 2005 Kleinberg received a MacArthur "genius" Fellowship from the John D. and Catherine T. MacArthur Foundation.

—from an IMU News Release

Mumford and Wu Receive 2006 Shaw Prize

David Mumford



Wu Wentsun

DAVID MUMFORD and WU WENTSUN have received the 2006 Shaw Prize in Mathematical Sciences. Presented by the Shaw Foundation, the prize carries a cash award of US$1 million, which will be divided evenly between the two laureates. Mumford was honored "for his contributions to mathematics, and to the new interdisciplinary fields of pattern theory and vision research," and Wu was honored for "for his contributions to the new interdisciplinary field of mathematics mechanization."

The Work of the Laureates

The Shaw Prize in Mathematical Sciences Committee wrote the following essay about the work of Mumford and Wu.

David Mumford and Wu Wentsun both started their careers in pure mathematics (algebraic geometry and topology respectively) but each then made a substantial move towards applied mathematics in the direction of computer science.

Mumford worked on computer aspects of vision and Wu on computer proofs in the field of geometry. In both cases their pioneering contributions to research and in the development of the field were outstanding. Many leading scientists in these areas were trained by them or followed in their footsteps.

Mumford's early work, for which he received the Fields Medal in 1974, was in algebraic geometry and especially the study of algebraic curves. This is an old and central subject in mathematics with contributions from many of the great names of the past. Despite this, much remained to be done, and Mumford's great achievement was to revitalize and push forward the theory of moduli. Algebraic curves depend on an important integer, the genus g. For $g = 0$ the curve is rational, for $g = 1$ it is elliptic and depends on an additional continuous parameter or modulus. For $g > 2$ there are $3g - 3$ moduli, forming a (complicated) space whose features give us information about the totality of all curves. Mumford laid the foundations for a systematic and fruitful study of this moduli space. This has been widely influential even, surprisingly, in the physics of string theory.

After two decades in this field, Mumford made a drastic switch to computer vision, where he used his mathematical abilities and insight to make original and fundamental contributions. He helped to provide a conceptual framework and to provide examples of specific solutions that can in principle be generalized to a range of problems. His 1985 paper with Shah on variational approaches to signal processing was recently awarded a prize by the Institute of Electrical and Electronics Engineers (IEEE).

Mumford's many original contributions to pattern theory and vision research were described in his 1999 book *Two and Three Dimensional Patterns of the Face* (A K Peters, Ltd.) and the forthcoming *Pattern Theory through Examples.*

Wu Wentsun was one of the geometers strongly influenced by Chern Shiing-Shen (Shaw Laureate in 2004). His early work, in the post-war period, centered on the topology of manifolds that underpins differential geometry and the area where the famous Chern classes provide important information. Wu discovered a parallel set of invariants, now called the Wu classes, which have proved almost equally important. Wu went on to use his classes for a beautiful result on the problem of embedding manifolds in Euclidean space.

In the 1970s Wu turned his attention to questions of computation, in particular the search for effective methods of automatic machine proofs in geometry. In 1977 Wu introduced a powerful mechanical method, based on Ritt's concept of characteristic sets. This transforms a problem in elementary geometry into an algebraic statement about polynomials that lends itself to effective computation.

This method of Wu completely revolutionized the field, effectively provoking a paradigm shift. Before Wu the dominant approach had been the use of AI search methods, which proved a computational dead end. By introducing sophisticated mathematical ideas Wu opened a whole new approach that has proved extremely effective on a wide range of problems, not just in elementary geometry.

Wu also returned to his early love, topology, and showed how the rational homotopy theory of Dennis Sullivan could be treated algorithmically, thus uniting the two areas of his mathematical life.

In his 1994 *Basic Principles in Mechanical Theorem Proving in Geometry* (Springer), and his 2000 *Mathematics Mechanization* (Science Press), Wu described his revolutionary ideas and subsequent developments. Under his leadership mathematics mechanization has expanded in recent years into a rapidly growing discipline, encompassing research in computational algebraic geometry, symbolic computation, computer theorem proving, and coding theory.

Although the mathematical careers of Mumford and Wu have been parallel rather than contiguous they have much in common. Beginning with the traditional mathematical field of geometry, contributing to its modern development and then moving into the new areas and opportunities that the advent of the computer has opened up, they demonstrate the breadth of mathematics. Together they represent a new role model for mathematicians of the future and are deserved winners of the Shaw Prize.

Biographical Sketches

David Mumford, born in 1937, is currently a professor in the Division of Applied Mathematics at Brown University. He received his Ph.D. at Harvard University in 1961, under the direction of Oscar Zariski. Mumford was a professor at Harvard for many years before moving to Brown. He received the Fields Medal in 1974. In 1975, he was elected to the U.S. National Academy of Sciences. From 1987 to 1992, he was a MacArthur Fellow.

Wu Wentsun, born in 1919, is an academician of the Chinese Academy of Sciences and a fellow of the Academy of Sciences for the Developing World in Trieste, Italy. He is presently the Honorary Director and Researcher of the Institute of Systems Sciences, Academy of Mathematics and Systems Sciences at the Chinese Academy of Sciences, Beijing. He graduated from the Shanghai Jiaotong University, China, in 1940, and received his *Docteur ès État* from the Université de Strasbourg in 1949, under the direction of Charles Ehresmann.

About the Prize

The Shaw Prize is an international award that honors individuals for achieving distinguished breakthroughs in academic and scientific research or applications, who have made outstanding contributions in culture and the arts, or who in other domains have achieved excellence. The award is dedicated to furthering societal progress, enhancing quality of life, and enriching humanity's spiritual civilization. The Shaw Prize is managed and administered by the Shaw Prize Foundation based in Hong Kong.

Previous recipients of the Shaw Prize in Mathematical Sciences are Shiing-Shen Chern (2004) and Andrew Wiles (2005).

—From Shaw Foundation announcements

Akaike Receives 2006 Kyoto Prize

Hirotugu Akaike

In June 2006 the Inamori Foundation announced the laureates who will receive its 22nd annual Kyoto Prize, Japan's highest private award for lifetime achievement, presented to individuals and groups worldwide who have contributed significantly to humankind's betterment. Receiving the prize in the Basic Sciences category is the Japanese statistical mathematician HIROTUGU AKAIKE, professor emeritus at the Institute of Statistical Mathematics. The prize consists of a diploma, a Kyoto Prize Medal of 20-karat gold, and a cash gift of 50 million yen (approximately US$446,000).

The Work of Hirotugu Akaike

Rapid advances in science and technology in the twentieth century brought numerous benefits to society, but at the same time exposed many new problems. Furthermore, in the twenty-first century, rapid globalization and "informatization" have resulted in the development of strong global links that have transformed the world into a huge network of mutually dependent systems. Consequently, it is no longer possible, in many cases, to solve problems within the framework of a single isolated system; it is instead necessary to grasp, analyze, and forecast problems in the context of this global network of closely linked systems. Modern statistical sciences are expected to help our understanding of the study of such complicated, uncertain, and dynamic systems, or the study of situations where only incomplete information is available. The main role of statistical sciences must be to give useful scientific methodologies for the development of new technologies and for the further development of society, which is characterized by increased uncertainty. One of the characteristics of the statistical sciences is their interdisciplinary nature, with applicability in various fields. For example, the role of the statistical sciences has recently become increasingly important in the understanding and forecasting of phenomena in economic-related fields, such as finance and insurance; safety-related fields, including pharmaceuticals, food, and transportation; natural phenomena, such as weather, natural disasters, and the environment; and in the management of huge systems.

Starting in the early 1970s Akaike explained the importance of modeling in analysis and in forecasting. He formulated the Akaike Information Criterion (AIC), which facilitates selection of the most appropriate model from a number of different types of models. Ever since, the AIC has been exerting a powerful influence on the development of the information and statistical sciences.

In order to understand and forecast phenomena from a vast quantity of data obtained in experiments or observations, it is necessary to construct a hypothetical statistical model. The selection of such a model is highly subjective, as it is made on the basis of a researcher's own ideas, knowledge, and experience. Therefore, it is essential to estimate the most adequate model among the possible candidates. However, from a practical standpoint, this was very difficult because of the finite number of data and the lack of an objective criterion for selection. The AIC offers a solution to this problem, which seems to be common in almost every field of engineering and science. Consequently, the role and meaning of the AIC as a criterion for estimating statistical models have become extremely significant in the development of statistical science. The AIC is built into commercial statistical software packages and is also widely used in such diverse areas as gene analysis, image compression technologies, and vehicle stability control technologies, among many others.

Biographical Sketch

Hirotugu Akaike was born on November 5, 1927, in Japan. He received a B.A. (1952) and a Ph.D. (1961) from the University of Tokyo. He started his career at the Institute of Statistical Mathematics, Japan, in 1961, serving as Director General of the Institute from 1986 to 1994, when he became a professor emeritus at the Institute. His honors include receiving the Okochi Memorial Technology Award (1980) in the field of industrial engineering and production technology, the Asahi Prize (1989), the Japanese Medal with Purple Ribbon (1989), and the Japan Statistical Society Award (1996).

About the Prize

The Inamori Foundation was established in 1984 by Kazuo Inamori, founder and chairman emeritus of Kyocera Corporation. The Kyoto Prize was founded in 1985 and is presented to individuals or groups in appreciation not only of their outstanding achievements, but also of the excellence of the personal characteristics on which they have built their contributions to humankind. The laureates are selected through a strict and impartial process considering candidates recommended from around the world. The other Kyoto Prize laureates for 2006 are immunologist and geneticist Leonard A. Herzenberg of Stanford University and Japanese designer Issey Miyake.

Other mathematical scientists who have received the Kyoto Prize are Simon Levin (2005), Mikhael Gromov (2002), Kiyosi Itô (1998), Donald Knuth (1996), André Weil (1994), Edward Lorenz (1991), I. M. Gelfand (1989), John McCarthy (1988), Rudolf Kalman (1985), and Claude Shannon (1985).

—From Inamori Foundation announcements

Tony Chan Named NSF Assistant Director

Tony F. Chan

The National Science Foundation (NSF) has named Tony F. Chan, professor of mathematics and dean of physical sciences at the University of California at Los Angeles, to be assistant director for Mathematics and Physical Sciences (MPS) at the NSF. The MPS directorate, which has an annual budget of approximately US$1 billion, is the larger organizational unit within the NSF that houses the Division of Mathematical Sciences. In addition to mathematics, the MPS funds astronomy, chemistry, materials science, physics, and multidisciplinary activities. Chan assumes his new position on October 1, 2006.

In an email interview, Chan said he took the position at the NSF for the opportunity to serve the MPS community at a national level. "MPS at NSF is one of the major federal funding agencies for math and physical sciences, and the assistant director can potentially have significant influence and impact on national science funding policy," he said. "Personally, it also means a new and exciting challenge, and interaction with new colleagues. I also look forward to the opportunity (and necessity) to learn more about cutting-edge science."

Chan's current research interests focus mainly on interdisciplinary mathematics in such fields as image processing and computer vision, multiscale computational methods, optimization and multilevel methods for electronics design, and computational geometry for brain mapping. He has written over 200 research publications and has won two best-paper awards from the Institute of Electrical and Electronics Engineers. He has supervised more than twenty-five Ph.D. students and fifteen postdoctoral fellows. His research is currently supported by the NSF as well as the Office of Naval Research and the National Institutes of Health (NIH).

The MPS directorate funds large, expensive facilities that attract a lot of attention, as well as "small science" like mathematics. Balancing the needs of the diverse disciplines within the MPS is a major challenge, Chan said. "But I see it not just between math and other sciences, but more generally the balance between support for major facilities/equipment and support for ideas and people, between research targeted around a certain theme (e.g., nano) and curiosity-driven research, between individual PI-led research and team-based research," he explained. "The ultimate goal should be a combination that produces the best 'return' for the national investment."

Chan also emphasized that, because the NSF is the only federal agency with a mandate to fund basic science, this must remain the focus of the foundation. "That should be its mission—science should always come first," he said. At the same time, science is the basis for technology, which in turn contributes to the economic health of the nation. "The on-going bipartisan support for the American Competitiveness Initiative [ACI] is a recognition of this fact and a great opportunity for NSF to take a leadership role in ensuring U.S. global competitiveness in science and technology," he noted. The ACI will support research and workforce training, both areas in which mathematics plays a critical role. Chan said that three funding agencies are targeted to receive increased funding through the ACI: the NSF, the Department of Energy, and the National Institute of Standards and Technology. Of these, the NSF "is the only one mandated to do basic science research," he noted. "Of the three, NSF probably also funds the training of the largest number of students. The challenge is to come up with creative programs that will respond directly to ACI and produce measurable results."

Chan received a B.S. in engineering and an M.S. in aeronautics from the California Institute of Technology in 1973, and a Ph.D. in computer science from Stanford University in 1978. He taught at Yale University from 1979 to 1986, when he moved to UCLA. While he served as UCLA's mathematics department chair from 1997 to 2000, he led the effort to establish an NSF-funded mathematics institute at UCLA, resulting in the founding of the Institute for Pure and Applied Mathematics (IPAM) in 2000. Chan served as the director of IPAM during 2000 and 2001.

Since becoming dean of the Division of Physical Sciences at UCLA in 2001, Chan has overseen six departments and several research institutes comprising more than 200 faculty, 1,700 undergraduates, and 700 graduate students. The division receives over US$60 million annually in research awards. Chan is also co-director of UCLA's NIH Center for Computational Biology.

Chan has been active in professional societies, particularly the Society of Industrial and Applied Mathematics (SIAM), where he currently serves on the Board of Trustees and the Committee on Science Policy. Previously he served on the SIAM Council and the Committee on Human Rights. He has served on the Editorial Boards Committee and the Committee on Committees of the AMS.

Chan said that he looks forward to working closely with the newly appointed director of the Division of Mathematical Sciences, Peter March of the Ohio State University. Chan added, "I welcome suggestions and ideas as to how MPS can do the best job in its mission, and I look forward to opportunities to engage directly with the mathematical sciences community in this context."

—Allyn Jackson

Mathematics People

Palis and Seshadri Awarded 2006 Trieste Science Prize

JACOB PALIS of the Instituto de Matemática Pura e Aplicada (IMPA), Rio de Janeiro, Brazil, and C. S. SESHADRI of the Chennai Mathematical Institute have been awarded the Trieste Science Prize for Mathematics for 2006. Two medical researchers were also honored with the Trieste Science Prize in Medicine, and the four researchers will share the cash award of US$100,000.

Palis was honored for his distinguished work in multivariable dynamical systems, a field of mathematics that tries to understand how nonlinear complex phenomena behave over the long term. Such studies have helped enhance understanding of population growth patterns, global climate change, and even fluctuations in the stock market. Palis has also been a driving force behind efforts to strengthen the study of mathematics in Latin America. As director of IMPA, he helped to transform the institute into a world-class center for mathematical research and Latin America's foremost institution for the training of young mathematicians.

Seshadri was honored for his role in shaping the field of algebraic geometry, one of the dominant fields in twenty-first century mathematics. He has made outstanding contributions to the theory of vector bundles and quotient and compact homogenous spaces and is the creator of the standard monomial theory and Seshadri constant, which have found important applications both in mathematics and physics. He has also been the leading force in the creation of the Chennai Mathematical Institute.

The Trieste Science Prize is administered by the Academy of Sciences for the Developing World (TWAS) and provides international recognition to outstanding scientists living and working in the developing world.

—From a TWAS announcement

Gunturk and Tanner Receive Monroe Martin Prize

The seventh Monroe H. Martin Prize presentation was held on May 12, 2006, at the University of Maryland, College Park. The prize has been awarded every five years by the Institute for Physical Science and Technology to honor outstanding sole-authored papers by junior mathematicians. The winners, each receiving US$5,000, are C. SINAN GUNTURK and JARED TANNER.

C. Sinan Gunturk of the Courant Institute of Mathematical Sciences, New York University, was awarded the prize for his paper "One-bit sigma-delta quantization with exponential accuracy", which appeared in *Communications on Pure and Applied Mathematics* **56** (2003), 1608–30. In this paper, Gunturk introduces a new family of one-bit sigma-delta quantization methods to reconstruct band-limited signals. By carefully analyzing the optimality of the so-called feasible filter pairs, Gunturk constructs new quantizers that retain the robustness of the finitely accurate quantizers studied earlier in the literature, yet they gain exponential accuracy.

Jared Tanner of the Department of Mathematics at the University of Utah and the Statistics Department at Stanford University was awarded the prize for his paper "Optimal filter and mollifier for piecewise smooth spectral data", which appeared in *Mathematics of Computation* **75** (2006), 767–90. In this paper Tanner revisits the issue of highly accurate reconstruction of piecewise smooth data from its (pseudo-)spectral information. Using the known time-frequency localization properties of certain truncated Hermite expansions, Tanner introduces optimal filters that retain the robustness of the finitely accurate local filters, yet they gain exponential accuracy in recovering piecewise-analytic data.

The Monroe H. Martin Prize was established to honor the outstanding contributions of Monroe H. Martin, professor emeritus at the University of Maryland, College Park. He was chair of the Department of Mathematics from 1942 until 1954 and the founding director of the Institute for Fluid Dynamics and Applied Mathematics (a forerunner of the Institute for Physical Science and Technology) from 1952 until 1968. Previous prizewinners are Neil Berger (1975), Marshall Slemrod (1980), Jonathan Goodman (1985), Marek Rychlik (1990), Andrew Stuart (1995), Zhihong Xia (1995), Yury Grabovsky (2000), and Robert McCann (2000).

—Frank W. J. Olver, Chair
Monroe H. Martin Prize Committee

SIAM Prizes Awarded

The Society for Industrial and Applied Mathematics (SIAM) awarded a number of prizes at its annual meeting, held in Boston, Massachusetts, in July 2006.

ÉVA TARDOS of Cornell University was awarded the George B. Dantzig Prize for her contributions to mathematical programming. The prize, awarded jointly with the Mathematical Programming Society (MPS), is given for original research that by its originality, breadth, and scope is having a major impact on the field of mathematical programming.

XINWEI YU of the University of California, Los Angeles, was awarded the Richard C. DiPrima Prize. This prize is awarded to a young scientist who has done outstanding research in applied mathematics

GREGORY F. LAWLER of Cornell University, ODED SCHRAMM of Microsoft Corporation, and WENDELIN WERNER of the Université de Paris-Sud in Orsay were awarded the George Pólya Prize. They received the prize for their groundbreaking work on the development and application of stochastic Loewner evolution (SLE). Of particular note is the rigorous establishment of the existence and conformal invariance of critical scaling limits of a number of 2-dimensional lattice models arising in statistical physics.

PETER KLOEDEN of the J. W. Goethe Universität, Germany, received the W. T. and Idalia Reid Prize in Mathematics, which is awarded for research in or other contributions to the broadly defined areas of differential equations and control theory. He delivered a prize lecture titled "Random attractors and the preservation of synchronization in the presence of noise".

PETER LAX of the Courant Institute of Mathematical Sciences, New York University, was awarded the SIAM Prize for Distinguished Service to the Profession. The prize is awarded to an applied mathematician who has made distinguished contributions to the furtherance of applied mathematics on the national level.

GEORGE C. PAPANICOLAOU of Stanford University was awarded the John von Neumann Lectureship, which is given for outstanding and distinguished contributions to the field of applied mathematical sciences and for the effective communication of these ideas to the community. He gave a lecture on imaging in random media.

SIMON LEVIN of Princeton University delivered the I. E. Block Community Lecture. His talk was titled "Individual choices, cooperation and the global commons: Mathematical challenges in uniting ecology and socioeconomics for a sustainable environment".

MICHAEL J. SHELLEY of the Courant Institute of Mathematical Sciences, New York University, gave the Julian Cole Lecture, titled "Bodies interacting with and through fluids". The lectureship is awarded for an outstanding contribution to the mathematical characterization and solution of a challenging problem in the physical or biological sciences or in engineering, or for the development of mathematical methods for the solution of such problems.

IRENE FONSECA of Carnegie Mellon University delivered the AWM-SIAM Sonia Kovalevsky Lecture, titled "New challenges in the calculus of variations". The lectureship is intended to highlight significant contributions of women to applied or computational mathematics.

FRANÇOIS GOLSE of the Université de Paris 7-Denis Diderot presented the SIAM Activity Group on Analysis of Partial Differential Equations Prize Lecture, titled "From the Boltzmann equation to incompressible hydrodynamic models". This lectureship is awarded to the author or authors of an outstanding paper on a topic in partial differential equations published in English in a peer-reviewed journal.

The Lagrange Prize in Continuous Optimization, awarded jointly with MPS, was awarded to ROGER FLETCHER of the University of Dundee, SVEN LEYFFER of Argonne National Laboratory, and PHILIPPE TOINT of the University of Namur, Belgium. The prize is awarded for outstanding works in the area of continuous optimization.

The SIAM Award in the Mathematical Contest in Modeling went to two teams: BRIAN CAMLEY, PASCAL GETREUER, and BRADLEY KLINGENBERG of the University of Colorado at Boulder and BENJAMIN CONLEE, NEAL GUPTA, and CHRISTOPHER YETTER of Harvard University.

Three Outstanding Paper Prizes were presented for articles published in SIAM journals. The winners are: GIRISH N. NAIR and ROBIN J. EVANS of the University of Melbourne, Australia, for their article "Stabilizability of stochastic linear systems with finite feedback data rates", *SIAM Journal on Control and Optimization* **43**, no. 2, 2004; JEAN-MICHEL CORON and EMMANUEL TRELAT of the Université Paris-Sud for their article "Global steady-state controllability of one-dimensional semilinear heat equations", *SIAM Journal on Control and Optimization* **43**, no. 2, 2004; and MICHAEL HINTERMUELLER and KARL KUNISCH of the University of Graz, Austria, and KAZUFUMI ITO of North Carolina State University for their article "The primal-dual active set strategy as a semismooth Newton method", *SIAM Journal on Optimization* **13**, no. 3, 2003.

The Student Paper Prizes were awarded to LAURENT DEMANET of the California Institute of Technology, EMANUELE VIOLA of Harvard University, and HONGCHAO ZHANG of the University of Florida.

—From a SIAM announcement

Jefferson Science Fellowships Awarded

PAUL DAVIS of Worcester Polytechnic Institute (WPI) is one of six scientists to be awarded Jefferson Science Fellowships for the year 2006–2007. Davis received his Ph.D. in applied mathematics from Rensselaer Polytechnic Institute in 1970. He is currently dean of Interdisciplinary and Global Studies at WPI, a program that places student teams around the world to solve open-ended technical and social problems. He has written textbooks and developed software to support student-centered learning in mathematical modeling. His major research interest is in operation and control and measurement problems for electric power networks. He has served as secretary of the

Society for Industrial and Applied Mathematics (SIAM) and as editor in chief of the *SIAM Review*.

Davis will spend one year at the U.S. Department of State in an on-site assignment in Washington, D.C., and will receive a stipend of US$50,000. The Jefferson Science Fellowships program is a three-year pilot program administered by the National Academies and supported through a partnership among the MacArthur Foundation; the Carnegie Corporation; the U.S. science, technology, and engineering academic communities; professional scientific societies; and the U.S. Department of State.

—Elaine Kehoe

Swinnerton-Dyer Receives Sylvester Medal

The 2006 Sylvester Medal has been awarded to Sir Peter Swinnerton-Dyer FRS for "his fundamental work in arithmetic geometry and his many contributions to the theory of ordinary differential equations." Swinnerton-Dyer is a professor emeritus in the Department of Pure Mathematics and Mathematical Statistics at the University of Cambridge.

The Sylvester Medal is awarded triennially by the Royal Society, London, for the encouragement of mathematical research. The bronze medal is accompanied by a gift of £1000 (approximately US$1,500). It is named after James Joseph Sylvester (1814–1897), who was Savilian Professor of Geometry, Oxford, in the 1880s.

—Allyn Jackson

LMS Prizes Awarded

The London Mathematical Society (LMS) has awarded a number of prizes for 2006.

Sir Henry Peter Francis Swinnerton-Dyer of the University of Cambridge has been awarded the Pólya Prize for his leadership in the field of diophantine number theory and for his pioneering work in practical computer science. The prize is given in recognition of outstanding creativity in, imaginative exposition of, or distinguished contribution to mathematics within the United Kingdom.

Miles Reid of the University of Warwick has been awarded the Senior Berwick Prize for his paper, coauthored with Alessio Corti and Alexander Puklihkov, titled "Fano 3-fold hypersurfaces", which was published in *Explicit Birational Geometry of 3-Folds* (LMS Lecture Notes Series 281). The paper represented a great advance in the study of 3-dimensional algebraic varieties. The prize is awarded in recognition of an outstanding piece of mathematical research published by the LMS.

Michael Weiss of the University of Aberdeen has been awarded the Fröhlich Prize for his use of algebraic topological methods to solve a number of different geometric problems. The prize recognizes original and extremely innovative work in any branch of mathematics by a mathematician less than fifty years of age and normally a resident in the United Kingdom.

Four Whitehead Prizes were awarded. Raphael Rouquier of the University of Leeds was honored for his contributions to representation theory. Jonathan Sherratt of Heriot-Watt University was recognized for his contribution to mathematical biology and, in particular, to the development and analysis of new mathematical models for complex biological processes. Agata Smoktunowicz of the University of Edinburgh was honored for her contributions to noncommutative algebra. Paul Sutcliffe of the University of Kent was chosen for his contributions to the study of topological solitons and their dynamics. The Whitehead Prizes are awarded to mathematicians under the age of forty years who were mainly educated in the United Kingdom and who are not already Fellows of the Royal Society. They cover all fields of mathematics, including applied mathematics, mathematical physics, and mathematical aspects of computer science.

—From an LMS announcement

Paul Erdős Award Recipients Announced

The 2006 recipients of the Paul Erdős Awards have been announced. They are Simon Chua, Philippines; Ali Rejali, Iran; and Alexander Soifer, University of Colorado.

Chua, the principal of Zamboanga Chong Hua High School, Zamboanga City, Mindanao, the Philippines, pioneered the Mathematics Trainers' Guild in the Philippines. Rejali is the cofounder of the Iranian national mathematics competitions and has contributed to the institution of a national mathematics syllabus in mathematics and statistics. Soifer is chair and founder of the Colorado Mathematical Olympiad and was a member of the USA Mathematics Olympiad Subcommittee (1996–2005) and the USSR National Mathematical Olympiad (1970–1973).

The Paul Erdős National Award is given by the World Federation of National Mathematics Competitions in recognition of mathematicians who have contributed to the development of mathematical challenges at the national level and to the enrichment of mathematics learning.

—From an Australian Mathematics Trust announcement

2006 d'Alembert and Decerf Prizes Announced

Every two years the Société Mathématique de France (SMF) presents the d'Alembert Prize. Established in 1984, the prize is intended to encourage mathematical works in the French language and the exposition of mathematics for the general public. The prize recognizes an article, book, radio or television broadcast, film, or other project that is designed to improve understanding of mathematics and its recent developments. The d'Alembert Prize for 2006 has been awarded to PHILIPPE BOULANGER, editor in chief, *Pour la Science*.

In addition, the SMF has awarded the Anatole Decerf Prize to Centre Sciences, Orleans. The Decerf Prize was established to promote the pedagogy of mathematics.

—From an SMF announcement

2006 International Mathematical Olympiad

The 47th International Mathematical Olympiad (IMO) was held in Ljubljana, Slovenia, July 12–13, 2006. The IMO is the preeminent mathematical competition for high-school-age students from around the world. This year 498 young mathematicians from 90 countries competed. The IMO consists of solving six extremely challenging mathematical problems in a nine-hour competition administered over two days.

The team from China finished first, with a total of 214 points and six gold medals, followed by Russia (174 points), Korea (170 points), and Germany (157 points). The United States finished fifth, with 154 points and two gold medals.

The U.S. team consisted of ZACHARY ABEL of Dallas, Texas; ZARATHUSTRA BRADY of Van Nuys, California; RYAN KO of Allendale, New Jersey; YI SUN of Saratoga, California; ARNAV TRIPATHY of Chapel Hill, North Carolina; and ALEX ZHAI of Champaign, Illinois. Brady and Tripathy received gold medals; Abel, Ko, Sun, and Zhai received silver medals.

The Mathematical Association of America sponsors the U.S. team through its American Mathematics Competitions program, with travel support provided by a grant from the Army Research Office. Training for the team at the University of Nebraska-Lincoln is aided by a grant from the Akamai Foundation. Additional support for the team is provided by the National Council of Teachers of Mathematics.

More information about the 47th International Mathematical Olympiad is available at `http://imo2006.dmfa.si`.

—Steven R. Dunbar
MAA American Mathematics Competitions

Royal Society of Canada Elections

Three mathematical scientists have been elected to the Royal Society of Canada. They are ANDREW GRANVILLE of the University of Montreal, and MING LI and MARY E. THOMPSON, both of the University of Waterloo.

—From a Royal Society of Canada announcement

About the Cover

This month's cover has been assembled from pen and watercolor drawings taken from the sketchbooks of the mathematician Karl Heinrich Hofmann. The view of St. Peter's Street on Jackson Square in the French Quarter of New Orleans dates from last New Year's Eve. New Orleans, Louisiana, is the site of the Joint Mathematics Meetings, January 5–8, 2007.

Karl Hofmann is a longtime member of the Mathematics Department of Tulane University in New Orleans and also a member of the faculty of the University of Technology in Darmstadt, Germany. Some other artwork of his is mentioned on his homepage `http://www.mathematik.tu-darmstadt.de:8080/ags/ag5/mitglieder/professoren/hofmann_en.html`

—Bill Casselman, Graphics Editor
`(notices-cover@ams.org)`