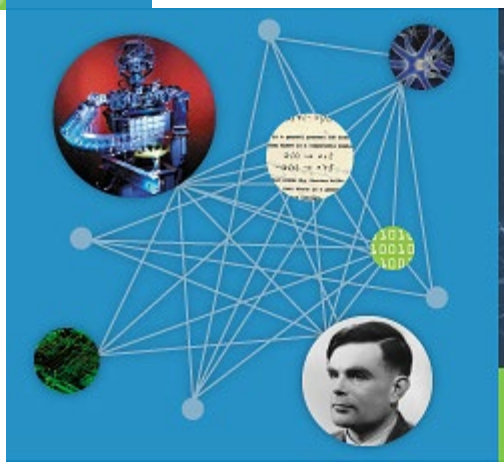
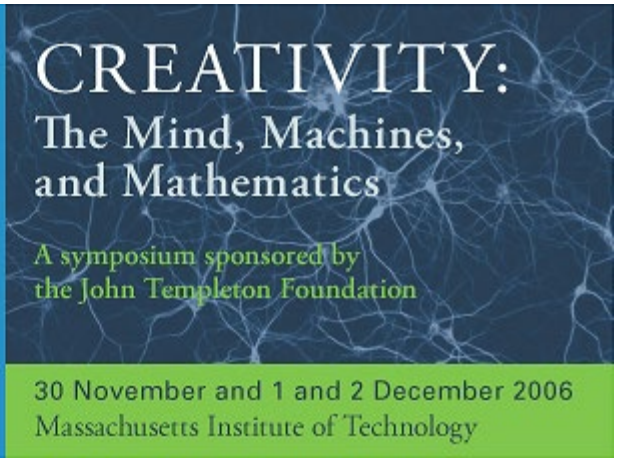
John Templeton Foundation

THE HUMBLE APPROACH INITIATIVE





Above: Mathematician, logician, and computer pioneer, Alan Turing sought to define logical systems modeled on interconnected neurons.

Credits: Photo © Sam Ogden (robot COG), Copyright © P.N. Furbank ("On Computable Numbers" excerpt), and © National Portrait Gallery, London (Turing portrait).

Contact: Mary Ann Meyers, Ph.D., Senior Fellow

PURPOSE

In the 70th anniversary year of Alan Turing's groundbreaking paper "On Computable Numbers," which is widely recognized as having laid a theoretical foundation for the computer revolution of the twentieth century, this symposium explores the current understanding of human creativity from scientific and philosophical perspectives. The year 2006 also marks the centennial of the reception of the Nobel Prize by Santiago Ramón y Cajal and Camillo Golgi for their discovery of neuron structures in the brain and the 25th anniversary of the awarding of the Nobel Prize to Roger Sperry for his work on information processing in the brain. The symposium takes note of their stunning achievements by focusing on creativity in the borderland between mathematics (computation), artificial intelligence, and neuroscience. In particular, the twelve scientists and philosophers meeting at the Massachusetts Institute of Technology (MIT) are investigating whether or not there are any intrinsic differences between creativity of the mind and "creativity" of artificial intelligence and whether or not the former can be captured or modeled fully by mathematical and/or mechanical processes. Key questions include: Are there intrinsic differences between the human mind and mechanical intelligence? Is the logic of a Turing machine (or its extensions and generalizations) sufficient to capture the creative workings of a human brain? Will artificial intelligence ever think and feel like the human mind? How do we deal with "subjective experiences" in machine modeling? What is the nature of machine creativity? What are the limits (if there are any) of artificial intelligence in the creative generation of ideas? Can creativity be effectively automated? What is the relationship between randomness and creativity? What are the roles of randomness in computation? What is the relationship, if any, between uncomputability and creativity? Are there any limits to mathematical modeling in the investigation of abilities of the human mind such as creativity? How can we, and up to what point can we, describe human creativity with mathematical models? How do mathematical and other human creativities relate to each other and to machine creativity? Can there be a grand background theory that would encompass all systems that "exhibit" creativity? Under the aegis of the John Templeton Foundation, the investigators probing such fundamental issues gather at the architecturally daring Stata Center, a building with tilted columns and swerving walls designed for MIT by Frank Gehry and described by the *Boston Globe* architecture critic Robert Campbell as "a metaphor for . . . creativity."

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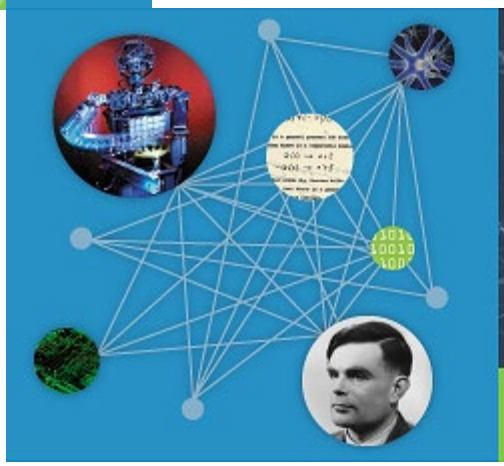

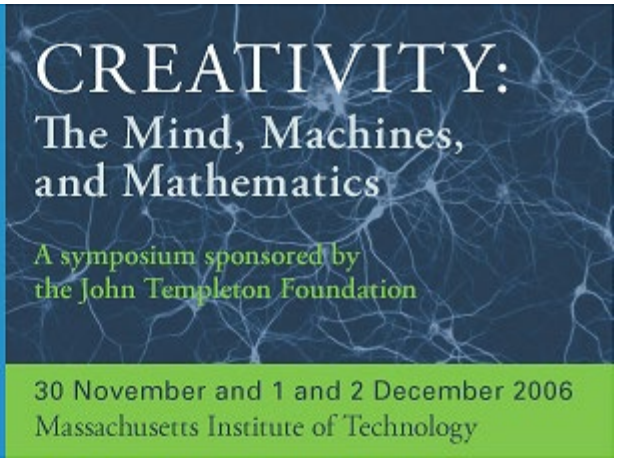

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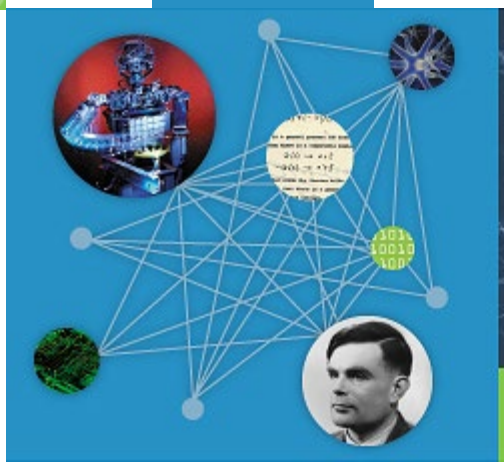

CREATIVITY:
The Mind, Machines, and Mathematics

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APPROACH

Cynthia Breazeal with Kismet, an autonomous robot she developed at MIT's Artificial Intelligence Laboratory. Kismet is designed to have social exchanges with humans. A wide variety of facial expressions allow Kismet to mimic or display emotions.

Credit: Photo © Sam Ogden

The symposium is part of the Templeton Foundation's *Humble Approach Initiative*. The goal of the initiative is to bring about the discovery of new spiritual information by furthering high-quality scientific research. The "humble approach" is inherently interdisciplinary, sensitive to nuance, and biased in favor of building linkages and connections. It assumes an openness to new ideas and a willingness to experiment. Placing high value upon patience and perseverance, it retains a sense of wondering expectation because it recognizes, in Loren Eisley's haunting phrase, "a constant emergent novelty in nature that does not lie totally behind us, or we would not be where we are." A fundamental principle of the Foundation, in the words of its founder, is that "humility is a gateway to greater understanding and open[s] the doors to progress" in all endeavors. Sir John Templeton believes that in their quest to comprehend foundational realities, scientists, philosophers, and theologians have much to learn about and from one another. The humble approach is intended as a corrective to parochialism. It encourages discovery and seeks to accelerate its pace.

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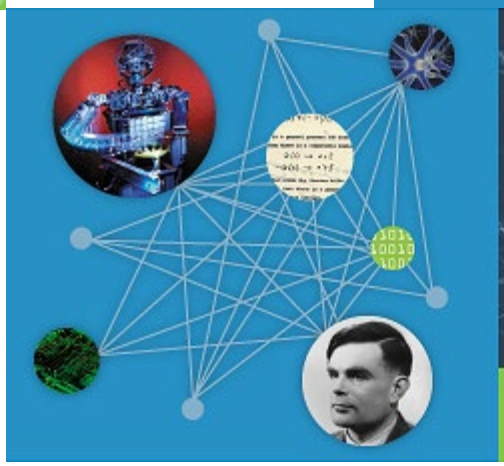

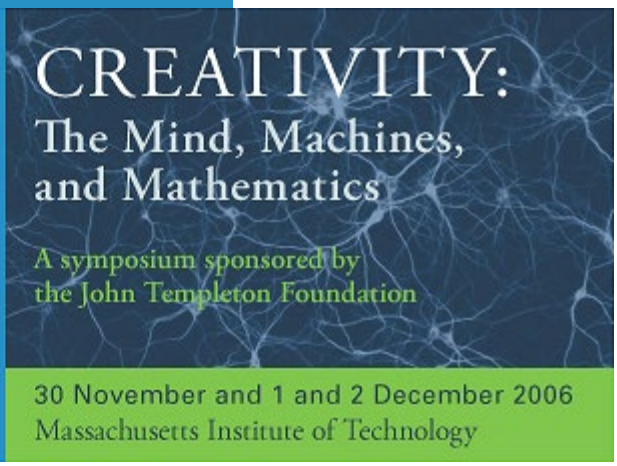

CO-CHAIRS

Rodney A. Brooks is the Panasonic Professor of Robotics and director of the Computer Science and Artificial Intelligence Laboratory at the Massachusetts Institute of Technology. Working at the forefront of robotics technology, he seeks to understand how intelligence emerges from interaction with the real world. With his MIT students, he has built Cog and Kismet, prototypical humanoid robots capable of learning from experience. His ultimate goal is to build a living machine. A native of Australia, Dr. Brooks was graduated from Flinders University. He received a Ph.D. in computer science from Stanford University in 1981 and held research positions at Carnegie Mellon University and MIT before joining the Stanford faculty in 1983. He returned to MIT the next year and was appointed Fujitsu Professor of Computer Science in 1996, a post he held until being named to his present chair last year. Dr. Brooks is the co-founder and chief technology officer of iRobot Corporation. A member of the National Academy of Engineering, he is a founding fellow of the American Association of Artificial Intelligence. He is also a fellow of the American Association for the Advancement of Science and of the Association for Computing Machinery, as well as a corresponding member of the Australian Academy of Science. He was the recipient of a Computers and Thought Award at the 1991 International Joint Conference on Artificial Intelligence. Dr. Brooks has delivered the Cray Lecture at the University of Minnesota, the Mellon Lecture at Dartmouth College, and the Hyland Lecture at the Hughes Research Laboratories in Malibu, California. He was the co-founding editor of the *International Journal of Computer Vision* and is a member of the editorial boards of *Adaptive Behavior, Applied Artificial Intelligence, Autonomous Robots,* and *New Generation Computing*. In addition to publishing some sixty-five articles in scientific journals and serving as the co-editor of two volumes, Dr. Brooks is the author of four books. In his latest study, *Flesh and Machines* (Pantheon, 2002), he outlines the history and development of robotics and discusses future prospects for the relationship between robots and humankind.

Professor of philosophy and director of the Turing Archive for the History of Computing at the University of Canterbury in Christchurch, New Zealand,
B. Jack Copeland also heads the academic program in philosophy and religious studies at Canterbury. He was educated at the University of Exeter, where he studied physics then

philosophy and took first class honors, and at Corpus Christi College, Oxford, where he was the only student in 1976 to earn a B.Phil. with distinction. He received his D.Phil. in mathematical logic from Oxford in 1979. Dr. Copeland was on the faculties of universities in Australia and the United Kingdom before joining the University of Canterbury philosophy faculty in 1985. He has been a visiting scholar at the University of California at Los Angeles, a visiting research fellow at Georgetown University, a visiting professor at the universities of Sydney, Aarhus, Melbourne, and Portsmouth, and a senior fellow of the Dibner Institute for the History of Science and Technology at the Massachusetts Institute of Technology. He is president of the U.S.-based Society for Machines and Mentality. In June of 2004, the 50th anniversary of Alan Turing's death, he delivered the first annual Turing Memorial Lecture at Bletchley Park National Museum and lectured on Turing's life at the Royal Institution of London. He is the founding editor of the *Rutherford Journal for the History and Philosophy of Science and Technology* and serves on the editorial boards of *Minds and Machines* and of the *Australasian Journal of Philosophy*. In addition to publishing more than one hundred articles in academic journals and chapters in volumes of collected works, he is the author of *Artificial Intelligence: A Philosophical Introduction*, published in 1993 by Blackwell (a second edition is forthcoming in 2007) and subsequently translated into Hebrew and Spanish, a study in which he weaves together material from several disciplines to explore the possibility of machines having free will and consciousness and also considers in what sense the human brain may be a computer. He served as editor of *Logic and Reality: Essays on the Legacy of Arthur Prior* (1996) and co-editor (with Per Hasle, Peter Øhrstrom, and Torben Braüner) of *Papers on Time and Tense* (2003), a new edition of Prior's influential book. Dr. Copeland's other books include *The Essential Turing: Seminal Writings in Computing, Logic, Philosophy, Artificial Intelligence, and Artificial Life* (2004), *Alan Turing's Automatic Computing Engine: The Master Codebreaker's Struggle to Build the Modern Computer* (2005), and *Colossus: The Secrets of Bletchley Park's Code-Breaking Computers*, which was published earlier this year by Oxford University Press (OUP). Two forthcoming books, *Turing's Machines* and (with Diane Proudfoot) *A Very Short Introduction to Philosophy of Religion*, also will be published by OUP.

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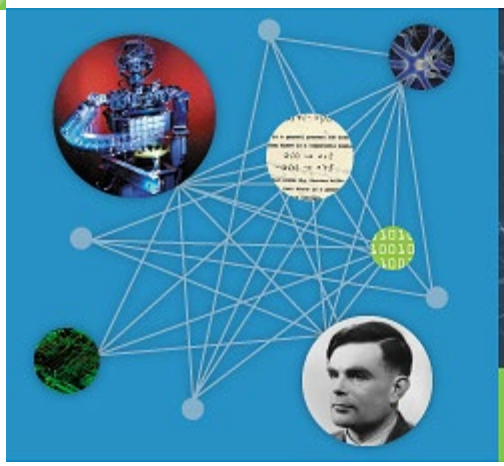

CREATIVITY:
The Mind, Machines, and Mathematics

A symposium sponsored by the John Templeton Foundation

30 November and 1 and 2 December 2006
Massachusetts Institute of Technology

PARTICIPANTS

Manuel Blum
Margaret Boden
Peter A. Cariani
David Gelernter
David E. Goldberg
Silvio Micali
Ronitt Rubinfeld
Madhu Sudan
Leslie G. Valiant
Avi Wigderson

Manuel Blum, the Bruce Nelson Professor of Computer Science at Carnegie Mellon University, is a pioneer in the field of theoretical computer science and the winner of the 1995 Turing Award in recognition of his contributions to the foundations of computational complexity theory and its applications to cryptography and program checking, a mathematical approach to writing programs that checks their work. He was born in Caracas, Venezuela, where his parents settled after fleeing Europe in the 1930s, and came to the United States in the mid-1950s to study at the Massachusetts Institute of Technology. While taking courses in electrical engineering, he pursued his desire to understand thinking and brains by working in the neurophysiology laboratory of Warren S. McCulloch and Walter Pitts, then concentrated on mathematical logic and recursion theory. He did his doctoral work under the supervision of artificial intelligence pioneer Marvin Minsky and earned a Ph.D. in mathematics in 1964. Dr. Blum began his teaching career at MIT as an assistant professor of mathematics and, in 1968, joined the faculty of the University of California at Berkeley as a tenured associate professor of electrical engineering and computer science. He was named the Arthur J. Chick Professor of Computer Science in 1995. Dr. Blum accepted his present position at Carnegie Mellon in 2001. The problems he has tackled in his long career include, among others, methods for measuring the intrinsic complexity of problems. Blum's Speedup theorem is an important proposition about the complexity of computable functions. The Blum axioms give a machine-independent way to understand the complexity of computation, whether that computation is done by a human or a computer. A member of the National Academy of Science and the National Academy of Engineering, he is a fellow of the American Academy of Arts and Sciences, the American Association for the Advancement of Science, and the Institute of Electrical and Electronics Engineers. Dr. Blum has held a Sloan Foundation Fellowship and received a University of California at Berkeley Distinguished Teaching Award and Sigma Xi's Monie A. Ferst Award among other honors. He is the author of more than fifty papers published in leading scientific journals and has supervised the theses of twenty-five doctoral students, many of whom are today's leaders in theoretical computer science.

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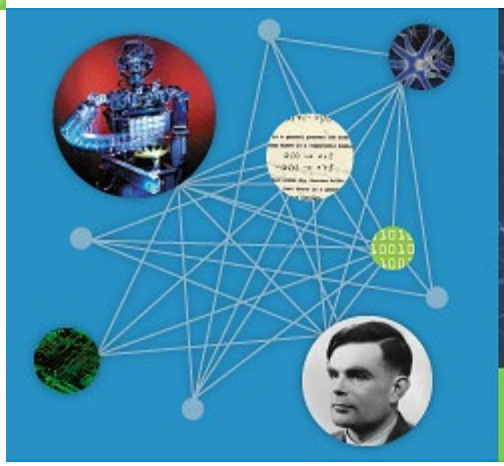

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The research professor of cognitive science at the University of Sussex, **Margaret Boden** was the founding dean of Sussex's School of Cognitive and Computing Sciences, a pioneering center for research on intelligence and the mechanisms underlying it. Her own research has been especially focused on the phenomena of purpose and creativity, and an early work, *Artificial Intelligence and Natural Man* (1977 and 1987), has become an academic classic. Educated at Newnham College, Cambridge, where she took first class honors in medical sciences and in the history of modern philosophy, she earned a Ph.D. in social psychology in 1968 from Harvard University, where she was a Harkness Fellow. Dr. Boden began her teaching career at the University of Birmingham and joined the philosophy faculty at Sussex in 1965. Named professor of philosophy and psychology in 1980, she was appointed to her present position in 2002. In 1979, she was sponsored by the Alfred P. Sloan Foundation as a visiting scientist in the Artificial Intelligence Group at Yale University. She has held the Nielsen Chair for Distinguished Scholars at Smith College and been an Erskine Visiting Fellow at the University of Canterbury in Christchurch, New Zealand, and a visiting professional fellow at the University of Technology in Sydney. Dr. Boden has delivered numerous invited lectures, including the Templeton Lecture at the University of Sydney, the Dacre Lecture at Peterhouse College, Cambridge, the Hagerstrom Lectures at the University of Uppsala, a Royal Institute of Philosophy Millennial Lecture, the Gramlich Lecture at Dartmouth University, and the Pufendorf Lecture at the University of Lund. She was awarded a Sc.D. (senior doctorate) by Cambridge and also holds three honorary doctorates—from the University of Sussex, the University of Bristol, and the Open University. In 2002, she was made an officer of the Order of the British Empire by Queen Elizabeth II for services to cognitive science. Dr. Boden is a fellow of the British Academy, the Royal Society of Arts, and the American Association for Artificial Intelligence, and a member of the Academia Europaea. The former president of Section X of the British Association for the Advancement of Science and the former honorary secretary of the British Society for the Philosophy of Science and of Analysis, she currently serves as a member of the advisory council of the International Institute for the Study of Consciousness. She is the co-founder of Harvester Press and has edited two series for Harvester, Studies in Cognitive Science and Studies in Philosophy, as well as editing the series Explorations in Cognitive Science for MIT Press. Dr. Boden

serves on the editorial boards of eleven academic journals. In addition to publishing more than 240 papers in scholarly journals, she is the editor or co-editor of six books, including, most recently, (with Michael Wheeler and John Ziman) *The Evolution of Cultural Entities* (2002) and the author of six others (plus two collections of her papers). One, *Piaget* (1979 and 1985), has been translated into six languages and another, *The Creative Mind: Myths and Mechanisms* (1990 and 2004), has been translated into seven. Her latest book, the two-volume *Mind as Machine: A History of Cognitive Science*, was published earlier this year by Oxford University Press.

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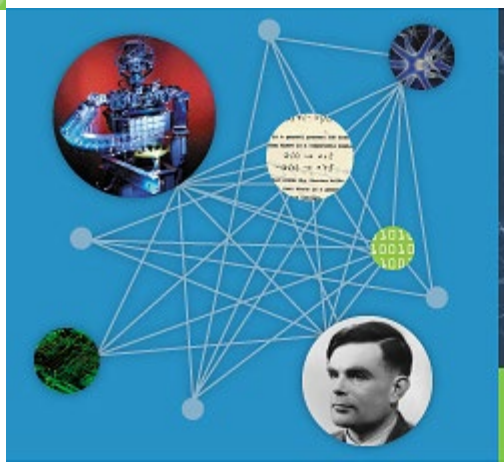

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Peter A. Cariani is currently on the faculty of the Institute for Music and Brain Science in Boston, Massachusetts, and teaches music perception and cognition in the Speech and Hearing Bioscience and Technology Program of the Harvard-Massachusetts Institute of Technology Division of Health Sciences and Technology. A graduate of MIT, where he studied biology, he earned a Ph.D. in systems science at the State University of New York at Binghamton in 1989. His doctoral work involving comparisons between biological organisms and computing machines in the context of the problem of functional emergence led to an interest in neural codes and computations in the brain. From 1990 to 2004, he carried out neurophysiological and neurocomputational investigations of the temporal coding of pitch at the Eaton Peabody Laboratory of Auditory Physiology at the Massachusetts Eye and Ear Infirmary, first as a postdoctoral fellow and then as an assistant professor in otology and layrngology at the Harvard Medical School. Two years ago, he became a research assistant professor at Tufts Medical School, where he developed electrophysiological methods for studying spinal cord regeneration. Dr. Cariani has recently proposed a new kind of neural network (neural timing nets) that processes temporal patterns. Co-editor of a special 2001 issue of the *Journal of New Music Research* on neurocomputational models of music, he has published more than twenty-five papers in scientific journals.

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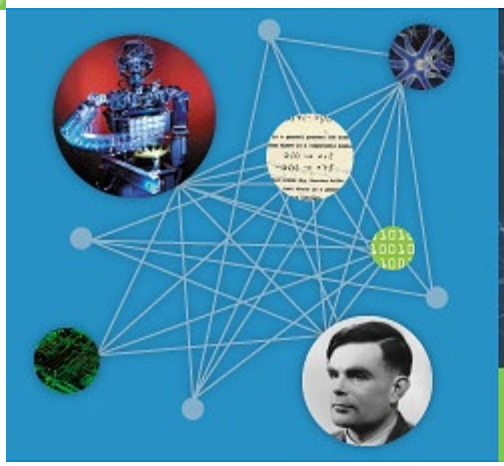

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A professor of computer science at Yale University, an essayist, and a painter, **David Gelernter** is also chief design officer at UR Inc., a new internet education company. He developed (with Nicolas Carriero) a coordination language called "Linda" that is widely used for parallel and distributed programming. His book *Mirror Worlds* (1991) is often described as foreseeing the rise of the worldwide web. Dr. Gelernter is a graduate of Yale, where he earned a B.A. and an M.A. in classical Hebrew literature; he received his Ph.D. in computer science from the State University of New York at Stony Brook in 1982, the year he returned to Yale as an assistant professor. He has been at Yale ever since. His ongoing research interests include applied artificial intelligence, philosophy of mind, and information management. He is a former member of the board of directors of the National Endowment for the Arts and is currently a national fellow of the American Enterprise Institute and a senior fellow in Jewish thought at the Shalem Institute in Jerusalem. In addition to many articles published in scholarly journals, essays in other publications, and two textbooks on software, he is the author, since *Mirror Worlds,* of *The Muse in the Machine: Computerizing the Poetry of Human Thought* (1994), the novel 1939: *The Lost World of the Fair* (1995), *Drawing a Life* (1997), a memoir, and *Machine Beauty: Elegance and the Heart of Technology*, a study of aesthetics and technology, which was published by Basic Books in 1998. His novella, *Swan House*, was published in *Commentary* last year. Two new books, *The Biblical Republic* (Doubleday) and *Judaism Beyond Words* (Shalem) will be published in 2007. His paintings have been exhibited at several shows ("Recent Works," 2001, and "Hebrew and Greek," 2005) at Yale's Slifka Gallery.

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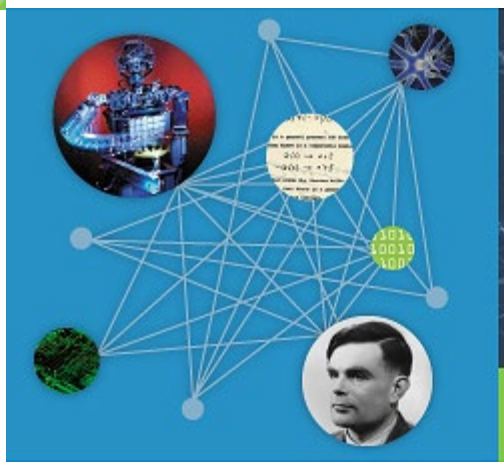

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A professor of computer science at the Massachusetts Institute of Technology, **Silvio Micali** is a world leader in the field of modern cryptography. He is widely acknowledged as the creator of the algorithmic theory of pseudorandomness, and his invention of zero-knowledge and interactive proofs was recognized by the 1993 Gödel Prize, the highest award in theoretical computer science. Born in Palermo, Italy, Dr. Micali studied mathematics at the University of Rome before coming to the United States for graduate work at the University of California at Berkeley, where he took his Ph.D. in computer science in 1982 under the supervision of Manuel Blum. The following year he was appointed to the MIT electrical engineering and computer science faculty. He has been a member of the Cryptography and Information Security Group in MIT's Computer Science and Artificial Intelligence Laboratory for more than two decades. A fellow of the American Academy of Arts and Sciences, he is the recipient of the 2004 RSA Mathematics Award, the 2006 Berkeley Distinguished Alumnus of the Year Award, and the 2006 ISE (Information Security Executive) New England Rising Star Award. Dr. Micali is the editor (with Franco Preparata, Paris Kanellakis, Christoff Hoffmann, and Robert Hawkins) of a five-volume series of textbooks, *Advances in Computing Research* (JAI Press, 1984-1993), and has published more than one hundred scientific papers.

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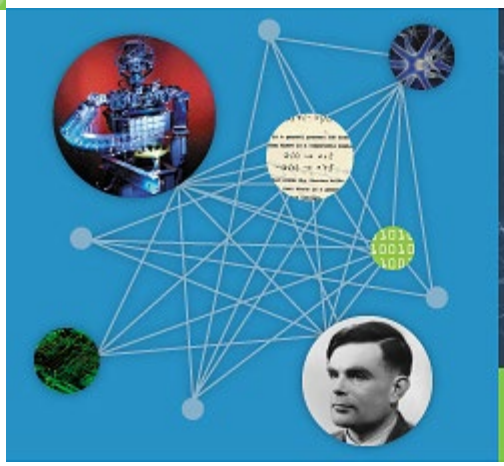

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Ronitt Rubinfeld is a professor of electrical engineering and computer science at the Massachusetts Institute of Technology and a member of MIT's Computer Science and Artificial Intelligence Laboratory. Her research focus is the theory of computation, and much of her current work involves randomized and sublinear time algorithms. A graduate of the University of Michigan, she earned a Ph.D. in computer science in 1990 at the University of California at Berkeley under the supervision of Manuel Blum. She held a postdoctoral research fellowship at Princeton University, followed by a year as a visiting research scholar at Hebrew University in Jerusalem. Dr. Rubinfeld joined the Cornell University computer science faculty as an assistant professor in 1992 and was promoted to associate professor six years later. She held visiting appointments at MIT and at the IBM Almaden Research Laboratory in San Jose, California, while at Cornell, and in 1999, she accepted a position as a senior research scientist at the NEC Research Laboratories in Princeton. She became a fellow at the Radcliffe Institute for Advanced Study in early 2004 and was named to her MIT professorship later that year. Dr. Rubinfeld has been the recipient of an Office of Naval Research Young Investigator Award, a Cornell Association for Computer Science Undergraduate Faculty of the Year Award as well as a Cornell College of Teaching Engineering Award, a National Science Foundation Career Award, and an Alfred P. Sloan Research Fellowship. A member of the editorial boards of the *Theory of Computing Systems Journal, Information and Computation,* and *Algorithmica*, she was guest co-editor of the *Journal of Computer Systems Sciences* special issue on the 1996 Symposium on the Theory of Computing. She has published more than twenty-five papers in scientific journals.

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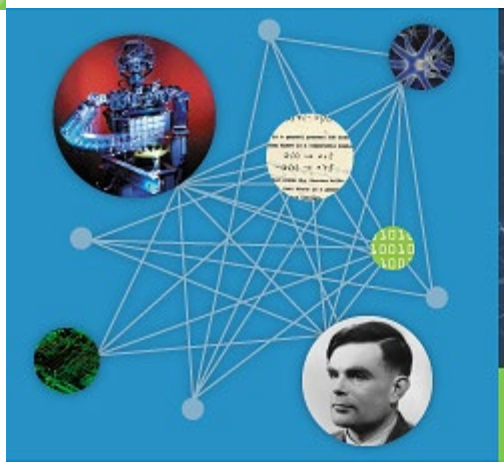

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The Fujitsu Professor of Computer Science at the Massachusetts Institute of Technology, **Madhu Sudan** is internationally recognized for his contributions to error-correcting codes and for foundational work in using probabilistic methods to verify proofs of mathematical statements. He was born in India and graduated from the Indian Institute of Technology in New Delhi. After earning a Ph.D. in computer science from the University of California at Berkeley in 1992 (and winning two awards for his doctoral dissertation), he worked as a staff scientist in mathematics at the IBM Thomas J. Watson Research Center in Yorktown Heights, New York. Dr. Sudan joined the MIT faculty as an associate professor of electrical engineering and computer science in 1997, was appointed professor in 2003, and named to his present chair last year. He is currently the research director for theoretical computer science at MIT's Computer Science and Artificial Intelligence Laboratory. Winner of the 2002 Nevanlinna Prize of the International Mathematical Union, he also has been the recipient of an Alfred P. Sloan Research Fellowship, a National Science Foundation Career Award, an IEEE Information Theory Paper Award, the 2001 Gödel Prize, distinguished alumnus awards from Berkeley and the Indian Institute of Technology, a Radcliffe Fellowship, and a Guggenheim Fellowship. Dr. Sudan has delivered invited lectures throughout North America and Europe, as well as in Israel, India, China, Japan, and Australia. Guest editor of a special issue of the *Journal of Computer and System Sciences* devoted to papers from the 2001 IEEE Conference on Computational Complexity, he formerly served on the editorial boards of *Information and Computation*, the *SIAM Journal of Discrete Mathematics*, and the *IEEE Transactions on Information Theory* and is currently editor-in-chief of *Foundations and Trends in Theoretical Computer Science* and a member of the editorial boards of the *Journal of the ACM* and the *SIAM Journal on Computing*. He is the author or co-author of more than one hundred papers published in scientific journals and conference proceedings and of two books, *Efficient Checking of Polynomials and Proofs and the Hardness of Approximation Problems* (1996) and, most recently, (with Nadia Creignou and Sanjeev Khanna) *Complexity Classifications of Boolean Constraint Satisfaction Problems*, which was published by SIAM Press in 2001.

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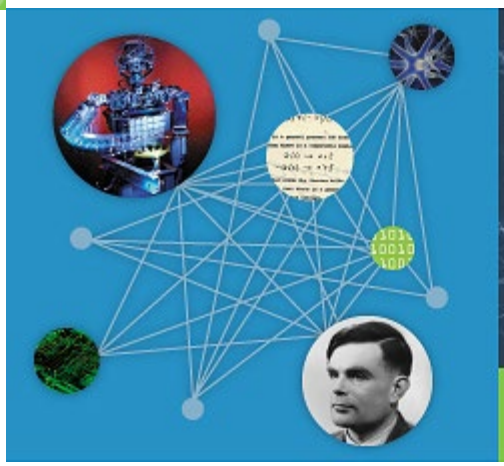
THE HUMBLE APPROACH INITIATIVE



CREATIVITY:
The Mind, Machines, and Mathematics

A symposium sponsored by the John Templeton Foundation

30 November and 1 and 2 December 2006
Massachusetts Institute of Technology

PARTICIPANTS

Leslie G. Valiant, the T. Jefferson Coolidge Professor of Computer Science and Applied Mathematics at Harvard University, has made far-reaching contributions to the study of computational complexity, parallel computation, and learning theory. Educated at King's College, Cambridge, where he studied mathematics, he went on to earn a DIC in computer science at Imperial College, London, and was awarded a Ph.D. in computer science by Warwick University in 1974. He taught at Carnegie Mellon University, Leeds University, and the University of Edinburgh before joining the Harvard computer science faculty as Gordon McKay Professor of Computer Science and Applied Mathematics in 1982. Dr. Valiant was named to his present chair in 2001. His work in theoretical computer science includes developing a formal system, called robust logics, that is intended to reconcile the apparent logical nature of reasoning and the statistical nature of learning, as well as finding computational explanations of how the brain performs its basic tasks of learning and memory. Very recently he has proposed a theory of evolvability that views evolution as a restricted form of learning. Dr. Valiant is a fellow of The Royal Society and a member of the National Academy of Sciences. Recipient of the Nevanlinna Prize in 1986 and the Knuth Prize in 1997, he has published some eighty-five papers in scientific journals. He is also the author of the widely-acclaimed *Circuits of the Mind* (Oxford University Press, 1994 and 2000) in which he details a promising new computational approach to studying the workings of the human brain.

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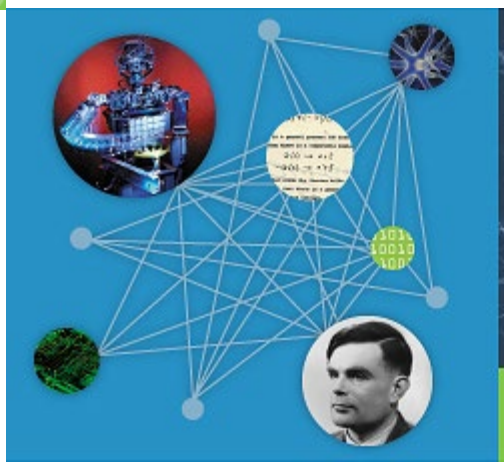

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Manuel Blum
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Peter A. Cariani
David Gelernter
David E. Goldberg
Silvio Micali
Ronitt Rubinfeld
Madhu Sudan
Leslie G. Valiant
Avi Wigderson

The Herbert Maass Professor in the School of Mathematics at the Institute for Advanced Study (IAS) in Princeton, **Avi Wigderson** is an expert in computational complexity theory. His research aims at understanding the powers and limits of efficient computation. It includes studying the power of randomness and quantum mechanics in computation, seeking to understand natural processes as computations, exploring the possibility of automating mathematical creativity, and investigating the limits of machine learning. Dr. Wigderson, a native of Israel, earned his B.S. degree *summa cum laude* at the Technion—Israel Institute of Technology. He received his Ph.D. in computer science from Princeton University in 1983. After a year as a visiting assistant professor of computer science at the University of California at Berkeley, he was a visiting scientist at the IBM Research Laboratory in San Jose, California, then returned to Berkeley as a fellow in the Mathematical Sciences Research Institute there. Dr. Wigderson joined the computer science faculty of Hebrew University in Jerusalem in 1986 as a lecturer and was named a professor in Hebrew University's Computer Science Institute in 1991. He held visiting appointments on Princeton's computer science faculty and at the IAS before accepting his present IAS professorship. He has given invited lectures at meetings of the International Congress of Mathematicians, including one in Koyto (1990), another in Zurich (1996), and a plenary lecture in Madrid (2006). He is the author of some 170 articles published in scientific journals and co-editor (with Steven Rudich) of *Computational Complexity Theory*, a volume of lectures issued in 2004 by the American Mathematical Society.