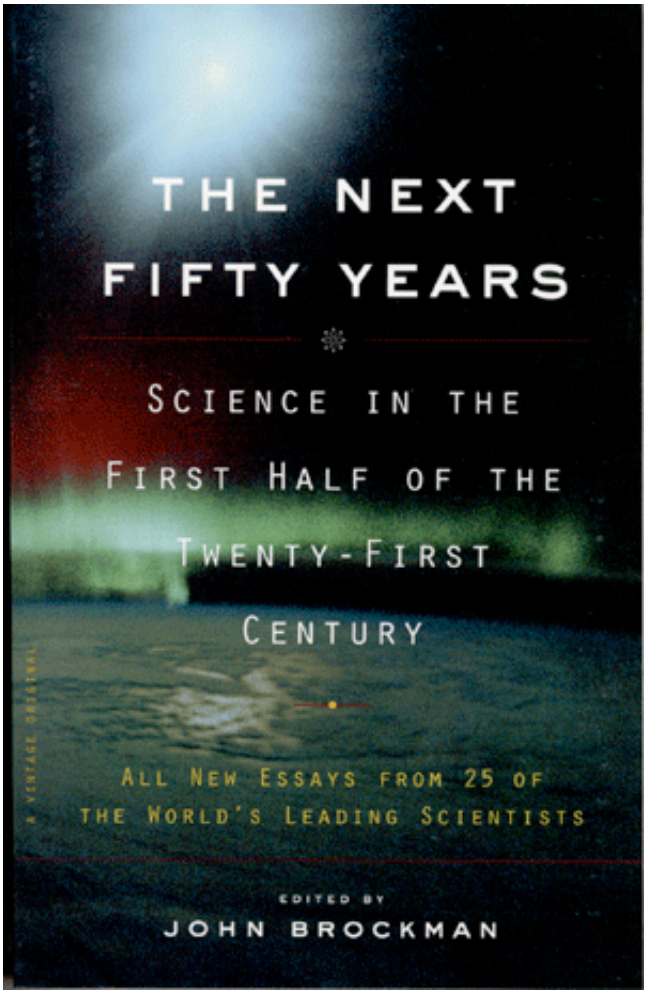
"Entertaining", *New Scientist* • **"Provocative"**, *Daily Telegraph* • **"Inspired"**, *Wired* • **"Mind-stretching"**, *Times Higher Education Supplement* • **"Fascinating"**, *Dallas Morning News* • **"Dazzling"**, *Washington Post Book World* • **"Bedazzled** , *Publisher's Weekly*

THE NEXT FIFTY YEARS

Science in the First Half of the Twenty-first Century



Edited, with an Introduction by John Brockman

US: Vintage Books
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May, 2002

Original essays by Peter Atkins, Samuel Barondes, Paul Bloom, Rodney Brooks, Mihalyi Csikszentmihalyi, Paul C. W. Davies, Richard Dawkins, Nancy Etcoff, Paul W. Ewald, David Gelernter, Brian Goodwin, Alison Gopnik, Judith Rich Harris, Marc D. Hauser, John H. Holland, Stuart Kauffman, Jaron Lanier, Joseph LeDoux, Geoffrey Miller, Martin Rees, Robert Sapolsky, Roger C. Schank, Lee Smolin, Ian Stewart, Steven Strogatz

Now In Bookstores! A brilliant ensemble of the world's most visionary scientists provides twenty-five original never-before-published essays about the advances in science and technology that we may see within our lifetimes.

The subject, and a starting point for the essays, is "the next 50 years" in the respective fields of the contributors. How will the achievements in science in the next fifty years affect the lives of everybody on the planet? How will such developments change the questions we are asking about who, and what, we are? What developments might we expect to see in specific fields or disciplines and how might these influence and cut across other disciplines? What current expectations will not be realized, and what will be the surprising misperceptions? How will changes in in specific fields cut across disciplines? What are the big questions scientists will be asking 50 years from now?

"Twenty-five writers discuss the future of science in their respective fields of study. Several of these writers surpass ordinary trend spotting to entertain some rather pulse-quickening ideas completely beyond the kin of the so-called dominant paradigm. And some are of a magnitude to radically advance the nature of humans' interaction with each other, the planet and beyond. The neurologist Robert Sapolsky, for example, posits that sadness will take its place alongside AIDS and Alzheimer's as the most notorious medical disasters of the next half-century. Brockman, who is also an author-editor (*The Third Culture; The Greatest Inventions of the Past 2,000 Years*, etc.), divides his collection into two parts: the future in theory and the future in practice. Theoretical topics include cosmology, what it means to be alive, the nature of consciousness and the possibility of extraterrestrial intelligence. Mars exploration, DNA sequencing, neuroscience, child rearing and the like are addressed in the practical half. These essays can be quite technical, intended as they are to make the latest scientific information available for cross-disciplinary research. The intellectual adventures collected here point to a future that is dazzlingly bright, at least to the eyes of these unorthodox thinkers. The general public, for whom these essays are also written, should be similarly bedazzled." — *Publisher's Weekly*

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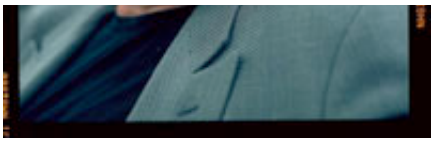
John Brockman, Editor
Introduction

The Next Fifty Years features thoughtful, challenging essays — intellectual adventures — by twenty-five leading scientists, all of them frequent communicators of their science in books and articles for the general public. They are the biologists Richard Dawkins, Paul W. Ewald, Brian Goodwin, Stuart Kauffman, and Robert Sapolsky; the chemist Peter Atkins; the psychologists Paul Bloom, Mihaly Csikszentmihalyi, Nancy Etcoff, Alison Gopnik, Judith Rich Harris, and Geoffrey Miller; the psychologist and computer scientist John H. Holland; the psychologist and AI researcher Roger C. Schank; neuroscientists Samuel Barondes, Marc D. Hauser, and Joseph LeDoux;



computer scientists David Gelernter and Jaron Lanier; Rodney Brooks, director of MIT's Artificial Intelligence Laboratory; the mathematicians Ian Stewart and Steven Strogatz; the astronomer Martin Rees; and theoretical physicists Paul Davies and Lee Smolin.

JOHN BROCKMAN is a cultural impresario whose career has encompassed the avant-garde art world, science, books, software, and the Internet. In the 1960s he coined the word "intermedia" and pioneered "intermedia kinetic environments" in art, theatre, and commerce, while also consulting for clients such as General Electric, Columbia Pictures, Scott Paper, The Pentagon, and the White House.

In 1973, he formed Brockman, Inc., the international literary and software agency specializing in serious nonfiction. He is the founder of the nonprofit Edge Foundation, Inc. and editor of Edge (www.edge.org), the highly acclaimed website devoted to discussions of cutting edge science by many of the world's brilliant thinkers, the leaders of what he has termed "the third culture".

A well-known computer and Internet entrepreneur and visionary, he is frequently featured in the media. Included in his works as author and/or editor are *By the Late John Brockman, The Third Culture, Digerati: Encounters with the Cyber Elite*; editor of *The Greatest Inventions in the Past Two Thousand Years*, and *The Next Fifty Years: Science in the First Half of the Twenty-First Century.*

Brockman has the distinction of being the only person to have been profiled on Page One of both *The New York Sunday Times* "Arts & Leisure" (1966), and *The New York Times "Science Times"* (1997).

Part I: The Future, in Theory

"The Future of the Nature of the Universe"
Lee Smolin

We will probably know more about the detailed history and properties of the universe than we know now about the history of the surface of our planet.

LEE SMOLIN is a founding member and research physicist at the Perimeter Institute for Theoretical Physics, in Waterloo, Ontario. A prominent contributor to the subject of quantum gravity, he is also the author of *The Life of the Cosmos* and *Three Roads to Quantum Gravity*.

"Cosmological Challenges: Are We Alone, and Where?"

Martin Rees

We can't predict what role life will eventually carve out for itself: It could become extinct, or it could achieve such dominance that it would influence the entire cosmos.

SIR MARTIN REES is Royal Society Professor at Kings College, Cambridge. He was previously Plumian Professor of Astronomy and Experimental Philosophy at Cambridge, having been elected to this chair at the age of thirty, succeeding Fred Hoyle. He has originated many key cosmological ideas: for example, he was the first to suggest that the fantastically energetic cores of quasars may be powered by giant black holes. For the last twenty years, he has directed a wide-ranging research program at Cambridge's Institute of Astronomy. He is the author of several books, including Gravity's Fatal Attraction (with Mitchell Begelman); New Perspectives in Astrophysical Astronomy; Before the Beginning : Our Universe and Others; Just Six Numbers: The Deep Forces that Shape the Universe ; and, most recently, Our Cosmic Habitat.

"The Mathematics of 2050"
Ian Stewart

There will be 'virtual unreality' systems, allowing mathematicians to 'visit' abstract conceptual structures such as non-euclidean geometries or ranges of giant primes and manipulate them at will.

IAN STEWART is the 1995 recipient of the Royal Society's Michael Faraday medal for outstanding contributions to the public understanding of science. He has written numerous articles on mathematics for such popular magazines as *Discover, New Scientist*, and *The Sciences*. For ten years he wrote the "Mathematical Recreations" column in *Scientific American*, and he is mathematics consultant to *New Scientist*. He is also coauthor (with Jack Cohen) of *The Collapse of Chaos* and *Figments of Reality*and author of *Does God Play Dice?*, *Fearful Symmetry*, *From Here to Infinity*, *Nature's Numbers*, *Life's Other Secret*, and *Flatterland.*

"In the Shadow of Culture"
Brian Goodwin

Why is animism so threatening to the Western scientific worldview? Is there any sign that the dialectic of science is beginning to bring this view into the light again?

BRIAN GOODWIN is a professor of biology at Schumacher Collegee, Dartington, in Devon, U.K., where he coordinates a master's program in holistic science. He is also a member of the Santa Fe Institute. He is the author of *Temporal Organization in Cells; Analytical Physiology of Cells and Developing Organisms; How The Leopard Changed Its Spots: The Evolution of Complexity*y; (with Gerry Webster) *Form and Transformation: Generative and Relational Principles in Biology*.; and (with Ricard Solé) *Signs of Life: How Complexity Pervades Biology.*

"Swappable Minds"
Marc D. Hauser

Imagine that we could download the neuronal signals from any animal, creating a kind of hard-drive library of their thoughts while they were interacting with the world.

MARC D. HAUSER a cognitive neuroscientist, is a professor in the departments of Psychology and the Program in Neurosciences at Harvard, where he is also a fellow of the Mind, Brain, and Behavior Program. He is the author of *The Evolution of Communication*, *The Design of Animal Communication* (with M. Konishi), and *Wild Minds: What Animals Really Think.*

"What Children Will Teach Scientists"
Alison Gopnik

The greatest achievement of a unified theory of learning may be to demonstrate that the most brilliant scientists and the most ordinary kids are engaged in the same enterprise.

ALISON GOPNIK is a professor of psychology at the University of California at Berkeley. She is an international leader in the field of children's learning and was one of the first cognitive scientists to show how developmental psychology could help solve ancient philosophical problems. She is the coauthor (with Andrew Meltzoff) of *Words, Thoughts, and Theories*, and (with Patricia Kuhl and Andrew Meltzoff) of *The Scientist in the Crib: Minds, Brains, and How Children Learn.*

"Toward A Theory Of Moral Development"
Paul Bloom

It may be that the nature of moral thought or consciousness is simply beyond our understanding, not because they have a special, mystical status but because we aren't smart enough to understand such things. We might be like dogs trying to understand calculus.

PAUL BLOOM is a professor of psychology at Yale University. He is an internationally recognized expert on language and development, and with Steven Pinker coauthored one of the seminal papers in the field. He is one of the youngest full professors at Yale and has published over fifty chapters and journal articles in psychology, linguistics, cognitive science,

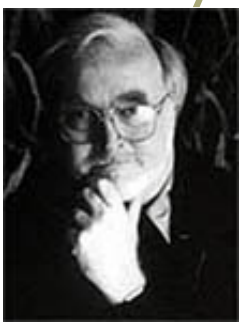
and neuroscience. Bloom is the author of *How Children Learn the Meanings of Words (Learning, Development, and Conceptual Change)* and the forthcoming *Bodies and Souls.*

"The Science Of Subtlety"
Geoffrey Miller

Our more recently evolved, distinctively human capacities--for creativity, kindness, humor, imagination--remain understudied in brain-imaging labs.

GEOFFREY MILLER, a widely respected evolutionary psychologist, is a senior research fellow at the Centre for Economic Learning and Social Evolution, University College London. He is the author of*The Mating Mind: How Sexual Choice Shaped Human Nature.*

"The Future of Happiness"
Mihalyi Csikszentmihalyi



In the past, we were like passengers on the slow coach of evolution. Now evolution is more like a rocket hurtling through space, and we are no longer passengers but its pilots.

MIHALY CSIKSZENTMIHALYI is a Hungarian-born polymath, formerly chairman of the Psychology Department at the University of Chicago and currently Davidson Professor of Management at the Claremont Graduate University, in Claremont, California. He has been thinking about the meaning of happiness since his childhood in wartime Europe. His research and theories in the psychology of optimal experience have revolutionized psychology and have been put into practice by such national leaders as Bill Clinton and Tony Blair, as well as the chief executive officers of many of the world's major corporations. Csikszentmihalyi is the author of several popular books about his theories, including the best selling *Flow: The Psychology Of Optimal Experience; The Evolving Self: A Psychology For The Third Millennium; Creativity;* and *Finding Flow*.*The Wall Street Journal* has llisted *Flow* among the six books "every well-stocked business library should have."

"Will We Still Be Sad Fifty Years from Now?"
Robert Sapolsky

Our technology isn't likely to help reduce our stress, despite (or maybe even because of) our expectation that it will.

ROBERT SAPOLSKY is a professor of biological sciences at

Stanford University and of neurology at Stanford's School of Medicine. He is also a research associate at the National Museums of Kenya. While his primary research, on stress and neurological disease, is in the laboratory, for twenty-three years he has made annual trips to the Serengeti of East Africa to study a population of wild baboons and the relationship between personality and patterns of stress-related disease in these animals. His latest book, *A Primate's Memoir,* grew out of the years spent in Africa. He is also the author of *Stress, the Aging Brain, and the Mechanisms of Neuron Death,* and two books for nonscientists, *The Trouble With Testosterone and Other Essays on the Biology of the Human Predicament* and *Why Zebras Don't Get Ulcers: A Guide to Stress, Stress-Related Diseases and Coping.*

"Fermi's 'Little Discovery' and the Future of Chaos and Complexity Theory"
Steven Strogatz

Nonlinearity giveth chaos, and nonlinearity taketh it away.

STEVEN STROGATZ is a professor in the Center for Applied Mathematics at Cornell University. He is the author of the best selling textbook *Nonlinear Dynamics and Chaos: With Applications to Physics, Biology, Chemistry, and Engineering* and the forthcoming trade book *Sync*. His seminal research on human sleep and circadian rhythms, scroll waves, coupled oscillators, synchronous fireflies, Josephson junctions, and small-world networks has been featured in *Nature, Science, Scientific American,* the *New York Times, US News and World Report, The New Yorker, Discover, American Scientist, Science News, Business Week, Die Zeit,* and London's *Daily Telegraph,* and broadcast on BBC Radio, National Public Radio, CBS News, and numerous other mass media outlets.

"What Is Life?"
Stuart A. Kauffman

The biosphere may actually be doing something that cannot be stated at all beforehand. If so, the way Newton, Einstein, Bohr, and Boltzmann taught us to do science is limited.

STUART A. KAUFFMAN, an emeritus professor of biochemistry at the University of Pennsylvania, is a theoretical biologist who studies the origin of life and the origins of molecular organization. He is a MacArthur Fellow and an external professor at the Santa Fe Institute. Twenty-five years ago, he developed the Kauffman models, which are random networks exhibiting a kind of self-organization that he terms "order for free." Dr. Kauffman is the founding general partner and chief scientific officer of The Bios Group, a company that applies the science of complexity to business management problems. He is the author of *The*

Origins of Orde and *Investigations* and the coauthor (with George Johnson) of *At Home in the Universe: The Search for the Laws of Self-Organization*.

Part I: The Future, in Theory

"Son of Moore's Law"
Richard Dawkins

Genetics today is pure information technology. This, precisely, is why an antifreeze gene can be copied from an arctic fish and pasted into a tomato.

RICHARD DAWKINS, an evolutionary biologist, is the Charles Simonyi Professor for the Public Understanding of Science at Oxford University. He is the author of *The Selfish Gene*, *The Extended Phenotype*, *The Blind Watchmaker*, *River out of Eden* (*ScienceMasters Series*), *Climbing Mount Improbable*, and *Unweaving the Rainbow*. He is a Fellow of the Royal Society and also a Fellow of the Royal Society of Literature, holds honorary doctorates in literature as well as in science, and is one of the few living scientists to have made it into the Oxford Dictionary of Quotations. He won the International Cosmos Prize for 1997, and is the 2001 winner of the Kistler Prize.

"Was There A Second Genesis?"
Paul C. W. Davies

The existence of complex life on Earth probably depends on certain rather special features of our solar system.

PAUL C. W. DAVIES, a theoretical physicist, is currently a visiting professor at Imperial College London and the University of Queensland. He is the author of over twenty books, including such best-selling popular science titles as *About Time, The Mind of God,* and *The Fifth Miracle: The Search for the Origin of Life*. Davies' research has been mainly in the field of quantum gravity and cosmology, and he has written two textbooks, *The Physics of Time Asymmetry* and *Quantum Fields in Curved Space;* however, his interests are much wider, ranging from particle physics to astrobiology. He is currently working on the problem of biogenesis and the role of cosmic impacts on the early development of life. For years he has written and lectured about the deeper implications of science, for which work he was awarded the $1 million Templeton Prize in 1995. His next book is the self explanatory *How to Build a Time Machine*.

"What Is to Come and How to Predict It"

John H. Holland

When complex adaptive systems are involved, prediction is fraught with hazard.

JOHN HENRY HOLLAND is a professor of psychology and a professor of computer science and engineering at the University of Michigan at Ann Arbor, and an external professor at the Santa Fe Institute. His main research interests are complex adaptive systems (natural and artificial), computer-based models of cognitive processes, and the construction of models for computer-based thought experiments. Known widely as the "father of genetic algorithms," he is a board member of the International Society for Genetic and Evolutionary Computation, and is a member of the Board of Trustees of the Santa Fe Institute. He has been named a MacArthur Fellow and is a Fellow of the World Economic Forum. His two most recent books are *Emergence: From Chaos to Order* and *Hidden Order: How Adaptation Builds Complexity.*

"The Merger of Flesh and Machines" Rodney Brooks

The generalization we are facing is that we humans are machines--and as such, subject to the same technological manipulations we routinely apply to machines.

RODNEY BROOKS is director of the Artificial Intelligence Laboratory and Fujitsu Professor of Computer Science at the Massachusetts Institute of Technology. He is also chairman and chief technical officer of iRobot Corporation, a company that partners with established companies in the toy, oil, consumer, and defense industries. Dr. Brooks appeared as one of the four principals in the 1997 Errol Morris movie "Fast, Cheap, and Out of Control" — named after one of his papers in the *Journal of the British Interplanetary Society.* He is the author of *Model-Based Computer Vision, Programming in Common LISP, Cambrian Intelligence*, and most recently *Flesh and Machines: How Robots Will Change Us.*

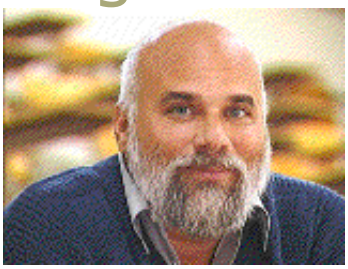
"The Future of Matter" Peter Atkins

By mid-century the bits and pieces of fully synthetic life will be in position....In the longer term there will be no need to stick with carbon, and the speculative dream of at least partial incorporation of silicon and germanium into living things and the generation of an entirely new kind of life will come true.

PETER ATKINS is professor of chemistry at the University of Oxford and a fellow of Lincoln College. His research has been in the field of theoretical chemistry, particularly magnetic resonance and the electromagnetic properties of molecules. Nowadays he spends virtually all his time writing; he is the author of several textbooks *(General Chemistry, Physical Chemistry, Inorganic Chemistry, Molecular Quantum Mechanics, Quanta, Concepts of Physical Chemistry)* and books for general audiences such as *Molecules; The Second Law;*

Atoms, Electrons, and Change; and most recently *The Periodic Kingdom.*

"Are We Going to Get Smarter?" Roger C. Schank



We will begin to understand in the next fifty years that experience and one's ability to extend its range is the ultimate measure of intelligence and the ultimate expression of freedom.

ROGER C. SCHANK, one of the world's leading researchers in artificial intelligence, is the chairman and chief technology officer for Cognitive Arts and Distinguished Career Professor in the School of Computer Science at Carnegie Mellon. He was formerly the director of the Institute for the Learning Sciences at Northwestern University, where he is professor emeritus. His books include *Dynamic Memory: A Theory of Learning in Computers and People; Dynamic Memory Revisited; Engines for Education; Tell Me a Story: A New Look at Real and Artificial Memory; The Connoisseur's Guide to the Mind; Engines for Education; Virtual Learning: A Revolutionary Approach to Building a Highly Skilled Workforce;Coloring Outside the Lines: Raising a Smarter Kid be Breaking all the Rules.; Scrooge Meets Dick and Jane; and Designing World Class E-Learning.*

"The Complexity Ceiling" Jaron Lanier

Accompanying the parade of quixotic overstatements of theoretical computer power has been a humiliating and unending sequence of disappointments in the performance of real information systems.

JARON LANIER, a computer scientist and musician, is best known for his work in virtual reality. He is the lead scientist for the National Tele-Immersion Initiative, a consortium of universities studying the implications and applications of next-generation Internet technologies.

"Tapping into the Beam " David Gelernter

The continuous, ubiquitous Cybersphere will replace today's chaotic, stuttering Internet.

DAVID GELERNTER is a professor of computer science at Yale and chief scientist at Mirror Worlds Technologies (New Haven). His research centers on information management, parallel programming, and artificial intelligence. The "tuple spaces" introduced in Nicholas Carriero and Gelernter's Linda system (1983) are the basis of many computer communication systems worldwide. Dr. Gelernter is the author of *Mirror Worlds*, *The Muse in the Machine*, *1939*, *Drawiing a Life*, and *Machine Beauty.*

"Mind, Brain, and Self"
Joseph LeDoux

New technologies are enabling us to study normal human brain function, and they promise a new level of understanding of the relation of the human brain to the human mind.

JOSEPH LEDOUX is the Henry and Lucy Moses Professor of Science in the Center for Neural Science, New York University. He has long sought to understand our emotions as biological states of the brain. His work emphasizes the role of learning and memory (in contrast to genetic predetermination) in emotional experience and seeks to relate memories of emotional experiences to synaptic events. His newest book is *Synaptic Self: How Our Brains Become Who We Are.* He is also the author of *The Emotional Brain: The Mysterious Underpinnings of Emotional Life;* coauthor (with Michael Gazzaniga) of *The Integrated Mind;* and editor (with W. Hirst) of *Mind and Brain: Dialogues in Cognitive Neuroscience*.

"What Makes Us The Way We Are?"
Judith Rich Harris

Developmentalists of the twentieth century...thought they understood the sources of individual differences in behavior and personality, but...they were mostly wrong.

JUDITH RICH HARRIS is a writer and developmental psychologist. A former writer of textbooks on child development, she realized one day that much of what she had been telling her readers was wrong. She stopped writing textbooks and instead wrote an article proposing a new theory of development; her article, published in the *Psychological Review*, received the George A. Miller Award from the American Psychological Association in 1998. Harris's book*The Nurture Assumption: Why Children Turn Out The Way They Do* (was a finalist for the Pulitzer Prize in 1999).

"Drugs, DNA, And The Psychiatric Couch "
Samuel Barondes

Fifty years from now, everyone who visits a psychiatrist will bring with them a new source of information--a password providing access to their personal DNA file on the National Health Service computer.

SAMUEL H. BARONDES, M.D., is the Jeanne and Sanford Robertson Professor and director of the Center for Neurobiology and Psychiatry at the University of California, San Francisco. He also serves as chair of the Board of Scientific Counselors of the National Institute of

Mental Health. He is the author of *Molecules and Mental Illness* and *Mood Genes: Hunting for Origins of Mania and Depression.*

"Brain Scans, Wearables, And Brief Encounters"
Nancy Etcoff

At a time of giddy optimism in the neurosciences, it is a time of discontent in psychiatry and wary optimism in clinical psychology. If current trends continue, there will be few psychiatrists in practice fifty years from now.

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NANCY ETCOFF is a member of the Harvard University Faculty of Medicine, the Massachusetts General Hospital Psychiatry staff, and the Harvard Mind/Brain/Behavior Initiative. Dr. Etcoff's research on the perception of beauty, emotion, and human faces has been published in Nature, Cognition, Neuron, and other scientific journals, has been cited frequently in the popular press, and has won numerous awards. She is the author of *Survival of the Prettiest: The Science of Beauty.*

"Mastering Disease"
Paul W.Ewald

Chronic diseases may be a consequence of infectious agents that cryptically cause tissue damage, which eventually manifests itself in such serious diseases as heart attack, cancer, or Alzheimer's.

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PAUL W. EWALD is a professor of biology at Amherst College and a specialist in evolutionary medicine, a discipline he helped to found and on which he has lectured extensively at college campuses, seminars, and symposia around the world. He is the author of *Evolution of Infectious Disease* (acknowledged as the watershed event in the emergence of that discipline) and *Plague Time: How Stealth Infections Are Causing Cancers, Heart Disease, and Other Deadly Ailments.*

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