Earth, Life & System

An Interdisciplinary Symposium on Environment and Evolution in honor of Lynn Margulis

The 2012 Donald R. Haragan Lectures

Texas Tech University, September 13 & 14, 2012

Cover Image: Cosmic Evolution as depicted by the Exobiology program at NASA Ames Research Center, 1986.

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The 2012 Donald R. Haragan Lectures

Texas Tech University
September 13 & 14, 2012
McKenzie-Merket Alumni Center, 17th & University, Lubbock, TX

Directors:

Bruce Clarke, Department of English
Michael San Francisco, Office of the Vice President for Research, and Biological Sciences

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The Haragan Lecture Series

This event is co-sponsored by the TTU/HHMI Science Education Program @ CISER and the President Donald R. Haragan Lecture Series Endowment, begun in 2001 in recognition of Dr. Haragan's unparalleled, distinguished service to Texas Tech University.

Program

Moderator: Manuela Rossini, Institute of Advanced Study in the Humanities and the Social Sciences, University of Bern, Switzerland

Symposium at a Glance

Thursday, September 13

8:45-10:15 a.m. Sankar Chatterjee, Horn Professor, Department of Geosciences, Curator of Paleontology, TTU: "Meteoritic Impacts and the Endoprebiotic Origin of Life"

10:30 a.m.-12:00 noon. Susan Squier, Julia Brill Professor of Women's Studies and English, Pennsylvania State University: "The 'World Egg' Reconsidered: Waddington, Margulis, and Feminist New Materialism"

1:00-2:30 p.m. Jan Sapp, Professor of Biology and History, York University: "On the Origins of Biological Kingdoms and Domains"

2:45-4:15 p.m. J. Baird Callicott, University Distinguished Research Professor, Philosophy and Religion Studies, University of North Texas: "Gaia and the History of the Biosphere Concept"

4:30-6:00 p.m. Dorion Sagan, Writer, Amherst, MA: "The World According to Margulis: An Abecedarium"

6:00-7:30 p.m. Public Reception, McKenzie-Merket Alumni Center Courtyard

Friday, September 14

8:45-10:15 a.m. Bruce Clarke, Horn Professor of Literature and Science, Department of English, TTU: "The Planetary Imagination"

10:30 a.m.-12:00 noon. James A. Shapiro, Professor of Biochemistry and Molecular Biophysics, University of Chicago: "Bringing Cell Action into Evolution"

1:00-2:30 p.m. James E. Strick, Associate Professor of Science, Technology and Society, Franklin & Marshall College: "The Serial Endosymbiosis and Gaia Theories: Their Incubation in NASA's Exobiology Program and Diverse Cultural Valences"

2:45-4:15 p.m. Susan Oyama, Professor Emerita of Psychology, John Jay College and the Graduate Center, CUNY: "Sustainable Development: Alternative Pathways in Developmental Systems Theory"

4:30-6:00 p.m. Peter Westbroek, Emeritus Professor of Geophysiology, Leiden University, Royal Netherlands Academy of Sciences and Arts: "Coming to Terms with Global Change: Technology is Not Enough"

Abstracts

Thursday, September 13

8:45-10:15 a.m. Sankar Chatterjee, "Meteoritic Impacts and the Endoprebiotic Origin of Life"

There are two distinct processes for the origin of life: exogenous delivery of biomolecules from space and endogenous synthesis of life on Earth. There is growing evidence that raining meteorites deposited building blocks of life and created the hydrothermal vent systems where primordial protocells were synthesized during the harsh, inhospitable, Late Heavy Bombardment Period (~4 to 3.8 billion years ago). Both comets and asteroids played roles in the prebiotic origin of life. Comets carried and deposited water and key ingredients of life from space to this planet, which were then concentrated and polymerized in crater basins created by the asteroids. The first forms of cellular life required self-assembled membranes that were followed by simultaneous emergence of polynucleotides and polypeptides. We suggest that the primordial polynucleotides and polypeptides that accumulated in mineral substrates of vent environments were the precursors to viruses and prions. Once the membranes encapsulated these simple RNA and protein molecules, they began to interact and initiate serial endoprebiosis, leading to hierarchical emergence of cell components including the plasma membrane, ribosome, and retrovirus, and finally, DNA. Proto-viruses and proto-prions performed two critical functions of a primitive cell, replication and metabolism respectively, which are similar to those of cellular function. Viruses and prions may represent evolutionary heirlooms of a microbial world that predated the appearance of the first cells.

10:30 a.m.-12:00 noon. Susan Squier, "The 'World Egg' Reconsidered: Waddington, Margulis, and Feminist New Materialism"

This paper takes as its text C. H. Waddington's image of the "World Egg" from a talk he gave in 1967 at the Second Serbelloni Symposium, "Towards a Theoretical Biology." The metaphor of the World Egg embodies Waddington's signature concept of epigenetics. Whether viewed as unsettling and sinister

or as engaging and familiar, this image marks the interwoven and contrasting theories of biology of Waddington and Lynn Margulis. Moving from epigenesis, a concept from the developmental biology of Waddington, to prototaxis, a concept from the endosymbiotic work of Margulis, and finally to bioanalysis, a concept put forth by Elizabeth Wilson, I will argue that when Waddington's epigenetics is read through the work of Margulis, it has useful implications for contemporary feminist theory. Although mainstream biology operationalized his concept primarily as a narrowly statistical analysis of the mechanisms of gene expression, it can also be read bioanalytically as a model of biological development that anticipates symbiogenesis and now activates the research of such feminist new materialist scholars as Karen Barad, Jane Bennett, and Elizabeth Wilson.

1:00-2:30 p.m. Jan Sapp, "On the Origins of Biological Kingdoms and Domains"

Neo-Darwinian evolutionary biology of the last century said nothing of the evolution of microorganisms, yet this is where the great diversity and great kingdoms of life lay hidden. Throughout most of the 20th century, discussions of kingdoms took place close to the margins of biology. Microbiology developed without an evolutionary context and mainly as an applied science associated with the study of disease. Based on classical comparative morphology, a phylogenetic understanding of bacterial taxa, long sought by some microbiologists, was deemed to be impossible. It was not until the last two decades of the twentieth century that biologists, led by Carl Woese, developed new molecular methods and concepts to investigate early microbial evolution with the aim of creating a universal phylogenetic tree. Those methods and concepts led to a taxonomic proposal of three domains representing three fundamental lineages of life, thus confronting the classical prokaryote-eukaryote dichotomy with an entirely different schema. That view of life also came to confront a five-kingdom system first proposed by Robert Whittaker and developed and championed by Lynn Margulis. My talk will survey

the development of these new phylogenetic concepts and the subsequent controversy over the domains and kingdoms to which they give rise, in the context of molecular phylogenetic evidence, considered by both Woese and Margulis, that horizontal gene transfer and symbiosis are major modes of evolutionary innovation.

2:45-4:15 p.m. J. Baird Callicott, "Gaia and the History of the Biosphere Concept"

In 1875, after organizing geology into the lithosphere, the baryosphere (aka the hydrosphere), and the atmosphere, Eduard Suess coined and defined the "biosphere" as "the place on Earth's surface where life dwells." Vladimir Vernadsky featured the concept by making the biosphere a geological force—according to Lynn Margulis, "not *a* but *the* geological force"—physically and chemically transforming not only the atmosphere and hydrosphere, but also the crustal zone of the lithosphere. Independently of Vernadsky, Aldo Leopold anticipated the Gaia Hypothesis, speculating that the Earth itself is a living planet, with metabolic and physiologic properties, and possibly a soul or consciousness—and therefore an appropriate object of ethical respect. Vernadsky borrowed the term "noösphere" from Edouard LeRoy and Pierre Teilhard de Chardin, but—in contrast to them and to Leopold— conceived of it materially: as electronically linked human brains and the corpus of scientific knowledge thus generated, technologically applied in furthering the age-old work of living matter. The biosphere crossed the Atlantic via Vernadsky's son George, a Yale professor of Russian history, and took root in the brain of Yale ecologist G. E. Hutchinson, who ecologized it. Lovelock's Gaia was but a personification of Vernadsky's biosphere—with, however, a focus more on its cybernetic than its metabolic character. Albeit collaborating with Lovelock in developing Gaia Theory, Margulis sided more with Vernadsky in conceiving of biospherical Gaia in biogeochemical terms and with Hutchinson in conceiving of biospherical Gaia as a superecosystem, not a superorganism, to which she attributed a proprioceptive sentience but not a robust consciousness.

4:30-6:00 p.m. Dorion Sagan, "The World According to Margulis: An Abecedarium"

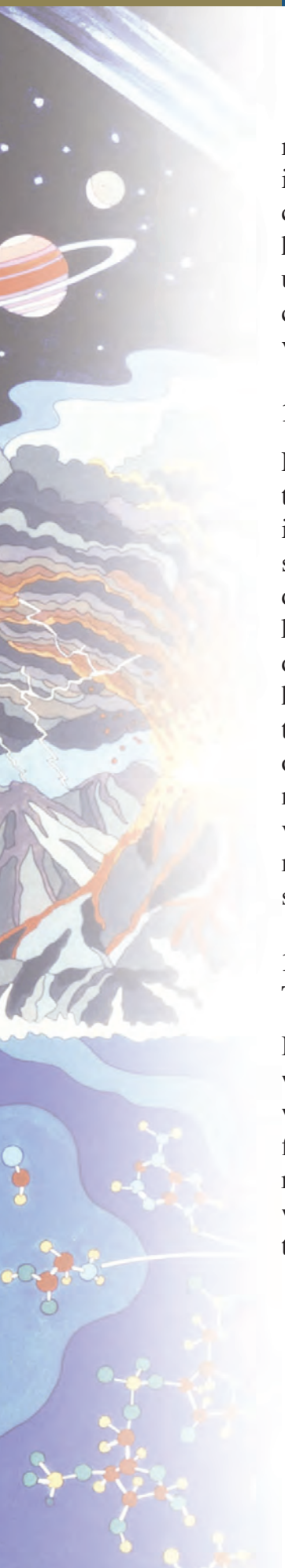
Lynn Margulis was one of the great scientists of the 20th century. Her core work on endosymbiosis was originally marginalized, but is now accepted and continues to unfold. I worked with her for over thirty years as her closest continuous collaborator in divulging her ideas to the public. Here I develop a preliminary summary of some of the high points and implications of her work. I will not attempt to be comprehensive; rather, I will focus on specific topics, alphabetically arranged, that reflect her overarching concerns. A is for Autopoiesis, which indicates her appreciation of an abstraction of a crucial aspect of life, more basic than reproduction and having to do with informational and causal closure, of which metabolism is the biological instantiation. Bacteria reflects on our preliminary deconstructive move, raising life's earliest forms to pride of place on the basis of seniority, a reversal of the usual hierarchy that places man at top. Chimerism, Disease, Ecology, Feminism, Gaia, Hybridism, Internship, Journeying, Karyotypes, Liminality, Mixotricha, Neodarwinism, Organisms, Perception, Questioning, Religion, Symbiogenetics, Thermodynamics, Undulations, Values, Xenophilia, YouTube, and Zoology round out this alphabetical foray into Margulis's world.

6:00-7:30 p.m. Public Reception, McKenzie-Merket Alumni Center Courtyard

Friday, September 14

8:45-10:15 a.m. Bruce Clarke, "The Planetary Imagination"

I will set forward the planetary imagination as a concept mediating literature and science. It occurs whenever an artist invents a planet, places it in a corresponding, perhaps imaginary cosmos, and bodies that construction forth in some workable medium. I will discuss the novels *Solaris* and *Dune* in this light. But it can also occur whenever the state and dynamics of the actual Earth and its observation are rendered in detailed descriptions that possess scientific heft. Gregory Bateson's ecology of mind and Margulis and Sagan's discourse on Gaia will be our primary examples here. What will be of particular significance about specific instances of the planetary imagination are the



models of knowing they convey—or again, the epistemological issues they put into play. A fully planetary imagination of the Earth observes a coupled and co-evolving metasystem of environment and life, an object far transcending the human. This faculty is especially significant, then, as a mode of observation that undercuts or goes beyond its own capacity to observe, and in which the theoretical construction of a planetary body for artistic, discursive, or scientific ends, for that very reason, intends to decenter the human in relation to its worldly situation.

10:30 a.m.-12:00 noon. James A. Shapiro, "Bringing Cell Action into Evolution"

Lynn Margulis was an indefatigable advocate of positive cell action in the evolutionary process. Lynn focused her work on observing real-time interactions between cells and advocating the major role of cell fusions and symbiogenesis in rapid evolutionary change. Confirmation of the mitochondrion and chloroplast in eukaryotic cells as descendants of well-defined prokaryotes was a major turning point away from the gradualist ideology that dominated evolutionary thinking for most of the 20th Century. Since then, we have come to appreciate more the major evolutionary roles of cell-cell interactions and cellular control of genome structure. The well-established phenomena of symbiosis, hybridization, horizontal DNA transfers, genome repair, and natural genetic engineering have revolutionized our understanding of genome variation. Rather than a series of accidents randomly changing a ROM (read-only memory) heredity system, we realize that active cell processes non-randomly restructure a RW (read-write) genomic storage system at all biological time scales.

1:00-2:30 p.m. James E. Strick, "The Serial Endosymbiosis and Gaia Theories: Their Incubation in NASA's Exobiology Program and Diverse Cultural Valences"

Both the Gaia hypothesis and the Serial Endosymbiosis Theory developed in and were funded by the NASA Exobiology Program first begun in 1960. This paper will explore the ways in which that program served as both crucial intellectual and financial support for each theory. Given prejudices about NASA science in the wider research community, this context also conditioned some of the skepticism with which both theories were initially received. A range of other implications of the theories is explored here, including the cultural valences that sometimes resulted

from the nature of the theories themselves and the cultural moment in which they appeared.

2:45-4:15 p.m. Susan Oyama, "Sustainable Development: Alternative Pathways in Developmental Systems Theory"

"Sustainable development" is intentionally ambiguous; much of the talk is about multiple meanings within and outside biology. The developmental analog of that multiplicity is flexibility, whose importance in evolution will be explored. Some key terms will also get attention, including transmission, construction, interaction, and contingency. Contingency is often associated with chance or randomness, but the operative meaning here is causal dependency. Organisms are ontogenetically contingent; countless dependencies can be studied within the skin and extending out beyond it to an indefinite series of conditions and processes that are themselves contingent on other factors. Yet these densely interlocked and variable complexes can generate both the variation and the stability and recurrence needed for evolution. The discussion concludes with a consideration of sustainable development, intended not only in its usual contexts of agriculture and economic growth, but also in developmental and evolutionary studies. It is both possible and satisfying to see such regularity, when it occurs, in terms of interconnected systems of contingent influences. These last include symbiotic associations, among the most sustained, and sustaining, examples of long-term resource management we have.

4:30-6:00 p.m. Peter Westbroek, "Coming to Terms with Global Change: Technology is Not Enough"

The multifarious problems of Global Change are overwhelmingly addressed in terms of management solutions through technological innovations. However, what the policy makers seem to forget is the greatest problem of all – the public disorientation and anxiety that global problems arouse. One may speak of a lingering, chronic and uncontrolled panic in large sectors of the population, already showing its ugly face in outbreaks of intolerance, fundamentalism, nationalism, and xenophobia. Instead of reacting responsibly and in concert, many people tend to take refuge in entirely counterproductive attitudes. Sadly, the great scientific programs of Global Change, for example, by the Intergovernmental Panel on Climate Change (IPPC),

tend not to diminish, but to intensify this tendency. Their short-term, century-scale perspective precludes unambiguous predictions and leaves ample room for confusion. Meanwhile, matters of public orientation are left to the free play of religious and other ideological forces, while science may only correct erroneous viewpoints, but is not thought to give rise to a coherent worldview by itself. In this paper, I shall argue that Earth System Science, with its perspective of global history over forty-six million centuries, is capable of inducing a new worldview, a universal, reality-congruent public orientation, essential for a proper response to Global Change.

Biographies

J. Baird Callicott is University Distinguished Research Professor of Philosophy and formerly Regents Professor of Philosophy at the University of North Texas. Callicott completed his MA (1966) and PhD (1972) in philosophy at Syracuse University. In 1969, he joined the philosophy department at the University of Wisconsin-Stevens Point, where he taught the world's first course in environmental ethics in 1971. He is co-Editor-in-Chief of the *Encyclopedia of Environmental Ethics and Philosophy* and author or editor of a score of books and author of dozens of journal articles, encyclopedia articles, and book chapters in environmental philosophy and ethics. Callicott has served as president of the International Society for Environmental Ethics, as Bioethicist-in-Residence at Yale University, and the UNT Department of Philosophy and Religion Studies as chair. His research goes forward on four main fronts: theoretical environmental ethics; comparative environmental ethics and philosophy; the philosophy of ecology and conservation policy; and biocomplexity in the environment, coupled natural and human systems (sponsored by the National Science Foundation). Callicott is perhaps best known as the leading contemporary exponent of Aldo Leopold's land ethic and is currently exploring an Aldo Leopold Earth ethic in response to global climate change. His teaching at UNT includes graduate and undergraduate courses in ancient Greek philosophy and ethical theory, in addition to environmental philosophy.

Sankar Chatterjee is Paul Whitfield Horn Professor of Geology and Curator of Paleontology at the Museum of Texas Tech University. He led several expeditions to India, China, Antarctica, and the American Southwest in search of dinosaurs and early birds and has discovered, named, and described several new taxa. His current research focuses on Mesozoic vertebrates, flight of pterosaurs and birds, origin of flight, mass extinction, macroevolution, plate tectonics, and paleobiogeography. His work on macroevolution encompasses the study of large-scale patterns of evolution above the species level, and mass extinctions and their long-term consequences in biodiversity. He has published more than 100 scientific papers and three books, including *New Concepts in Global Tectonics* (1992, co-edited with Nicholas Hotton), *The Rise of Birds* (1997), and *Posture, Locomotion, and Paleoecology of Pterosaurs* (2004, with R. J. Templin). His work on animal flight and Shiva

crater received national and international media coverage. With Richard Lind he is currently designing a pterodactyl-inspired drone, a robotic spy plane to master air, ground, and sea. Chatterjee has received numerous awards in recognition of his distinguished and continuing achievements in original research including the Antarctic Service Medal, Scientist of the Year (Achievement Rewards for College Scientists), L. Rama Rao Birth Centenary Award (Geological Society of India), Elected Fellow (Geological Society of America and American Association of Advancement of Sciences), Honorary Member (Golden Key National Honor Society), Best Research Scientist (Texas Tech University), and Best Bengali Scientist (Star Ananda).

Bruce Clarke is the Paul Whitfield Horn Professor of Literature and Science in the Department of English at Texas Tech University. His book publications are *Allegories of Writing: The Subject of Metamorphosis* (1995), *Dora Marsden and Early Modernism: Gender, Individualism, Science* (1996), *Energy Forms: Allegory and Science in the Era of Classical Thermodynamics* (2001), and *Posthuman Metamorphosis: Narrative and Systems* (2008). He has co-edited *From Energy to Information: Representation in Science and Technology, Art, and Literature* (2002), *Emergence and Embodiment: New Essays in Second-Order Systems Theory* (2009), and the *Routledge Companion to Literature and Science* (2010; paperback, 2012). His manuscript *Narrative, Media, Systems*, developing systems theory as a matrix of operations for narrative and media theory, is currently submitted. His ongoing book project is *Systems Countercultures*, examining American systems discourses since the *Whole Earth Catalog*. With Henry Sussman he edits the book series *Meaning Systems*, published by Fordham University Press.

Susan Oyama trained at Harvard University and is now Professor Emeritus at the John Jay College of Criminal Justice and the Graduate School and University Center (both of the City University of New York). She has written widely on the nature/nurture opposition and on the concepts of development, evolution, and genetic information. With others, she wrote and edited *Aggression* (1988), under the pen name John Klama, but is best known for her work on Developmental Systems Theory, to which many were introduced by her 1985 book, *The Ontogeny of Information: Developmental Systems and Evolution*. An expanded edition of that work appeared in 2000, along with *Evolution's Eye: A*

Systems View of the Biology-Culture Divide. With Paul Griffiths and Russell Gray, Oyama edited *Cycles of Contingency*, a volume of papers on developmental systems by scholars from many fields. She is especially interested in the role of theory in transdisciplinary relations.

Manuela Rossini holds an MA in English and Spanish Philology from the University of Basel and an MA in Critical and Cultural Theory from the University of Cardiff. She did her PhD at the University of Basel on the family in early modern drama and culture. A postdoctoral scholarship from the Swiss National Science Foundation took her to the Netherlands for six years before she returned to Switzerland in 2008 to work for the Transdisciplinary Network (td-net) of the Swiss Academies of Arts and Sciences, and, since 2009, as the co-ordinator of the Graduate School of the Institute of Advanced Study in the Humanities and the Social Sciences at the University of Bern, Switzerland. She is also the Executive Director and Vice President of the European Society for Literature, Science and the Arts (SLSA-Europe). She edits the Rodopi book series *Experimental Practices*. Her research interests include inter- and transdisciplinarity, posthumanism, animal studies, and feminism. Her recent books and editions include *From House to Home: Family Matters in Early Modern Drama and Culture* (2009), *Animal Encounters* (2009), *The Routledge Companion to Literature and Science* (2010); and *Energy Connections* (2011).

Dorion Sagan worked closely with Lynn Margulis for over 30 years, coauthoring works such as *Microcosmos*, *What is Life?*, and *Dazzle Gradually*. Author or coauthor of twenty-four books translated into eleven languages, Sagan's works include *Death and Sex*—winner of the Bookbinder's Guild of New York 2009 award for best nonfiction hardcover—and *Into the Cool*, a sustained track on the thermodynamics of life with a chapter on life's natural purpose. Sagan has lectured widely, including at the American Museum of Natural History, the Smithsonian Institution, the Artist's Institute in Manhattan, and in Xi'an, China. His writings have appeared in the *New York Times*, the *New York Times Book Review*, *Wired*, and *Cabinet*. His most recent projects include *Lynn Margulis: The Life and Legacy of a Scientific Rebel*, a book of essays with contributions from, among others, David Abram, David Ray Griffin, and Niles Eldridge, and *Cosmic Apprentice: Dispatches from the Edges of Science*, forthcoming from the University of Minnesota Press.

Jan Sapp is professor in the Department of Biology at York University in Toronto, Canada. He received his PhD in the history of science from the University of Montréal in 1984. He subsequently held an appointment at the University of Melbourne for eight years, where he also served as chair of the Department of History and Philosophy of Science. He was Andrew Mellon Fellow at the Rockefeller University, 1991-92. He held the Canada Research Chair in the History of the Biological Sciences at the University of Québec at Montréal from 2001-03 before returning to York University, where he has been a professor since 1992. His writings focus especially on evolutionary biology and ecology, emphasizing the fundamental importance of symbiosis and horizontal gene transfer in heredity and evolution. He is the author of numerous papers and several books, including *Beyond the Gene* (1987), *Where The Truth Lies* (1990), *Evolution by Association: A History of Symbiosis* (1994), *What is Natural? Coral Reef Crisis* (1999), *Genesis: The Evolution of Biology* (2003), an edited volume on *Microbial Phylogeny and Evolution: Concepts and Controversies* (2005), and, more recently, *The New Foundations of Evolution: On the Tree of Life* (2009).

James A. Shapiro is Professor of Microbiology at the University of Chicago. He has a BA in English Literature from Harvard (1964) and a PhD in Genetics from Cambridge (1968). His thesis, *The Structure of the Galactose Operon in Escherichia coli K12*, contains the first suggestion of transposable elements in bacteria. He confirmed this hypothesis in 1968 during his postdoctoral tenure in the laboratory of Francois Jacob at the Pasteur Institute in Paris. In Jonathan Beckwith's laboratory at Harvard Medical School the following year, he and his colleagues used in vivo genetic manipulations to clone and purify the lac operon of E. coli, an accomplishment that received international attention. In 1979, Shapiro formulated the first precise molecular model for transposition and replication of phage Mu and other transposons. Since 1992, he has been writing about the importance of biologically regulated natural genetic engineering as a fundamental new concept in evolution science. He is editor of *DNA Insertion Elements, Episomes and Plasmids* (1977 with Bukhari and Adhya), *Mobile Genetic Elements* (1983), and *Bacteria as Multicellular Organisms* (1997 with Martin Dworkin). He has been a leading scientific critic of orthodox

evolutionary theory for 20 years and received an honorary O.B.E. from Queen Elizabeth for services to higher education in the UK and US.

Susan Merrill Squier is Brill Professor of Women's Studies and English at Penn State University. She is the author or editor of eight books, including *Babies in Bottles: Twentieth-Century Visions of Reproductive Technology* (1984), *Liminal Lives: Imagining* the *Human at the Frontiers of Biomedicine* (2004), and *Poultry Science, Chicken Culture: A Partial Alphabet* (2011). She was scholar in residence at the Bellagio Study and Conference Center (2001); Visiting Distinguished Fellow, LaTrobe University, Melbourne, Australia; and Fulbright Senior Research Scholar, Melbourne, Australia. She is Advisory Board Member of SymbioticA Biological Arts (Perth) and of the Society for Literature, Science, and the Arts. She co-directed an NEH Institute on "Medicine, Literature and Culture" at the Penn State College of Medicine, Hershey Medical Center. She co-organized three international conferences on comics and medicine: "Graphic Medicine" (London 2010), "Comics and Medicine: Sequential Art and Illness" (Chicago 2011), and "Graphic Medicine: Voices from the Margins" (Toronto 2012). She co-edits the *Graphic Medicine* book series at Penn State Press.

James E. Strick is Associate Professor in the Program in Science, Technology and Society, and chair of the Department of Earth and Environment at Franklin and Marshall College in Lancaster, PA. Originally trained in microbiology, and later in history of science, Dr. Strick has published extensively on the history of ideas and experiments about the origin of life, including *Sparks of Life: Darwinism and* the *Victorian Debates over Spontaneous Generation* (2000) and, with Steven Dick, *The Living Universe:* NASA *and the Development of Astrobiology* (2004). He is also the editor of two six volume collections of primary sources: *Evolution and the Spontaneous Generation Debate* (2001) and *The Origin of Life Debate: Molecules, Cells, and Generation* (2004). Strick has been an advisory editor of *ISIS* and a member of the History of Science Society Council. He is currently at work on a book about Wilhelm Reich's bion experiments on the origin of life, 1934-1939, under contract with Harvard University Press.

Peter Westbroek is Emeritus Professor of Geophysiology at Leiden University and a member of the Royal Netherlands Academy of Sciences and Arts. He occupied the European Chair of the Colege of France in 1996–97. Westbroek studied geology and did his PhD in fossil brachiopod paleobiology at Leiden University in the Netherlands. He then had a post-doctoral position at Queen's University in Belfast, where he began biochemical research on biomineralization. In 1970 he started a small group in the Department of Biochemistry at Leiden University, with research on calcification in the coccolithophore Emiliania huxleyi, immunology of fossil macromolecules, and bacterial manganese and iron oxidation. Westbroek gave regular lecture courses on the influence of biological systems on Earth dynamics, and published *Life as a Geological Force* in 1992. He started the Global Emiliania Modeling Initiative (GEM), an international and interdisciplinary project on the climatic effects of marine phytoplanton. He recently co-founded the Gaia Science Center. A book in English, *Discovery of the Earth: Big History of a Small Planet*, is forth coming.