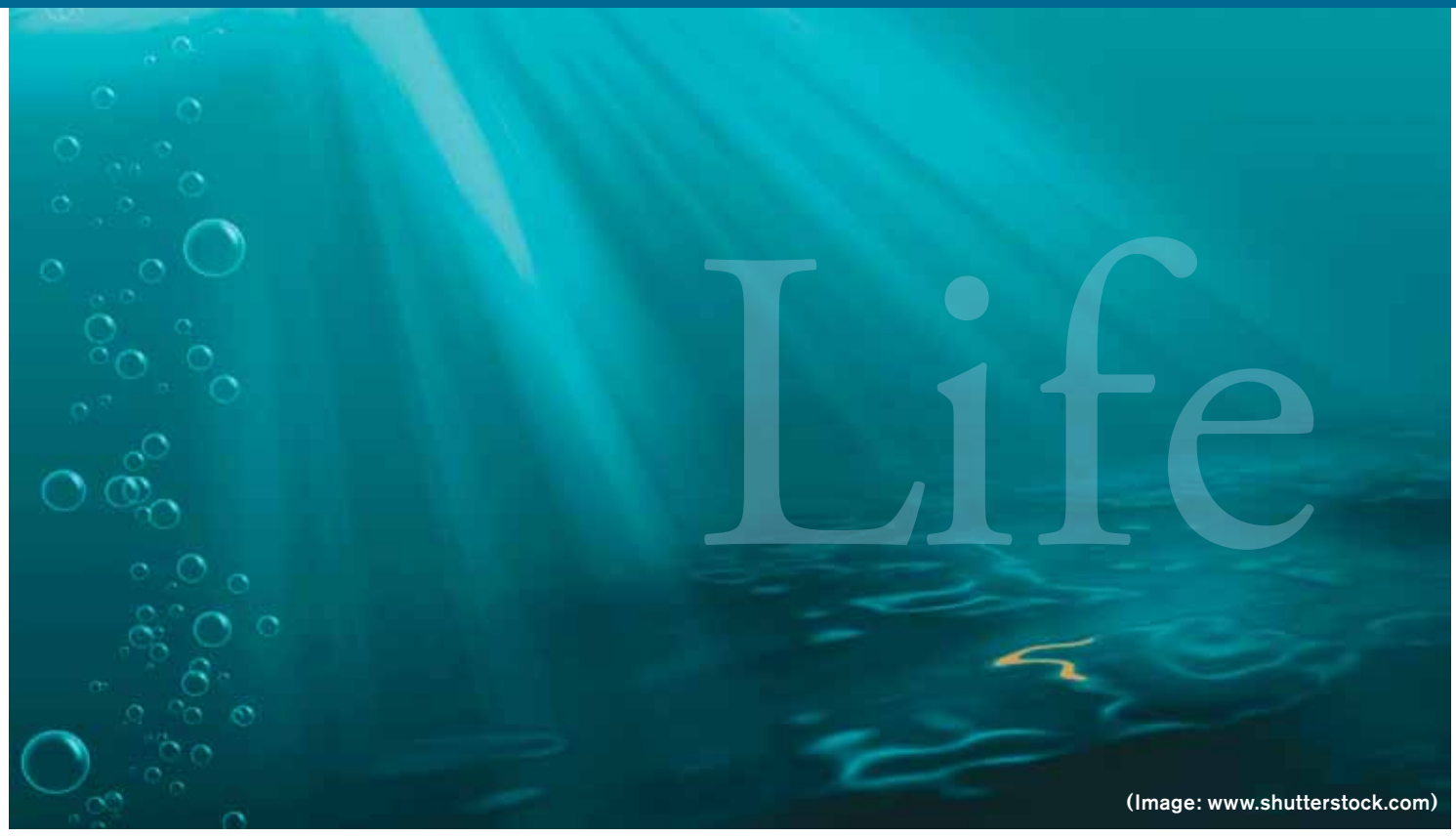
SANTA FE INSTITUTE

# Update

May / June 2011




(Image: www.shutterstock.com)

## Tying Earth's chemistry to life's beginnings

Every living thing we know of derives from existing biology, but scientists still don't agree on how abiotic molecules originally bootstrapped themselves into the building blocks of life four billion years ago.

Now, three SFI researchers are are taking a fresh look at what physics, chemistry, and biology can tell us about which processes viably contributed to life, and which probably did not. Their work could shed new light on one theory of the origin of life, known as the metabolism-first theory. (See "Competing theories describe the origin of life" on page 3.)

With his background in statistical mechanics, SFI Professor D. Eric Smith is applying first principles to the metabolism-first theory by looking at how the fundamental constraints of physics and chemistry drive reaction networks in such a way that organic order could have emerged in a randomly varying environment – in other words, what, mathematically speaking, was likely to have happened and what wasn't likely given what we know.

"The phylogenetic tree is tied to the chemistry of the rocks and minerals of Earth – even to where we are around this star [a reference to the temperature conditions needed for initial life]," he points out, and it makes the most sense to look for biological processes initially occurring in simple networks under likely conditions, he says.

Eric's work complements that of SFI Science Board Chair Emeritus Harold Morowitz, a professor of biology and natural philosophy at George Mason University and the Krasnow Institute. Harold's five decades of research on the origins of life has advanced the biochemical approach in the metabolism-first theory, inferring what was necessary in the origin of life from what is universal in the biosphere today.

His work supports the idea that the citric acid cycle – the chemical reaction in cells that leads to the conversion of carbohydrates, fats, and proteins into carbon dioxide and water to generate usable energy – is at the core of all life. Harold cites the discovery in the late 1970s that when this cycle is run in reverse, it converts carbon into organic molecules, and he argues it thus provides a viable pathway for life to have begun in Earth's early, oxygen-free environment.

"Remarkably, life's very basic metabolism hasn't changed in the last four billion years," explains Harold – even in bacteria that reproduce every 20 minutes. Such intense conservation means the pathway is either a fortuitous

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RESEARCH NEWS

## Life is rife with quantum mechanics

Seth Lloyd got interested in the quantum mechanics of biological processes in an unusual way. Back in 2007, the *New York Times* reported on a team of physicists who suggested that a particular microorganism called green sulphur bacteria acted like a quantum computer, and it was doing so to make photosynthesis more efficient.

Initially Seth, an SFI External Professor now visiting SFI as an Institute Miller Scholar, and his MIT colleagues didn't take it seriously. "We thought this was really funny, [but] I got designated to look into it," he says. While some of the details in the article were off, it turned out that green sulphur bacteria *were* doing quantum computations.

Life, it turns out, is full of quantum mechanics, he says. This spring Seth is hosting a series of workshops to explore the young field of quantum biology and the role of quantum mechanics in everything from photosynthesis to our highly discriminating sense of smell.

Although many biological processes take place on the level of atoms and molecules

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Seth Lloyd (SFI photo by Insight Foto, Inc.)

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RESEARCH NEWS

## Slow and steady wins evolution race

Slower-evolving bacteria start slow, but their gradual adaptation means they take advantage of later mutations passed up by faster-evolving bacteria – and eventually out-evolve their speedier rivals – according to a study led by SFI Science Board member Richard Lenski.

The research carried out in Richard's lab at Michigan State University on lineages of *E. coli* shows that rapidly evolving "hare" bacteria were eventually overtaken by slower adapting "tortoise" bacteria.

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RESEARCH NEWS

## Physical sciences will inform new theories in biology

A *Journal of Theoretical Biology* paper co-authored by several SFI scientists explores the prospects for general, predictive theories in biology akin to those in the physical sciences, and suggests that such theories take inspiration from physics and the information sciences.

Scientific theories seek to provide simple explanations for significant empirical regularities based on fundamental physical and mechanistic constraints, the authors write. But biological theories have rarely reached a level of generality and predictive power comparable to physical theories.

At the same time, model building has proven to be useful for explaining and predicting the behavior of particular biological systems. In this respect biology resembles alternative model-rich frameworks, such as economics and engineering.

"Future theoretical biology is likely to represent a hybrid of parsimonious reasoning and algorithmic or rule-based explanation," the authors write. "In this context, we discuss the role of machine learning in the early stages of scientific discovery."

Authors of the March 7 paper include SFI Faculty Chair David Krakauer; James Collins

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## LIT BITS

Modalities of word usage in intentionality and causality; **Herbert Gintis**; *Behavioral and Brain Sciences* 33 (4), August 2010

Phase transitions in least-effort communications; Prokopenko, M.; **Nihat Ay**; Obst, O.; Polani, D.; *Journal of Statistical Mechanics – Theory and Experiment*, November 2010

Nonperturbative predictions for cold atom Bose gases with tunable interactions; **Fred Cooper**; Chien, C.C.; Mihaila, B.; Dawson, J.F.; Timmermans, E.; *Physical Review Letters* 105 (24), December 2010

Combinatorial vector fields and the valley structure of fitness landscapes; Stadler, B.M.R.; **Peter Stadler;** *Journal of Mathematical Biology* 61 (6), December 2010

Stability and dynamical properties of Cooper-Shepard-Sodano compactons; Mihaila, B.; Cardenas, A.; **Fred Cooper**; Saxena, A.; *Physical Review E* 82 (6 pt. 2), December 2, 2010

Time evolution towards q-Gaussian stationary states through unified Ito-Stratonovich stochastic equation; dos Santos, B.C.; **Constantino Tsallis**; *Physical Review E* 82 (6 pt. 1), December 13, 2010

Exploring the randomness of directed acyclic networks; Goni, J.; Corominas-Murtra, B.; **Ricard Solé**; Rodriguez-Caso, C.; *Physical Review E* 82 (6 pt. 1), December 13, 2010

Random graphs containing arbitrary distributions of subgraphs; Karrer, B.; **Mark Newman**; *Physical Review E* 82 (6 pt. 2), December 30, 2010

Evolvability and robustness in a complex signaling circuit; Raman, K.; **Andreas Wagner**; *Molecular Biosystems* 7 (4), 2011

The unsmooth trajectory of Benoit Mandelbrot; **J. Doyne Farmer**; *Quantitative Finance* 11, 2011

Energetic limits to economic growth; **Jim Brown**; Burnside, W.R.; Davidson, A.D.; DeLong, J.P.; Dunn, W.C.; **Marcus Hamilton**; Mercado-Silva, N.; Nekola, J.C.; Okie, J.G.; **Woody Woodruff**; Zuo, W.Y.; *Bioscience* 61 (1), January 2011

Community characterization of heterogeneous complex systems; Tumminello, M.; Micciche, S.; **Fabrizio Lillo**; Varho, J.; Piilo, J.; Mantegna, R.N.; *Journal of Statistical Mechanics – Theory and Experiment*, January 2011

A comprehensive classification of complex statistical systems and an axiomatic derivation of their entropy and distribution functions; Hanel, R.; **Stefan Thurner;** *EPL* 93 (2), January 2011

Erratic flu vaccination emerges from short-sighted behavior in contact networks; Cornforth, D.M.; Reluga, T.C.; Shim, E.; Bauch, C.T.; Galvani, A.P.; **Lauren Ancel Meyers**; *PLOS Computational Biology* 70 (1), January 2011

# Achievements

SFI Science Board Co-Chair and External Professor Marcus Feldman of Stanford University will receive one of three 2011 Dan David Prizes on May 15 at Tel Aviv University. The $1 million prize recognizes his research in human and animal evolution, as well as mathematical theory applied to evolution of behavior.

SFI Trustee Mari Kooi, CEO of Wolf Asset Management International, has been named by the *Financial Times* as one of the top 100 board candidates for Fortune 1000 companies. Kooi has more than three decades experience in direct trading and investment management and has served on more than 40 boards of companies, funds, and nonprofits.

SFI External Professor Scott Page will be among 212 fellows inducted into the American Academy of Arts and Sciences on October 1, 2011, in Cambridge, Mass. Scott is the Leonid Hurwicz Collegiate Professor of Complex Systems, Political Science, and Economics at the University of Michigan.

Former SFI Omidyar Fellow Willemien Kets has accepted an offer to join the Kellogg School of Management at Northwestern University in summer 2012 as an assistant professor.

X-Ray Earth, a two-hour National Geographic Channel special expected to debut May 15 at 8 p.m. EST, will feature the city scaling work of SFI External Professor Luis Bettencourt and Distinguished Professor Geoffrey West.

### > *Theories in biology*

**continued from page 1**

(Arizona State University); SFI Professor Doug Erwin; SFI Professor Jessica Flack; SFI Science Board member and External Professor Walter Fontana; Manfred Laubichler (Arizona State University); Sonja Prohaska (University of Leipzig); SFI Distinguished Professor Geoffrey West; and SFI External Professor Peter Stadler. ■


## CREDITS

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The *SFI Update* is published bi-monthly by the Institute to keep its community informed. Please send comments or questions to John German at *jdg@santafe.edu*.

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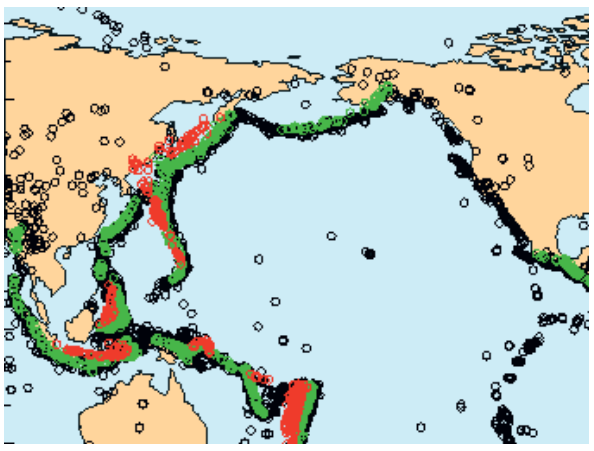
RESEARCH NEWS

# Mathematically, market and tectonic plate stresses have much in common

Studying the unbalanced, punctuated movement of land during a large earthquake reminds SFI External Professor John Rundle of the 2007 housing market financial crash.

John, a distinguished professor in the UC Davis departments of geology and physics, has been looking at large quakes as examples of first order phase transitions that create sudden dramatic shifts not common to systems that are in equilibrium.



Seismic activity around the Pacific (Image: Lamont-Doherty Cooperative Seismographic Network)

For quakes, motion on either side of a tectonic plate boundary gradually creates stresses that build up between the plates, which will then slip periodically.

"In a financial situation, there's a buildup in leverage or a buildup in debt that causes that sort of stress or pressure," he says. "Asset values can increase unsustainably during the process, leading eventually to a sudden adjustment or 'crash' and a state of lower wealth." The crash and subsequent time-clustered adjustments in other market sectors can be described mathematically, he says, in much the same way mathematics can describe earthquakes.

The 9.0 quake that devastated the area around Sendai, Japan in March is an example of that dramatic movement, and also reason to be wary because it could be part of what John thinks is a clustering of large earthquakes over short periods of time.

"If you look at the largest earthquakes, larger than 8.5, over the last 100 years, you'll see most of them occurred between 1960 and 1965 – and there's a second period now with five large earthquakes that have occurred between 2007 and today," he says. "There seem to be these big pulses."

If that clustering effect holds, we might expect more large quakes around the Pacific Plate in the next couple of years, possibly even along the San Andreas in California, he says.

John and a group of scientists have launched a website that looks into these ideas in more detail at www.openhazards.com. ■

RESEARCH NEWS

# Initially farming was a step backward

Economist and SFI Professor Sam Bowles says the agricultural revolution that saw the advent of farming and herding 12,000 years ago was, in fact, a step backward technologically.

The traditional view of agriculture's adoption – during what's called the "Holocene Revolution" – is that hunter-gatherers took up cultivation because it was a better, more efficient way to make a living, Sam says. Like the bow and arrow, the steam engine, or the computer, in this widely held economic model of technical change, cultivating plants rather than foraging wild species is believed to have raised the productivity of human labor, encouraging adoption of the new technology and allowing farming populations to grow.

Sam, using archaeological evidence and data about hunting and gathering technologies and primitive farming, estimated the calories produced by an hour of work in both pre-historic farming and foraging and found that individual farmers were about two-thirds as productive as individual foragers, on average.

"It certainly wasn't a better mouse trap," says Sam. "Farming did not take off because it lessened the toil of subsistence. Rather, its early success probably had more to do with its social, military, and demographic advantages."

In particular, he suggests, the reduced mobility of farming might have lowered the costs of child rearing because hunter-gatherer women had to carry their children while farmers didn't. In addition, stored grain and livestock had to be protected from looters, which might have encouraged farming populations to stay close and invest in defense.

(Image: USAID)

His paper was published online March 7 in *Proceedings of the National Academy of Sciences.* ■

INSIDE SFI

# New SFI board, faculty members

SFI made several appointments to its advisory boards and faculty during the Institute's annual science board symposium and meeting in April. Terms begin July 1, 2011.

## Board of Trustees

Five people have been named to the Institute's Board of Trustees.

**Greg Amadon**, Founder and CEO of Terabeam Corporation, and founder of Virtual i-O Inc., Cellular Technical Services Company, Inc., and Portable Technologies

**Karen Heim-Amadon**, philanthropist, angel investor, and entrepreneur

**Jenne Britell**, Chairman of the Board of United Rentals, Inc. and Senior Managing Director of Brock Capital Group LLC

**Michael Collins**, President of Collins Capital, former President and Chairman of Fidelity Union Life Insurance Company, and former President of Allianz of America

**Cormac McCarthy**, Pulitzer Prize-winning novelist and playwright and longtime SFI writer in residence

The Institute also reappointed **Pierre Omidyar,** Founder and Chairman of eBay. Omidyar rotated off the Board in 2010 for a mandatory one-year hiatus.

## Science Board

SFI has made ten new appointments and three reappointments to its Science Board.

**New appointments:**

Nina Fedoroff, Penn State University; Nigel Goldenfeld, University of Illinois at Urbana-Champaign; Erica Jen, Signition, Inc.; Tim Kohler, Washington State University; Peter Littlewood, Argonne National Laboratory; Seth Lloyd, MIT; Lauren Ancel Meyers, UT Austin; Dawn Rose, UC Berkeley; Thomas Rosenbaum, University of Chicago; Montgomery Slatkin, UC Berkeley

**Reappointments:**

David Campbell, Boston University; Simon Levin, Princeton University; Robert May, Baron of Oxford, University of Oxford, Imperial College London

## Science Steering Committee

SFI has reappointed Doug Erwin, Smithsonian Institution, and Henry Wright, University of Michigan Museum of Anthropology, to its Science Steering Committee.

## External professors

Eight scientists have been appointed to SFI's external faculty: Jenna Bednar, University of Michigan; Elhanan Borenstein, University of Washington; Fred Cooper, Los Alamos National Laboratory; Katherine Demuth, Macquarie University; Daniel Dennett, Tufts University; Mark Johnson, Macquarie University; Patricia McAnany, University of North Carolina, Chapel Hill; David Wolpert, NASA Ames Research Center. ■

## LIT BITS (cont.)

PLEXY: Efficient target prediction for box C/D snoRNAs; Kehr, S.; Bartschat, S.; **Peter Stadler**; Tafer, H.; *Bioinformatics* 27 (2), January 15, 2011

Optimizing tactics for use of the U.S. antiviral strategic national stockpile for pandemic influenza; Dimitrov, N.B.; Goll, S.; Hupert, N.; Pourbohloul, B.; **Lauren Ancel Meyers**; *PLOS One* 6 (1) January 19, 2011

Identification of amino acid substitutions associated with neutralization phenotype in the Human Immunodeficiency Virus Type-1 Subtype C gp120; Kirchherr, J.L.; Hamilton, J.; Lu, X.Z.; Gnanakaran, S.; Muldoon, M.; Daniels, M.; Kasongo, W.; Chalwe, V.; Mulenga, C.; Mwananyanda, L.; Musonda, R.M.; Yuan, X.; Montefiori, D.C.; **Bette Korber**; Haynes, B.F.; Gao, F.; *Virology 409* (2), January 20, 2011

Chinese characters reveal impacts of prior experience on very early stages of perception; Elze, T.; Song, C.; Stollhoff, R.; **Jüergen Jost**; *BMC Neuroscience* 12, January 26, 2011

Deficits in long-term recognition memory reveal dissociated subtypes in congenital prosopagnosia; Stollhoff, R.; **Jüergen Jost**; Elze, T.; Kennerknecht, I.; *PLOS One* 6 (1), January 25, 2011

Improving community detection in networks by targeted node removal; Wen, H.R.; Leicht, E.A.; **Raissa D'Souza**; *Physical Review E* 83 (1 pt. 2), January 28, 2011

Reconstructing the history of marriage strategies in Indo-European-speaking societies: Monogamy and polygyny; **Laura Fortunato**; *Human Biology* 83 (1), February 2011

Reconstructing the history of residence strategies in Indo-European-speaking societies: Neo-, uxori-, and virilocality; **Laura Fortunato**; *Human Biology* 83 (1), February 2011

Reconstructing the history of marriage and residence strategies in Indo-European-speaking societies; **Laura Fortunato**; *Human Biology* 83 (1), February 2011

The domain of the replicators selection, neutrality, and cultural evolution; **Stephen Lansing**; Cox, M.P.; *Current Anthropology* 52 (1), February 2011

Venation networks and the origin of the leaf economics spectrum; Blonder, B.; Violle, C.; Bentley, L.P.; **Brian Enquist**; *Ecology Letters* 14 (2), February 2011

Spatial patterns of phylogenetic diversity; Morlon, H.; Schwilk, D.W.; Bryant, J.A.; **Pablo Marquet**; Rebelo, A.G.; Tauss, C.; Bohannan, B.J.M.; **Jessica Green**; *Ecology Letters* 14 (2), February 2011

Genomic imprinting and conflict-induced decanalization; **Jon Wilkins**; *Evolution* 65 (2), February 2011

## > *Beginnings of life* continued from page 1

accident, the best way to turn Earth's rocks and minerals into life, or the only solution – "in which case, it will be found everywhere in the universe."

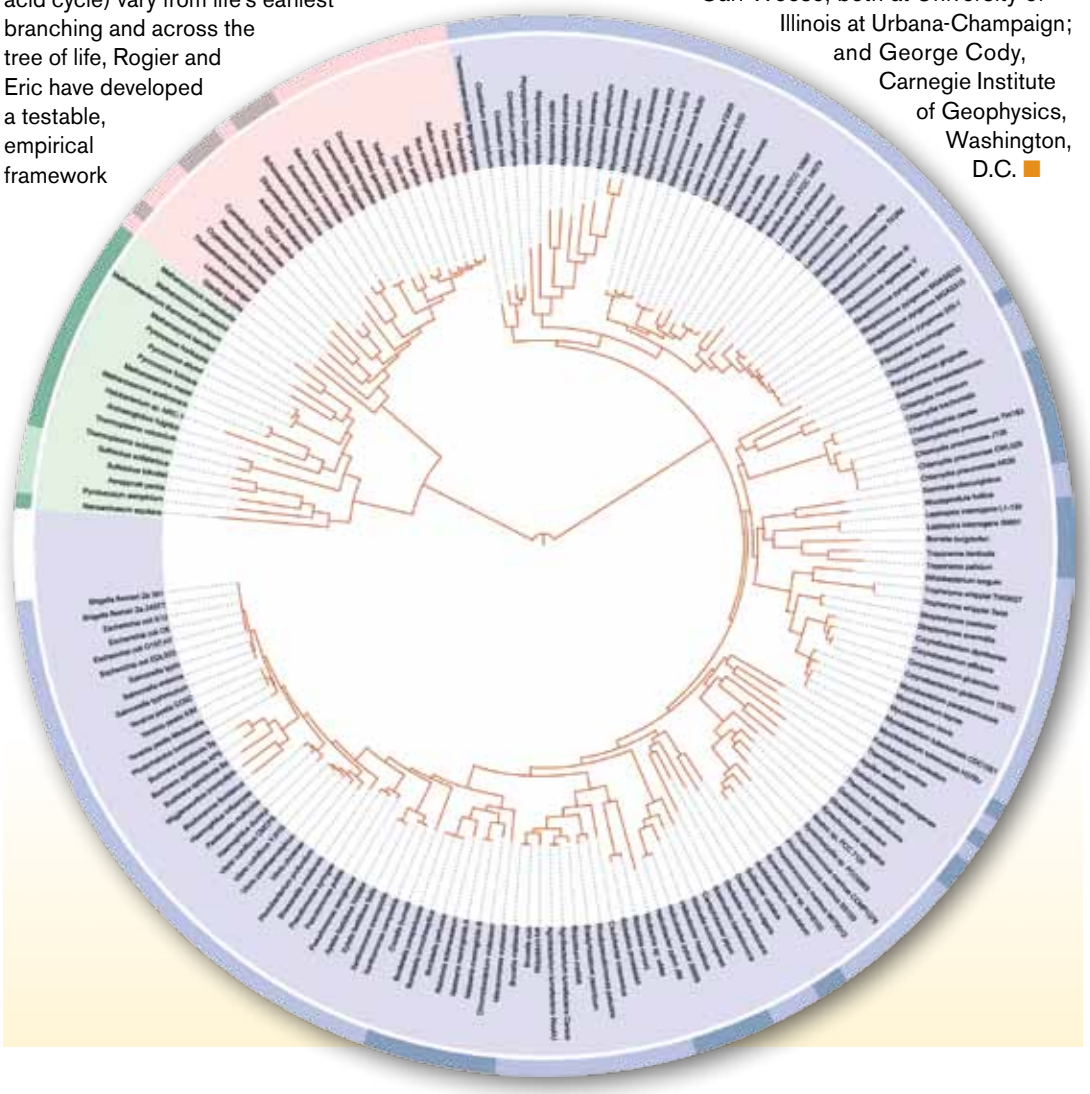
Currently, Harold is using the hardy thermophilic bacteria *Aquifex aeolicus* to study transition points, such as how the cycle originated from organics and then proceeded to make building blocks like amino acids and nucleotides to put together living cells. He and Eric also have modeled molecular structures including transition metals and ligands, concluding these structures could act as catalysts for basic biochemicals.

SFI Omidyar Fellow Rogier Braakman is taking a systems look at the metabolism-first theory, mapping the development of carbon fixation throughout the history of the biosphere. By looking at how these metabolic pathways (which include the reverse citric acid cycle) vary from life's earliest branching and across the tree of life, Rogier and Eric have developed a testable, empirical framework for the evolution of carbon fixation. The work could lead to a "phylometabolic tree" that illuminates much about the shape and structure of the phylogenetic tree.

"If you can show how the main pathways are related, you can say a lot about living systems as a whole," Rogier says. "It feels like you're getting a glimpse of the fabric of life at its deepest, most primitive level."

The SFI scientists expect to publish a series of new findings in the coming months.

Their work forms part of a five-year, $5 million Frontiers in Integrative Biological Research (FIBR) grant from the National Science Foundation. Other contributors include Shelley Copley at the University of Colorado, Boulder; Nigel Goldenfeld and Carl Woese, both at University of Illinois at Urbana-Champaign; and George Cody, Carnegie Institute of Geophysics, Washington, D.C. ■



A phylogenetic tree of life. The center represents the last universal ancestor of all life on Earth. Colors represent the three domains of life: pink for eukaryota (animals and plants); blue for bacteria; and green for archaea.

## > *Quantum life* continued from page 1

– the level quantum mechanics was designed to understand – most physicists thought biological processes could be explained without worrying about the quantum details.

In cases like photosynthesis, that turns out to be wrong. Photosynthesis requires moving light energy to reaction centers, which convert it to chemical energy, but there are many paths to take and not all lead to reaction centers. Seth and others recently showed that quantum coherence and entanglement allow the energy to take many paths at once and use information from each path to find reaction centers quickly, making efficient photosynthesis – and plant life – possible.

Quantum biology brings with it even odder possibilities. Among them, our noses could be detecting molecules' quantum mechanical vibrations, and birds might be using a quantum property of electrons as tiny compasses, guiding them north and south during migration.

The results are exciting, though Seth says he isn't sure where the field is headed. "One possibility is there's loads of quantum hanky panky going on in these living systems that's just waiting to be discovered," or quantum biology might comprise photosynthesis and a few other things. Likewise, the field might give us new insight into the origin of life – or it might only reveal some of nature's more impressive feats of engineering.

Even if photosynthesis is the only place where quantum biology matters, that's still important, he says. "The unphotosynthetic life," says Seth, "is not worth living." ■

## Competing theories describe the origin of life

The famous Miller-Urey experiment in 1953 showed it's possible to get organic molecules from simple compounds under the right, vaguely primordial conditions. Subsequent research has led to two major origin of life camps: RNA World adherents and metabolism first proponents.

Following two Nobel-prize-winning discoveries showing that RNA can serve as a hereditary template *and* catalyze reactions, RNA World proponents suggest that this molecule (or an earlier version) played both roles in all early life, before DNA and proteins appeared and took on their specialized roles.

Some RNA World adherents go further, asserting that the hereditary role of RNA was the defining essence of early life, creating metabolism, cells, and everything else about life from an almost-free range of possibilities.

Metabolism-first adherents generally accept the dual function of RNA in very early life, but they are skeptical that the Darwinian role of RNA was the *first* step, or the one that defined life. They argue that the initial appearance of such a heavy organic molecule as RNA is just too serendipitous, unless it occurs within a chemical environment that is already structured, in which case much of that structure did not come *from* RNA but rather was given *to* it.

They posit that chemical reaction pathways emerged to convert carbon into organic compounds, giving rise to a system that could speed reactions, ensure its own persistence, and allow increasingly complex molecules and systems to form. ■

## Exhibit: Origin of life science as it happens

A team led by SFI Science Board member Harold Morowitz and SFI Professor D. Eric Smith is developing "Emergence: A New View of Life's Origins," a permanent exhibit for the New Mexico Museum of Natural History & Science in Albuquerque. The exhibit, developed with a National Science Foundation grant of $162,822, is scheduled to open at the museum this summer.

The development team includes media arts students at New Mexico Highlands University, museum staff, and representatives from the Institute of Complex Adaptive Matter, Americorps, and the New Mexico Department of Cultural Affairs.

Mimi Roberts, Director for Media Projects at Cultural Affairs, says the exhibit offers "the opportunity to present to the public something museums rarely have the opportunity to put on exhibit, which is science as it is happening. Origin of life research is happening all over the world, but some of the most important and exciting discoveries are being made right here in New Mexico."

This project is valuable experience for the students involved, says Highlands Media Arts Assistant Professor Megan Jacobs. "They learn how to work, how to collaborate. It's valuable in the transition from student to professional work. They have to take cutting-edge information and make it visually interesting. The classroom setting is important, but knowing the public will see their work makes it really important, and rewarding." ■

## Workshop: Teaching the origins of life

The discovery of extrasolar planets, detection of evidence for life on Mars and Titan, and the exploration of extreme terrestrial environments, – all during the last decade – underscore the need for a better understanding of the definition of life and the factors that led to its emergence.

This summer 25 high school science teachers from New Mexico, Colorado, Wyoming, Illinois, Virginia, and the District of Columbia will be on the Fairfax, Virginia, campus of George Mason University for a joint SFI-GMU workshop on the origins of life. Participating teachers will hear from scientists working at the frontiers of the field. Collaborating with the scientists and curriculum experts, they will develop course materials and plans for their classrooms.

Program coordinator Paul A. Cammer, Director of the Neuroscience Research Laboratory at Thomas Jefferson High School for Science and Technology in Alexandria, Virginia, says, "We worked hard at achieving a balance of disciplines: There are teachers of biology, chemistry, physics, geology, and math from urban and rural schools. It's quite a mix, and it should be very interesting." ■

## > *Slow and steady* continued from page 1

The researchers sampled the bacteria after 500, 1,000, and 1,500 generations of evolution. By looking for the presence of five beneficial mutations, the researchers found that the "hare" bacteria had more advantageous genetic changes than "tortoises" after 500 generations, suggesting they were more likely to go on to successfully survive and reproduce, and to eventually wipe out their competitors altogether.

But looking at the later generations, the team found that "tortoises" had overtaken "hares" and gone on to dominate the population.

The paper was published online March 18 in *Science*. ■

(Image: Mattosaurus, Wikimedia Commons)

## SFI IN THE NEWS

Three recent columns in the *Santa Fe New Mexican*, all written by SFI Omidyar Fellow Nathan Collins, covered the work of SFI Professor Jennifer Dunne and her collaborators to quantify the complex interactions among humans and other species in their food web, SFI Omidyar Fellow Scott Ortman's investigation of human migration in the U.S. Southwest, and SFI Miller Scholar Seth Lloyd's efforts to understand the roles quantum mechanics plays in biological systems.

*USA Today* and ABCNews.com covered a March 7 *PNAS* paper by SFI Professor Sam Bowles suggesting that the advent of farming and herding 12,000 years ago was, in fact, a step backward technologically.

*USA Today, San Jose Mercury News,* and *Seattle Times* recently covered a study published in the March 7 PNAS co-authored by SFI Science Board Co-Chair Marcus Feldman suggesting, based on new analysis of genetic diversity among hunter-gatherer populations, that modern humans likely originated in southern Africa rather than eastern Africa as was generally assumed.

A March 18 *Wired* article about co-movement in stock values as a signal for impending market crashes quotes SFI External Professor Dirk Helbing on the limitations of mainstream economic theory.

The March 21 *New York Times* and several other national publications covered recent research led by SFI Science Board member Richard Lenski on the evolutionary patterns in many generations of bacteria.

In the April 4 *Arizona Daily Star*, SFI External Professor Brian Enquist describes recent work to discover what mathematical rules govern the size, shape, and other features of trees and plants.

*The American Prospect* on April 10 covered a recent talk by SFI Science Board member W. Brian Arthur at the Institute for New Economic Thinking's 2nd annual conference, at which he says we're in a complex economy that is "organic, self-constructing, roiling with change, history-contingent, imperfect, and messy."

An April 15 *Wall Street Journal* article on human language evolution quotes SFI's Murray Gell-Mann, who suggests it is possible to use data from modern languages to trace language origins back 10,000 years or further.

In an April 15 interview with the online magazine *Ubiquity*, SFI Science Board member Melanie Mitchell surveys the history, status, and promise of the sciences of complexity.

An April 23 *Wall Street Journal* article about how researchers are harvesting details of cell phone data to uncover the hidden patterns of human society quotes former SFI Omidyar Fellow Nathan Eagle, who says we can quantify human movement on a scale that wasn't possible before.

An April 25 interview with SFI Professor Jennifer Dunne on SmartPlanet.com, a CBS Interactive news site on environment and ecology, covers her work with collaborators to quantify the interactions among humans and other species in their food webs.

***Find these articles and more SFI news – and sign up to receive notifications via Twitter, Facebook, or RSS – at www.santafe.edu.***

# Upcoming SFI community lectures

**Wednesday, May 18 – Can financial engineering cure cancer, solve the energy crisis, and stop global warming?** Lessons from the financial crisis could pave the way for future achievements, according to Andrew Lo, Harris & Harris Group Professor at the MIT Sloan School of Management and Director of MIT's Laboratory for Financial Engineering. Lo will provide an overview of the crisis, describe the role mathematics played, and suggest how a deeper understanding of human nature may allow us to focus the power of global financial markets on key societal challenges. Generously underwritten by Dr. Penelope Penland.

**Wednesday, June 29 – From democratic consensus to cannibalistic hordes: The principles of collective animal behavior.** Iain Couzin, assistant professor of ecology and evolutionary biology at Princeton University, will explore how individual behavior produces group dynamics, from locust swarms to human society. Generously underwritten by the Allene and Jerome Lapides Foundation in honor of the Santa Fe Animal Shelter.

Los Alamos National Bank is sponsoring the 2011 SFI community lecture series. All lectures are at the James A. Little Theater in Santa Fe and begin at 7:30 p.m. Admission is free, but seating is limited. ■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## RESEARCH NEWS

# Did Four Corners people leave Mesa Verde for a better life?

SFI Omidyar Fellow Scott Ortman has proposed a new, transdisciplinary answer to a longstanding puzzle – why the Mesa Verde people of the U.S. Southwest's Four Corners region left the area 700 years ago, and what became of them.

Archaeologists know the Mesa Verde population collapsed around the same time the Tewa population exploded, suggesting Mesa Verde people migrated to northern New Mexico from the Four Corners. But Tewa pottery and architecture don't match that of Mesa Verde, meaning Mesa Verde culture was somehow lost – or Mesa Verde people went elsewhere.

Using previously collected craniometric data and models drawn from population genetics, Scott identified genetic links between ancestral Tewa and Mesa Verde people, proving that the Tewa people did come to northern New Mexico from the area around Mesa Verde.

Combining this evidence with archaeological studies of the speed and magnitude of the migration, he hypothesizes that Tewa ancestors deliberately changed their culture when they moved.

That change, Scott says, likely involved the rejection of Mesa Verde culture. The Mesa Verde society had a pronounced social hierarchy – it's "pretty obvious" where their leaders lived, he says – while ancestral Tewa society did not, indicating they may have come to New Mexico to make a clean break with the past and to create a more communal and egalitarian society.

Questions remain, Scott says, but his results suggest that major political movements and social transformations, what complexity theorists call "phase transitions," are not limited to modern or complex urban societies. Rather, they may be an inherent feature of human evolution. ■

## *DONOR PROFILE*

# Andy Berg: 'What box? There is no box'

As a transactional attorney at the Debevoise and Plimpton law firm in New York, Andy Berg solves complicated puzzles. He works on large international acquisition transactions, which – like complex adaptive systems – take on a life of their own.

Every deal requires navigating a maze of international statutes and regulations in a changing environment. Berg says he enjoys the creativity required of ensuring that clients reach their goal of closing the deal when the path to that goal is never straight or clear. "You have to get used to the floor moving under your feet," he says.

The phrase "think outside the box" is a cliché, but Berg believes SFI takes the metaphor to a higher level. "What box? There is no box," he says. "When you have a problem, you approach it with any tools you have; you don't categorize it first."

Originally planning to be a mathematician, Berg changed career paths but retained his appreciation for the beauty and power of mathematics. One of the characteristics that lit his interest in SFI was its application of mathematics to a wide range of problems, including social sciences.

"Mathematics imposes a high level of discipline on your thinking and your ability to distill something to its essence," he says. Remaining involved in the sciences through SFI has been an outlet for his insatiable curiosity.

He believes SFI researchers are working on important problems, but their contributions are magnified because of the potential for an interdisciplinary approach to produce real-world results.

He explains his generosity to SFI this way: "Here's this spectacular little place doing incredible work. It has virtually no endowment, and its staff recently had to take a pay cut. It's an institution making an outsized contribution." ■

# SFI Online

**Multimedia and supplementary content available at *www.santafe.edu/news.***

**Video: Cryptography in a quantum world**
SFI Professor Cris Moore, in an April 13 SFI community lecture, describes the history of cryptography, discusses how modern cryptosystems work, and explains how a future quantum computer would break them.

**Audio: What science and art have in common**
On NPR's Science Friday, author and SFI Trustee Cormac McCarthy trades quips with host Ira Flatow about the relationships between science and art.

**Audio: Scientists should address food, energy, and water**
In an online interview, AAAS President and SFI External Professor Nina Fedoroff says it has "never been more important for scientists to work together on the big issues confronting the world: food, energy, and water."

**Video: How inheritance sustains inequality**
In a PBS News Hour special report, economist and SFI Professor Sam Bowles explains why inequalities passed from generation to generation through wealth inheritance are persistent and problematic.

**Video: Finding a way forward in Afghanistan**
During an SFI community lecture on March 2, SFI Diplomat in Residence Bill Frej describes the complex system of Afghanistan and the challenges of achieving sustainable development in that war-torn country.

**Video: The physics of urbanization**
As part of *The Economist* magazine's "Ideas Economy: Intelligent Infrastructure" event in New York City in February, SFI Distinguished Professor Geoffrey West describes some findings he and SFI External Professor Luis Bettencourt and their collaborators have made about cities and urbanization.

**Additional videos of SFI science seminar speakers are available at *www.santafe.edu/research/videos/catalog/***