



January / February 2014

UPDATE



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SANTA FE INSTITUTE

New Science. New Horizons.

1984 - 2014

In 2014, SFI celebrates its 30th anniversary. Watch SFI's website and publications for a yearlong celebration of the Institute's storied history, and for opportunities to be an active member of SFI's community. SFI's special 30th anniversary logo (above) was created by graphic designer Michael Vittitow to mark the occasion.



RESEARCH NEWS

Spectral redemption: Finding the hidden groupings in networks

A persistent problem for mathematicians trying to understand the structures of networks is community detection: finding groups of related data points, or nodes.

Detecting communities in real-world network data is important for understanding, for example, how fast a disease will spread in one community and how likely it is for it to cross to another community.

Traditionally, mathematicians find communities in one of two ways: *statistical inference*, a highly iterative method that reassesses network-wide probabilities at each step, and *spectral analysis*, a faster "random walk" technique that groups nodes by focusing on the flow of information or probability through a network.

Both techniques work well for networks with dense webs of links between nodes, says SFI Professor Cris Moore.

Spectrum of the non-backtracking matrix indicating the community structure of the network being analyzed.

standing of complex adaptive systems. So they instituted, almost into SFI's DNA, a transdisciplinary approach – anthropologists working with computer scientists and mathematicians and biologists and so on. This methodology has proven to be incredibly successful, and it is now widely adopted in universities and research centers and funding agencies in this country and around

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But in sparse networks where each node is linked to just a few others, as in the case in many real-world networks, classic spectral techniques fall short – meaning that unlike statistical methods, spectral methods often fail to find groupings down to a theoretical limit revealed by Moore and collaborators in a 2011 paper.

The challenge for mathematicians has been, then, to find a spectral method that is computationally efficient and that reliably finds groupings down to the theoretical limit.

In a recent paper in *PNAS* aptly titled "Spectral Redemption," Moore and collaborators try out a modified spectral method they call the "non-backtracking operator." Put simply, it specifies that during analysis, information flowing from node to node may not immediately return from whence it came.

"Traditional spectral methods get stuck on highly connected nodes, rattling back and forth between those nodes and their neighbors," Moore says. "They get confused

> [more on page 2](#)

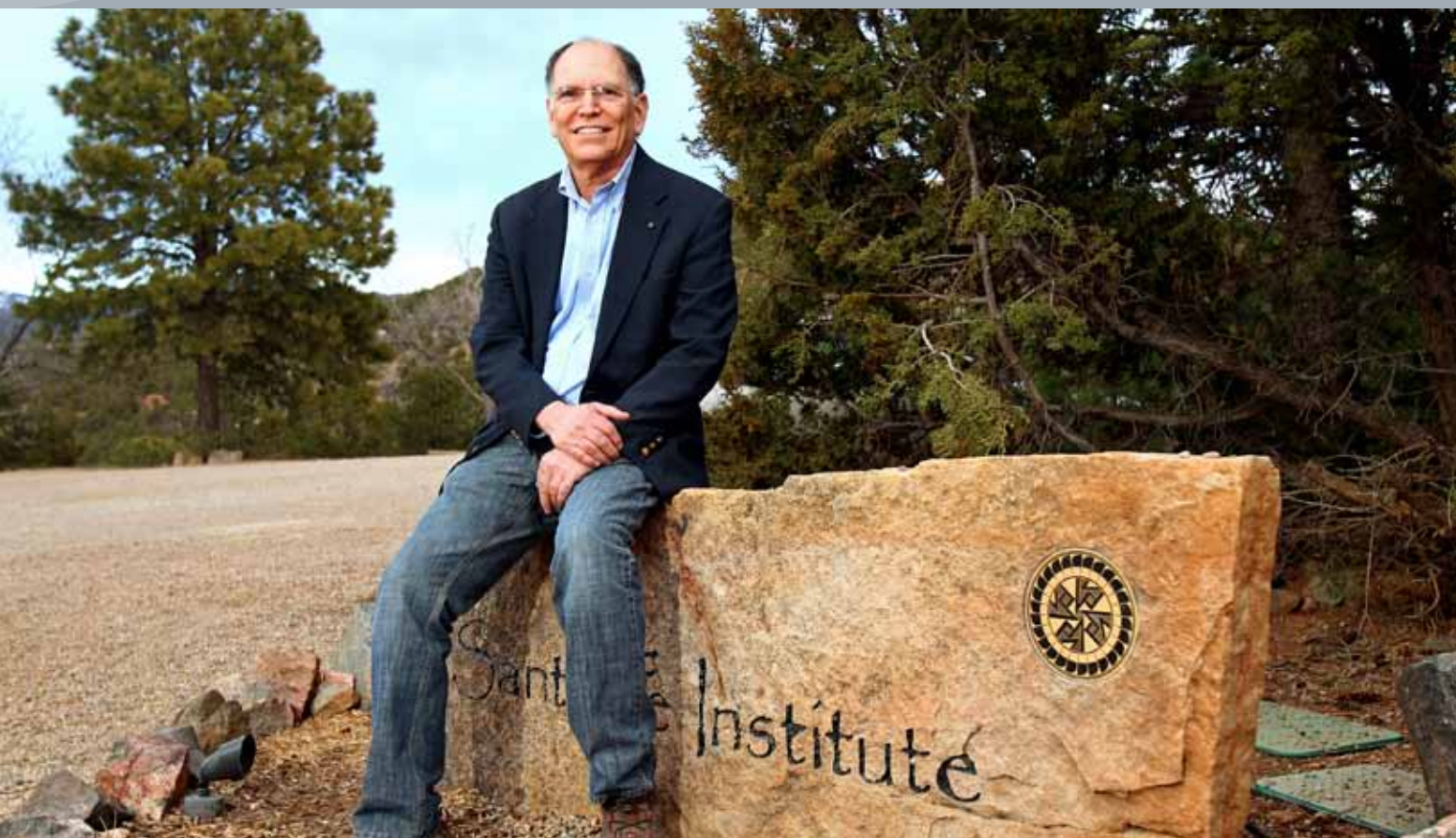
RESEARCH NEWS

How a species stays relevant as it changes its world

How complexity evolved in cells is a question as intriguing as it is difficult to explain. Though we cannot fully solve the puzzle, we can learn how species give themselves time to go from random to programmed development. A new study reveals an optimal switching rate between forms of a species as it makes its environment less livable.

"If you're a bacterium in a beaker, just by the process of growing and dividing, you're changing the environment into one that no longer favors you," explains Eric Libby, an SFI Omidyar Fellow who specializes in mathematical microbial evolution. "You then have two options. One, go extinct. Two, throw off a mutant that's adapted to the new environment."

> [more on page 5](#)



Q&A: Jerry Sabloff on 30 years of complexity

At the turn of the new year, Institute President Jerry Sabloff offers his thoughts about SFI's outlook for 2014 and beyond.

Update: Today, with this interview, SFI begins to mark its 30th year. What are SFI's top achievements, in your mind, since its founding in 1984?

Jerry Sabloff: The key contributions, I think,

are important new insights into the nature of complex adaptive systems and the transdisciplinary methodologies that SFI has used to explore the emergence and continuing development of complexity at all scales, from atoms and cells to human societies. One of the great insights of SFI's founders – the late George Cowan, Murray Gell-Mann, David Pines, and their colleagues – was that no single discipline could achieve a full under-

In a January 6 article in the *Santa Fe New Mexican*, SFI President Jerry Sabloff reviews three decades of complexity science and notes the continued need for scientists, CEOs, and policy makers to understand the forces that define our world and to think beyond the next funding cycle, election, or quarterly earnings report.

In the *Huffington Post* on December 12, geriatrician Walter Bortz II, M.D. laments the shortcomings of reductionism, particularly in medicine, and notes SFI's interest in emergence.

In a December 12 *Forbes* article, SFI Trustee John Chisholm writes of the tension between new technologies and their tendency to make jobs obsolete, citing a 2010 *McKinsey Quarterly* essay by SFI External Professor W. Brian

Arthur that predicts the digital economy will soon rival the human economy.

In a December 9 essay in *New Scientist*, SFI Professor Luis Bettencourt explains how cities are like stars — in one sense, both are implosions of interaction — and offers four principles for understanding cities.

In a December 2 article in the *Santa Fe New Mexican*, SFI's Chris Wood offers perspectives from a recent SFI meeting in Santa Fe about Big Data and predictive analytics and whether they are a gold mine for business, science, and government or a serious threat to privacy and freedom.

In an interview in the December issue of *International Innovation* magazine, SFI

President Jerry Sabloff discusses the Institute's history, its contributions to complex systems science, and his hopes for the Institute's future.

Several publications covered a December paper in *Preventive Medicine* by a team that includes SFI Omidyar Fellow Ben Althouse, which found that celebrity cancer diagnoses and resulting media coverage are a more powerful motivator in smoking cessation than other cessation-awareness events.

An article published November 28 in the *New Statesman* about the fortunes and failures of Apple, Google, and Facebook cites Distinguished Professor Geoffrey West and SFI research on the life cycles of companies.

In a November 25 article in *Time* magazine

about the cultural ingredients of inventiveness, SFI Distinguished Professor Geoffrey West notes that creativity and social interaction accelerate in cities, one reason they generate so many patents.

In *Scientific American* on November 6, Jaron Lanier explores the dilemmas of data privacy, citing his work with economist and SFI External Professor W. Brian Arthur to understand what happens when users of personal data pay for that use.

In an October 28 article in the *Santa Fe New Mexican*, SFI Professor Cris Moore explores the hidden patterns in music and mathematics and discusses a special orchestra concert November 2 at the Lensic Performing Arts Center in Santa Fe.

Nonlinearities

From the editor

With this issue we begin the Institute's 30th year. SFI's past is rich with stories and even legends, and we plan to share much of that lore with you over the next 12 months. It starts on page 4 of this issue with a peek back into the Institute's pre-history, when a group of senior scientists imagined a place where they could do research across disciplinary boundaries, nurture emerging disciplines, and venture into new theoretical territory.

This was revolutionary thinking, and at its core was a character of mythic proportions. What has struck me, as I've interviewed many of the people who were there, is just how easily it could have gone wrong without the unifying force of George Cowan and his conviction to see this grand experiment through.

We've launched a 30th anniversary website at www.santafe.edu/sfi30, where all year you will find storytelling about SFI's past.

None of this work has ever been possible, of course, without the generous support of SFI's community. The only way for the founders to reach the scientific Nirvana they sought was to break the mold, especially the funding mold, that constrained academic and government research freedom. Our 30th anniversary comes with a campaign, and Nancy Deutsch and her Advancement team have put together a number of compelling opportunities for you to get involved. See page 8.

Tanya Elliot, one of SFI's first Omidyar Fellows, succumbed to cancer in November. This news sent reverberations of sadness through the Institute. She was young and talented and she left behind a family. She is deeply missed. To leave a remembrance, please visit SFI's website.

We held a special tea for Research Fellow Simon DeDeo, another of SFI's inaugural class of Omidyar Fellows, in December. If there's one thing about Simon, it's that he can't leave data alone, especially about human behavior. His brief goodbye speech, apparently written on the back of a napkin, featured a quantitative analysis of his own tea drinking. In short, while at SFI he estimates he drank 569 gallons of tea, an average of 400 cups of tea per research paper. All Simon. He's an excellent science communicator and friend, and I will miss him. Good luck Professor DeDeo.

Congratulations to past Omidyar Fellow Nathan Collins. He and his wife Theresa Buckley were blessed with a boy, Connor Collins, on December 9.

Finally, a recent exchange at SFI: "When are you due?" Female visitor: "February 10, but the standard deviation is 10 days." ■

— John German, jdg@santafe.edu

RESEARCH NEWS

Who drinks with whom when? Drinking and reciprocity

Some groups keep spirits high by taking turns hosting events or buying the next rounds of drinks. SFI Omidyar Fellow Paul Hooper, SFI Research Fellow Simon DeDeo, and their colleagues recently explored how patterns of reciprocity vary with people's closeness, both geographically and genet-

cally, by analyzing who drinks with whom and how often.

Evolutionary biology holds that social relationships can form in a number of ways. One is by virtue of kinship: related organisms, be they slime molds or baboons, have a shared

interest in keeping their shared genes going, explains Hooper. Another is simple reciprocity: where kindness is repaid, evolution favors the bond of friendship.

During a research trip in Bolivia, Hooper, an evolutionary anthropologist, and his partner Ann Hooper Caldwell looked at how reciprocity varied with kinship and distance based on a favorite local pastime. Families in villages throughout South and Central America frequently host parties where friends and relatives gather to socialize over rounds of *chicha*, a lightly alcoholic beer. By peeling and boiling sweet manioc (a starchy tuber), then chewing boiled pieces to introduce enzymes, women prepare jugs of it every few days.

The pair interviewed household members of a small Amazonian village of the indigenous Tsimané' tribe twice a week over four months to see who hosted whom at chicha parties, and how often the favor was repaid.

Using computational analysis techniques developed by DeDeo, the team found that the more related the households, the more often they drank together. (As relatedness is also a determinant of living proximity, an indirect effect of kinship emerges where a household ends up partying with neighbors who tend to be kin.)

The study, "Dynamical Structure of a Traditional Amazonian Social Network," published in the journal *Entropy*, also found a reciprocity signature among friends and distant relations: one family hosting another doubles the chance the second will host the first within three days. Hooper explains that rules of etiquette appear to apply to more distant bonds, as it's polite to return the favor promptly, but closer relations don't keep such score.

"It's a clear test of the theory of reciprocity, which has been beset by a lot of doubt since it was introduced in the early seventies," says Hooper. The study's novel analyses make the findings particularly robust and offer new methods for future studies, he notes. ■

> Spectral redemption

continued from page 1

by localized structures in the network rather than finding the large-scale structures we care about."

The researchers tested their non-backtracking method on several networks commonly used to benchmark clustering methods. They found that their method succeeds all the way down to the theoretical limit, performing as well as any algorithm can. It also provides an estimate of the number of clusters, helping solve another thorny problem in network analysis.

Co-authors include Elchanan Mossel, Joe Neeman, and Allan Sly (UC Berkeley); Lenka Zdeborová and Florent Krzakala (CNRS, France); SFI Postdoctoral Fellow Pan Zhang; and Moore. ■



SFI Omidyar Fellow Paul Hooper (center) drinking chicha with Tsimané men. (Image: Ann Hooper Caldwell)

RESEARCH NEWS

Reality check: Can scientists know that they do not know?

What if you knew everything about the current universe — the state of every single particle — and all the laws governing the universe's evolution? Endowed with such knowledge, you could then predict the future, right? French philosopher Henri Laplace thought so.



Not so, contends SFI Professor David Wolpert — not even for the non-chaotic, non-quantum-mechanical universe that Laplace assumed.

This unknowability, says Wolpert, is the true nature of reality. With the help of a \$50,000 grant from the Foundational Questions Institute, an organization that funds research on physics, cosmology, and the underpinnings of reality, he hopes to extend his ideas from the realm of theory and allow them to be validated experimentally.

To understand Wolpert's claim, start with a philosophy classic: "this sentence is not true." If that's true, then it's false. If it's false, then it's true. Whether it's true is a question without an answer: a mathematical chicken-or-egg problem. Early last century, Alan Turing showed that such unanswerable questions are inevitable in any sufficiently powerful computer.

Wolpert says he's always been dissatisfied with attempts to use Turing's result to analyze the universe — to do so requires making elaborate assumptions about the computational nature of the laws of the universe. Instead Wolpert uses a different approach to analyze what it would mean for a scientist to accurately know something about the external universe, whether by observing the universe's present, predicting its future, or remembering its past.

Wolpert's approach requires no assumptions about the laws of the universe. But it leads to an even wilder conclusion than Turing's: simply for there to be a physical reality that contains scientists observing, predicting, and recollecting, there must be unanswerable questions.

He has already used the approach to derive results with tantalizing connections to the uncertainty principle of quantum mechanics. He says he plans to investigate other possible connections.

"It would be drop-dead totally cool if the laws of quantum mechanics popped out," he says, though he concedes that's a long shot. At a minimum, he expects the work to further our understanding of the fundamental limitations on what we can know about physical reality. ■



Video: SFI President Jerry Sabloff on SFI's progress in the Templeton Foundation-funded project seeking patterns in the emergence of complex human societies. SFI project video



Video: SFI Distinguished Professor Geoffrey West on SFI's progress in the Templeton-funded project seeking the hidden laws underlying complex biological and social systems. SFI project video



Video: SFI External Professor David Krakauer on SFI's progress in the Templeton-funded project to understand the evolution of complexity and intelligence on earth. SFI project video



Video: Historian George Dyson on the geniuses who invented the digital universe. SFI 2013 Community Lecture



Audio: SFI External Professor John Pepper shows how an understanding of evolution might suggest new ways to beat cancer. Santa Fe Radio Café interview



Audio: SFI Research Fellow Simon DeDeo describes SFI research to find and explain patterns of human social behavior in data from the online encyclopedia Wikipedia. Santa Fe Radio Café interview

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The *SFI Update* is published bimonthly 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

How shifts in behavior shape human institutions

Whether they're incremental or cataclysmic, shifts in behavior often prompt feedback effects through social systems.

For example, a wartime labor shortage, post-war economic growth, and a growing sense of gender egalitarianism are a few of the interrelated factors that have led women in Western European countries to work outside the home.

Often, drivers of change in attitudes and behaviors among people, social groups, and institutions in turn affect other sources of governance. These reciprocal relationships are what SFI's Coevolution of Behaviors and Institutions working group has explored since it started meeting in 1998.

The group gathers again in January at SFI, led by SFI Professor Sam Bowles, head of the Institute's Behavioral Sciences Program. Participants include anthropologist Robert Boyd (Arizona State University, SFI Cowan Professor), and economists Larry Blume (Cornell, SFI External Professor), Peyton Young (Oxford), and Herbert Gintis (Central European University, SFI External Professor).

Its members study how the institutions that regulate social interactions – such as economic exchange, marital matching, and cooperation and conflict within and between groups – shape the evolution of individual preferences, norms, and other motivations, and in turn how the resulting individual behaviors shape the evolution of social institutions.

"To sharpen the theory-building process, we address such empirical puzzles as the innovation, persistence, and demise of institutions regulating economic activity and the distribution of wealth," explains Bowles. By applying methods including empirical cases, agent-based simulations, and stochastic evolutionary game theory, they hope to use our understanding of these system dynamics to find ways institutions can better serve the needs of all people, particularly the least well-off, he says.



1942 wartime poster by J. Howard Miller for Westinghouse. Pictured is Geraldine Doyle (1924-2010) at age 17. (Image: Wikimedia Commons)

Among the attendees this January are Diego Gambetta, a sociologist from Oxford with expertise in trust within extra-legal systems such as the Mafia; he will present results of behavioral experiments seeking to understand cultural differences between

North and South Italy. Presenter Amanda Lea Robinson, a political scientist at Ohio State University, will show how collective identity affects trust and cooperation between ethnic groups in her session "The Geography of Ethnic Diversity." ■

RESEARCH NEWS

Ruben Andrist: Quantum memory and fragility

Quantum computers offer a radical leap in computing power because quantum bits can exist in parallel states, thus taking on many values at the same time. Theoretically, this means a quantum computer could run all the rows of a multiplication table at once rather than computing it row by row, one factor at a time, as classical computers must.



"The beauty of [quantum computing] is that the brute force is done by the physics and not by the machine," says SFI Omidyar Fellow Ruben Andrist.

But there are many obstacles in the construction of a true quantum computing system. With his background in statistical physics and spin glass theory, Andrist's research focuses on the comparison of quantum memories and how they would allow for error control in a quantum computing system. "It turns out the reason we don't have quantum computers yet is that the systems you use to build the quantum computer are very fragile," he says. "If you want to be able to control [a quantum system], you have to fiddle with it, touch it, and deal with any errors."

But to observe any part of the quantum system is to destroy the very property of parallelism that makes it powerful. "There is a trade-off between you isolating the system and you actually being able to control the system – it is an inherent flaw of a quantum computer," he says.

The method Andrist uses to test the validity of quantum layouts is to deduce, from the interaction of the individual elements, which qubits in the system might be faulty: in other words, identify faulty elements of the system without directly observing them. This allows him to figure out how many qubits, and in what arrangement, would allow programmers to store information reliably and correct errors along the way.

"A quantum computing system sort of forces you to do what I wish many of the programmers of the software we use today would have done: To be mindful at every step of all the possible things that could go wrong and fix them as you go." ■

RESEARCH NEWS

Infectious notions: Applying disease dynamics to ideas

When Ben Althouse and Laurent Hebert-Dufresne attended SFI's 2012 Complex Systems Summer School, they began a productive collaboration, developing a model of influenza resistance to antiviral medications. Later, working with SFI Research Fellow Simon DeDeo, the team applied the contagion model to social dynamics.

"It turns out the models are equally applicable to both systems," explains Althouse, who recently joined SFI as an Omidyar Fellow.

In the biological case, when someone is treated with antivirals, there's a chance the viral strain will develop a mutation that makes the antiviral ineffective. The infected person then can have two strains: susceptible and resistant.

In the world of ideas, a person being aware of two complementary or conflicting thoughts simultaneously can result in the ideas boosting each other, or one notion replacing the other. As ideas spread through a population, this phenomenon is repeated, each idea spreading and lingering at various speeds.

Idea modeling breeds its own set of complexities distinct from disease modeling; for example, one can harbor dozens of ideas rather than a strain or two of a pathogen.

A recent SFI working group on the topic, From Coinfection to Cultural Dissonance: New Challenges for Biological and Cultural Evolution, involving the three researchers ran for a month.

They looked to perhaps the best high-volume, publicly available, and massively interconnected contemporary network to develop and test its idea models: Twitter. They sampled one percent of all tweets from Twitter users globally for over a year. The amount of data is staggering: a single 30-minute interval can yield 75,000 samples.

"Twitter is vast," says Althouse. "There are a lot of ideas bouncing around, a lot of memes, ideas that come up quickly, hang around, then go away, so it's a good place to look at the replacement of one idea with another."

Following a good deal of brainstorming about the best ways to apply epidemiological models to memes, the group is now running simulations of how contagious ideas spread. ■



1984-2014

New Science. New Horizons.

SFI@30

Conception to birth: A gleam in one scientist's eye

Editor's note: This is the first in a series of Update articles recounting the history of the Santa Fe Institute drawn from, where possible, primary sources. Special thanks to SFI Co-founder in Residence David Pines for his recollections and insights. For a more detailed article and more stories about the Institute's past, please visit www.santafe.edu/sfi30.

By John German

In George Cowan's telling, the notion for a Santa Fe Institute began to form in the summer of 1956. He had been invited to the Aspen Institute, where prominent intellectuals from the arts, science, and culture gathered for free-form philosophical exchanges. He had just participated as the lone scientist in a discussion of literature.

For his part, he had chosen to talk about entropy – the tendency of systems to move toward disorder – and what insights this principle from thermodynamics might offer about the workings of human society. His talk was not well received by the other participants, who were more accustomed to the ideas of Socrates, Aristotle, and Plato than those of Boltzmann.

Nor was Cowan fully satisfied. Although he was energized by the mingling of perspectives, as a scientist he thought: "This would be an even greater idea if the discussion were driven by facts rather than essays."

Science serving society

Cowan had always believed the physical sciences held great promise for solving human problems, and he had good reason. As a promising young chemist before and

some of his own scientific passions. The Council, he thought, was an opportunity for scientists to lend a helpful hand to policy makers. Given the issues at hand – the Cold War, AIDS, energy supply – it should have been.

But plain talk from scientists was, perhaps, not what the politicians always wanted to hear. In his memoirs *The Manhattan Project to the Santa Fe Institute*, Cowan lamented that "it soon became clear that scientific factors mattered considerably less to the White House staff than political considerations."

The Cowan Collaborative

It was in this context that Cowan, in 1982, convened a group of senior fellows at Los Alamos National Lab (LANL) for weekly discussions about big problems in science. These leading thinkers – including Stirling Colgate, Nick Metropolis, Herb Anderson, Darragh Nagle, Peter Caruthers, and others – typically met in a conference room outside the office of Sig Hecker, the Lab's forward-thinking director.

At Cowan's urging, the discussions centered on a concept for a new education and research institute that would tackle emerging questions between the traditional academic disciplines.

David Pines, a renowned physicist from the University of Illinois at Urbana-Champaign and an advisor to the Lab's theory division, was invited in early 1983 to join the discussions, along with a few other frequent LANL collaborators such as mathematician Gian-Carlo Rota from MIT and radiochemist Tony Turkevich from the University of Chicago.

"At the time the concept was to create a new kind of teaching institution for gradu-

ate students," says Pines. "We wanted to attack problems that cut across many fields, problems like human behavior and cognition. It was all about really good people who were crossing disciplines. We recognized that universities were ill-equipped to nurture emerging new fields, and we were thinking about how we could help them grow."

The power of prestige

As a member of the National Academies, Pines knew nearly every leading scientist in America. He soon invited Nobel laureate Murray Gell-Mann, the Caltech physicist, to the discussions.



David Pines at SFI in 2013

The prestige of Pines, Gell-Mann, Anderson, Metropolis, and others would prove to be a key factor in attracting top minds to the fledgling institute, Cowan later wrote.

Pines, whose present-day title is SFI Co-founder In Residence, today calls the founders group the "Cowan Collaborative." "It was a truly collaborative effort, with George guiding our discussions," he says. "He practiced

true leadership. He had the vision, but most of the time he did not talk."

As the discussions continued in Los Alamos, Cowan secured a post office box in Santa Fe, P.O. Box 9020, and the founders began to reach out to potential backers in Santa Fe, Los Alamos, and Albuquerque. Helene Slansky, wife of senior fellow Richard Slansky, volunteered to play an organizational role.



Murray Gell-Mann, unknown date

The first Institute phone was in the Slansky bedroom, recalls Helene, who first heard about the idea from Gell-Mann in 1983 during a senior fellows dinner. "He explained that it was difficult to get funding for cross-disciplinary science," she says. "If a physicist and a biologist wanted to work together, they would have to request funding from either the physics or biology department. Government agencies weren't going to fund an institute without a track record. It made a lot of sense to me."

The founders always wanted to name the new center the "Santa Fe Institute." But a local treatment center for recovering alcoholics already held claim to the name. In May 1984 the Institute was incorporated under the alternative name "Rio Grande Institute." (Several months later, Cowan purchased the preferred name "Santa Fe Institute" from the struggling treatment center for \$5,000 and changed the Institute's name to the "Santa Fe Institute for Science.")

In summer 1984 there were still many questions, of course. The founders group knew private funding would be needed to foster the independent nature they envisioned for the new center. They knew it would need a physical presence in Santa Fe, and thus an attractive building and a staff. There was little consensus regarding what scientific themes the center would tackle.

"Everybody had their favorite topics," Pines says. "Mine was to have an institution without fiefdoms and to find and bring in people like us, but 30, 40, 50 years younger."

But by far the biggest obstacle, says Pines, was that "we had no audience."

Bringing in the best

Herb Anderson offered a possible solution. He suggested a workshop in Santa Fe with as many top scientists as would participate. "The idea was to bounce our idea off of people and see what they thought of our game plan," says Pines.

That plan included developing networks of researchers around particular cross-disciplinary topics of interest to the scientific community. Wrote Cowan: "Herb Anderson said, 'Pick out the best people, bring them in, and ask them to tell us what interests them'...We were picking the people, not the topics."

Assuming the rate of acceptance would be low, the organizers extended many invitations. To their surprise, says Pines, "about 90 percent of the people we asked accepted."

To accommodate the larger crowd, the founders asked Santa Fe's School for Advanced Research for the use of SAR's meeting room, beginning an informal institutional tie that continues to this day. Two workshops were scheduled rather than one.

The week-long workshops, which took place in late October and early November 1984, were titled "Emerging Syntheses in Science." They are memorialized in a printed volume by the same name, SFI's first tangible scientific result.

"I would argue that the founding workshops were the beginning of SFI," says Pines. "Before the workshops, we didn't know if our institute was going to fly or flop. After the workshops, we knew we were on to something. There was a lot of energy and support. All we needed was a few million dollars, a building, a staff, and a great deal of luck." ■

Who were SFI's founders? Visit www.santafe.edu/sfi30 for more about some of the people who helped define the Santa Fe Institute.

In the March / April issue of the Update: SFI@30 continues with "Something from nothing: SFI emerges and synthesizes."



George Cowan, circa 1987, at the Institute's then-headquarters in the Cristo Rey Convent, looking through the papers of Stanislaw Ulam. The collection of papers, donated by the Ulam family, were the beginning of the SFI Library.

during World War II, he was among the scientists at the center of the international race with Nazi Germany to be the first to harness the power of the atom and to wield that power for socio-political ends. After the war, the urgency intensified as the U.S. and Soviet Union engaged in a struggle for technological dominance that would last four more decades.

But in the summer of 1956, in Aspen, his talk on social entropy was probably before its time.

Statistical mechanics, and probability theory in particular, had not yet shown scientists new ways to quantify uncertainty in dynamical systems. Among its promises was that a richer understanding of human behavior – what Cowan would later call "the daily, messy world of human affairs" – might be within reach of the math-speaking sciences.

Computers, too, were to become more powerful, and some scientists had begun dreaming of the day they might simulate highly complex systems, even living systems, *in silico*.

The unscience of politics

Thus, it wasn't for nearly 30 more years, in the early 1980's, that Cowan took the first tangible steps toward a pioneering, transdisciplinary research center. He had been invited to serve on the White House Science Council, a group of leading scientists charged with advising the White House staff and the President.

President Reagan's administration was engaged in a scientific (and fiscal) standoff with the Soviets over strategic missile defense. Cowan, as a senior fellow at Los Alamos National Lab, had been afforded the latitude to pursue



Three ‘Majesty of Music & Mathematics’ concerts thrill Santa Fe crowds



In early November, The Santa Fe Symphony and the Santa Fe Institute presented a unique symphony of science. “The Majesty of Music and Mathematics” featured remarks by SFI Professor Cris Moore (top left), a mathematician and computer scientist. Musical selections from The Symphony, conducted by David Felberg, and an expansive overhead multimedia presentation, developed by Moore and Symphony Director Greg Heltman, helped demonstrate Moore’s tour of mathematical patterns in life and music, such as the alluring fractal image known as the Mandelbrot Set (above). The concert was performed three times to packed houses at the Lensic Performing Arts Center in Santa Fe, once to a Saturday night adult crowd and twice to Monday morning audiences (left) of northern New Mexico students. (Images: InSightFoto)

ADVANCEMENT NEWS

Breakfasts serve up eggs, bacon, & science

SFI has been taking a new approach to reaching its far-flung community lately: breakfast.

Most recently, SFI External Professor Raissa D’Souza helped serve up eggs, bacon, and network science to a few dozen Silicon Valley entrepreneurs and researchers at a December SFI event in Palo Alto.

D’Souza, a professor of computer science and mechanical engineering at UC Davis, spoke about the new, often counterintuitive world of network science, a world where more connectivity isn’t always better. “Some networking is good. Too much is overwhelming,” she told the crowd.

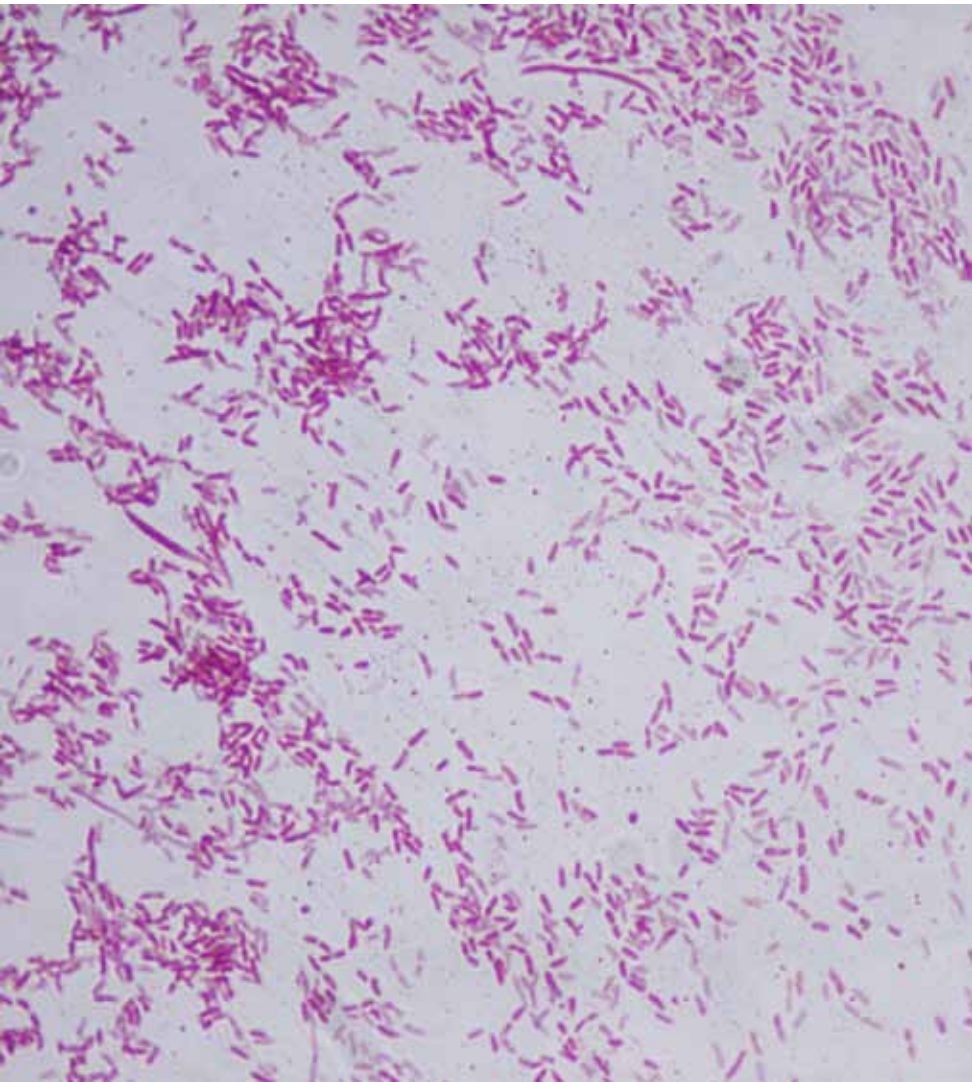
Past breakfasts featured such speakers as SFI Distinguished Professor Geoffrey West, then-SFI Faculty Chair Doug Erwin, and SFI Science Board member Dawn Song, who gave attendees a peek at next-generation web security tools the UC Berkeley computer scientist is developing. SFI External Professor and UC Davis geophysicist John Rundle considered what one could learn about financial markets

using earthquake prediction models.

Ike Nassi, a former executive at tech stalwarts Apple and SAP, says the latest event was his third or fourth time coming. “I always walk away with more ideas,” he says, and, perhaps, collaborations. Nassi says he’s looking forward to hearing more about D’Souza’s ideas.

For her part, D’Souza told the crowd she’s eager to learn more about the real-world challenges those in the tech industry face when working with interconnected communications, supply, and electrical power networks.

SFI VP for Advancement Nancy Deutsch, who helps organize the meetings, says she hopes to expand the breakfasts to East Coast cities and perhaps overseas. “The breakfasts are great ways to extend the message of what an SFI approach to science is all about,” she says. “They’re more friend-raising than directly fundraising opportunities, although we certainly hope the participants will continue to support SFI in meaningful ways.” ■



Pseudomonas fluorescens (Image: Wikimedia Commons)

> **Staying relevant** continued from page 1

To see how a species adjusts to the conditions it creates, Libby and colleague Paul Rainey at the New Zealand Institute for Advanced Study looked to *Pseudomonas fluorescens*. The free-living bacterium has two forms: the smooth type proliferates in a broth, but by doing so uses up the oxygen. A single mutation produces the second wrinkly type, which makes a glue that sticks offspring together.

The resulting bacterial mat rises to the surface – the only place oxygen is available in a beaker choked by the smooth type. (Conversely, as the mat grows and provides stable access to oxygen, wrinkly types randomly produce smooth types.) Eventually the mat collapses, letting oxygen stream back into the broth.

Based on this simple life cycle, the researchers ran simulations where *P. fluorescens* drove the environment between two states,

one state favorable to each population type, to see at what switching rates the species flourished. The results surprised them.

“The best strategy is to produce the kind that’s not good in the current environment about 10 percent of the time,” says Libby. That rate is independent of environmental factors and is three orders of magnitude higher than the researchers expected, he says. Further, letting some of both types survive through an environment switch also led to a surprising response: one organism will thrive, nearly driving the other to oblivion, then will suddenly collapse and die.

Libby reasons that these findings, published December 18, 2013 in *PLOS ONE*, suggest that a simple relationship between organisms and environments could provide a possible route for the evolution of developmental programs from random mutation-driven change. ■

Gell-Mann honored at Caltech’s ‘50 years of the quark’ celebration



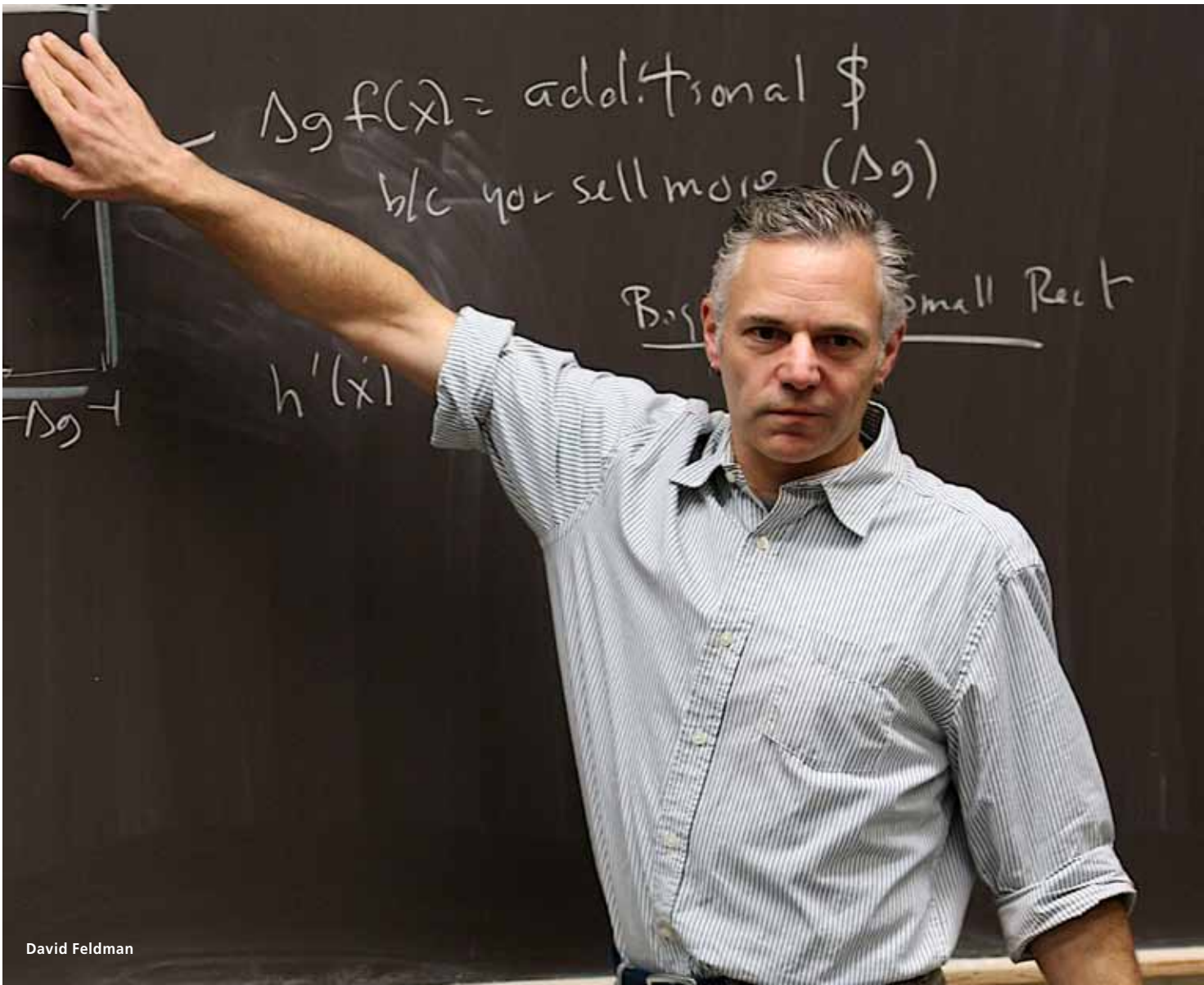
SFI Distinguished Fellow and co-founder Murray Gell-Mann was honored at the California Institute of Technology December 9 and 10 as part of an event celebrating “50 years of the quark.”

While at Caltech in the 1950s and 60s, Gell-Mann theorized the existence of and helped establish the characteristics of subatomic particles he named quarks. He was awarded the Nobel Prize in physics in 1969 for his work on the theory of elementary particles.

SFI Distinguished Professor Geoffrey West was among those who spoke at the event. ■

Murray Gell-Mann gives a talk during Caltech’s ‘50 years of the quark’ celebration in his honor. (Image: Caltech)

Q&A with dynamics MOOC instructor David Feldman



David Feldman

Starting this month, College of the Atlantic physics and mathematics professor David Feldman is offering a free online course: “Introduction to Dynamical Systems and Chaos.”

The course is offered through SFI’s Complexity Explorer (www.complexityexplorer.org) beginning January 6, 2014. You can enroll and begin taking the course any time during the eight-week course.

The course is a continuation of the successful massive open online course (MOOC) series that began with two offerings of SFI External Professor Melanie Mitchell’s “Introduction to Complexity.”

Feldman recently fielded some questions about the new course from the Complexity Explorer’s Erin Kenzie:

Kenzie: Why was this course chosen as a MOOC offering by SFI? How does it fit within the Complexity Explorer project?

Feldman: Chaos and dynamics are core topics for the study of complex systems. They show us that simple, deterministic systems can produce unpredictable and complex behavior. Thus, it is possible that complex or unpredictable phenomena have simple origins or explanations. One of the key themes of dynamical systems is that order and disorder are not mutually exclusive categories; they can exist together in the same system and have the same origins. These are important lessons for the study of complex

systems, and so it seemed appropriate that the next online course offered through the Complexity Explorer project was on chaos and dynamics.

Kenzie: What kind of student did you have in mind when you designed the course?

Feldman: I can imagine many types of students who might be interested in this course: someone who has taken Melanie’s “Introduction to Complexity” and who wants to dig deeper into chaos; someone who has heard about the butterfly effect and strange attractors and wants to learn a little bit about the mathematics behind these phenomena; someone with a background in science or social science who is looking for a thematic overview of dynamical systems before launching into more advanced study; someone with an interest in complex systems – or anything for that matter – who thinks chaos and dynamics might relate to their interests and would like to find out if that’s the case.

Kenzie: How much math background is necessary?

Feldman: The course will make use of elementary high school algebra. We will review math topics along the way and help will be available in the online discussion forum. There will be optional assignments for those with a more extensive math background. I think the course will be accessible and of interest to almost anyone who wants to gain a solid in-

troduction to chaos and dynamical systems, regardless of their mathematical levels.

Kenzie: How do you anticipate students will benefit from taking your course?

Feldman: My goal is to present an intellectually honest introduction to the key results and big themes and ideas of chaos and dynamical systems, and to do so in a general enough way so that it is valuable to a wide range of course participants with different motivations and goals.

Kenzie: Have you taught a MOOC before? What interests or excites you about the opportunity?

Feldman: This is my first MOOC. I have, however, taught a course on chaos and dynamical systems at this level for many years at College of the Atlantic. This course has been well received and I have enjoyed teaching it. It has been very satisfying to help students discover the important and fun surprises that dynamical systems hold, and then to see how they apply these ideas in their own areas of interest. I’m excited to bring chaos and dynamics to a larger audience and to interact with students of all backgrounds from all over the world. Teaching a large online class will be a challenge. I’m a bit nervous about it, since this is a new experience for me, but I’m also very excited. ■



Complex systems pioneer and SFI External Professor John Holland, a member of SFI’s Board of Trustees and Science Board, is among five people selected to receive awards from Montana State University for pioneering work in computers, communications, and biodiversity. Holland is awarded the George R. Stibitz Computer and Communications Award.



A positive review of SFI Professor Paula Sabloff’s *Does Everyone Want Democracy? Insights from Mongolia* in *Choice* magazine says her book is an essential addition to academic library collections, as well as for those seeking to understand Mongolians’ complex attitudes about democracy. *Choice* is used by librarians at academic institutions to decide whether to purchase recently published books. Reviews are by scholars in fields relevant to each book.



SFI Science Board member Thomas F. Rosenbaum has been named President of the California Institute of Technology. Since January 2007, Rosenbaum has served as provost at the University of Chicago. He is expected to take office at Caltech in July. ■

2014 SFI education program deadlines

Undergraduate students - Research Experiences for Undergraduates summer internship program, June 8 - August 16, 2014 in Santa Fe: apply by February 7, 2014.

Graduate students - Graduate Workshop in Computational Social Science, Modeling, and Complexity, June 22 - July 5, 2014 in Santa Fe: apply by February 14, 2014.

High school students - Summer Complexity and Modeling Program (CAMP), July 13 - 25, 2014 in Groton, Massachusetts: apply by April 21, 2014. ■

SFI’s Project GUTS receives national award

The Afterschool Alliance and the Noyce Foundation have recognized SFI’s Project GUTS (Growing Up Thinking Scientifically) with one of two inaugural Afterschool STEM Impact Awards. (STEM stands for science, technology, engineering, and mathematics.)

The award was announced during the Project GUTS Lights On! Afterschool event in Santa Fe on October 20 – one of 8,000 events held across the country in October as part of the nationwide rally for afterschool STEM and computing programs.

The Afterschool STEM Impact Awards recognize outstanding afterschool STEM

programs that target students in fourth through eighth grades, serve students from populations underrepresented in STEM fields, and can demonstrate the impact of their programs on students who participate.

“We are thrilled to receive this national recognition and award,” said Irene Lee, who directs SFI’s K-12 STEM programs, including Project GUTS and GUTS y Girls, as part of SFI’s K-12 Learning Lab. “Our students have demonstrated that learners as young as middle school age can engage in computational modeling and scientific inquiry to understand and potentially solve problems in their local communities. Through Project

GUTS we want to offer them the chance to develop computing and STEM inquiry skills while strengthening the connections they see between computing and solving real-world problems.” ■

Angelina Tucker works with Josiah Tucker during the October 20, 2013 Lights On! Afterschool event in Santa Fe. (Image: Melissa Fricek)



> **Sabloff Q&A** continued from page 1

the world. That's not to say we were the innovator of transdisciplinary thinking. But I think it's fair to say that the success in understanding complex adaptive systems through transdisciplinary approaches has been the major achievement of the Institute.

This emphasis on complexity, along with the transdisciplinary approach, has led to a number of specific scientific advancements. SFI has played a foundational role, for example, in developing and applying methods for analysis and computational modeling of complex systems such as nonlinear dynamics, agent-based modeling, information theory, machine learning, game theory, genetic algorithms, network community detection, and so forth. Many early and continuing contributions to what is now called "complexity economics" were made here. Foundational work in applying scaling and metabolic theories from biology to cities, both modern and ancient, was accomplished here. The list goes on and encompasses progress in many areas, from evolutionary computation and computational immunology to cultural evolution, innovation, and wealth inequality. In these cases and numerous others, the Institute's scientists and their collaborators played and are playing a major role.

Update: How does the ethos instilled by SFI's founders connect to the Institute's future?



Sabloff: SFI has been extraordinarily successful at making connections among top scientists from many fields, giving them the opportunity to gather in Santa Fe and collaborate on important new insights into how our world operates – not only today but also in the past, and even how it might function in the future. These insights, I think, give us hope of finding new ways to cope with many of the challenges the world faces today.

So the simple answer to your question is that the approach and the accomplishments of SFI's first three decades have given the Institute great credibility and respect, both in the scientific community and in the wider academic community. This credibility, I think, serves as a foundation for the kinds of research the Institute will be doing and the kinds of insights it will attain during the next three decades.

In terms of specific directions for the future, SFI's Board of Trustees has put together a strategic thinking committee, which has produced a set of key questions that all of SFI's faculty and staff will be looking at in the coming months to help us focus on not only what major questions the Institute



From left: Jennifer Dunne, Jerry Sabloff, and Cris Moore

should be thinking about, but also what approaches it should adopt in the coming years. In essence, we'll be asking ourselves whether we should continue along the same path, whether we should modify it, or whether we should significantly change it. I very much look forward to the outcome of that effort, and we'll be hearing more by the May 2014 board meeting.

Update: How would you characterize the Institute's health, both scientifically and fiscally, at this milestone?

Sabloff: On the scientific side, the Institute is very strong. We've come through a challenging period, given the economic situation since October 2008, a period that has been particularly difficult for nonprofits. We lost some key resident faculty members during that time, but I'm happy to say we've just hired three new resident professors. David Wolpert has joined us on a part-time basis from Los Alamos National Laboratory. Both Sidney Redner, currently the chair of the physics department at Boston University, and Michael Lachmann, an evolutionary biologist at the Max Planck Institute, will be joining us full-time this summer. They join the two full-time professors we hired last year: Cris Moore and Luis Bettencourt. This gives me a lot of reason for optimism.

During the economic downturn, we were forced to cut back on support for some of our scientific activities. We've seen a significant pickup this past year, under the leadership of Chair of the Faculty Jennifer Dunne, in workshops and working groups, as well as an increase in the number of visitors. The feeling at SFI this past summer was more like the Institute of old, with people, ideas, energy, and a lot of excitement. These are all positive trends.

On the fiscal side, clearly we're better off than we were in late 2008 and throughout 2009. We've been able to pay off the mortgage on our Cowan Campus that we took out in 2009 at the beginning of the economic crisis, so it feels good to be debt free. But there's still a long way to go. The fiscal environment for SFI in particular, and for nonprofits in this country in general, is still extremely challenging. That's true in terms of general private philanthropy, federal grants, Business Network memberships, and so on. With the economy improving and the market up, I think there is reason to be guardedly optimistic, but the budget is still very tight and there are a number of factors beyond our control that continue to worry us.

Update: Other than financial, what do you see as SFI's biggest challenges for the next few years and beyond?

Sabloff: By far the major challenge for us is to continue to attract top scientists at all career levels, from undergraduate students and graduate students to postdocs – those in our groundbreaking Omidyar Fellowship

and those who come to work with us on specific research programs – to new external faculty and resident faculty and Science Board members. All the indicators are positive in this regard. The numbers and quality of applicants to our Omidyar Fellowship and for our Cowan Chair in Human Social Dynamics have been top notch, for example. So I'm feeling good, but this is going to be a continuing challenge.

Another challenge of a different sort is to continue the integration of our terrific new Tesuque Campus, generously donated to SFI late last year by Clare and Eugene Thaw. We've already used it for small working groups and for housing visitors, but we're continuing to find better ways to integrate it into the daily life of the Institute.

Update: What can we expect to see in 2014 with regards to celebrating the Institute's 30th?

Sabloff: You can read all about it in this issue, but the synopsis is that we have launched a 30th year campaign where we hope to raise \$30 million in the next several years. This could help improve our financial strength, and on a pragmatic level that is very important. But I think this anniversary is also a good chance to celebrate the people who participated in our first 30 years and the scientific progress the Institute has helped make possible, as well as to call attention to our vision for the future of science. [More about the campaign on page 8.]

Update: Your term as president ends in 2015 and you have announced your intention to retire at that time. What is the

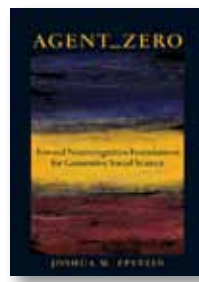
> [more on page 8](#)

BOOK NEWS



In *Cultural Evolution: Society, Technology, Language, and Religion* (MIT Press, 2013), co-edited by Peter Richerson and SFI External Professor Morten Christiansen, leading researchers from theoretical biology, development

tal and cognitive psychology, linguistics, anthropology, sociology, religious studies, history, and economics come together to explore the central role of cultural evolution in human affairs. Several SFI researchers and collaborators are among the contributors.



In *Agent_Zero: Toward Neurocognitive Foundations for Generative Social Science* (Princeton University Press, 2014), SFI External Professor Josh Epstein introduces a new

Four elected to SFI's Board of Trustees

Four people have been elected to SFI's Board of Trustees:



Andrew Berg is a former tax partner at New York law firm Debevoise & Plimpton. His practice included mergers and acquisitions, debt restructuring, spin-offs, private equity, and real estate joint ventures. He is an adjunct professor of law in the graduate division of New York University School of Law, where he teaches advanced partnership taxation. His three-year appointment began November 3, 2013.



Katherine Collins is founder and CEO of Honeybee Capital, a firm focused on research into sustainable investing and behavioral finance. Previously she served in numerous high-level investment and philanthropy positions at Fidelity Management and Research Company. She is author of the forthcoming book, *The Nature of Investing*. Her three-year appointment began November 3, 2013.



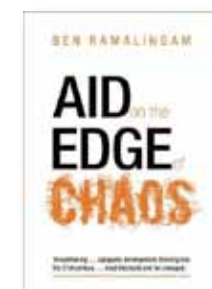
Ian McKinnon is the president of ZBI Equities, L.L.C. and a managing partner of Ziff Brothers Investments. Since joining ZBI, he has executed investments across most segments of the capital markets, including private equity, venture capital, public equity, and certain macro sectors such as sovereign debt. His three-year appointment began January 1, 2014.



Sam Peters is the portfolio manager of the Legg Mason Capital Management Value Trust mutual fund and the related Value Equity strategy for institutional investors. Prior to joining Legg Mason he served as portfolio manager of the Fidelity Select Health Care Fund and the Fidelity Select Medical Equipment Fund. In 1996 he founded Samuel M. Peters Investment Advisors, an independent advisory firm. His three-year appointment began November 3, 2013.

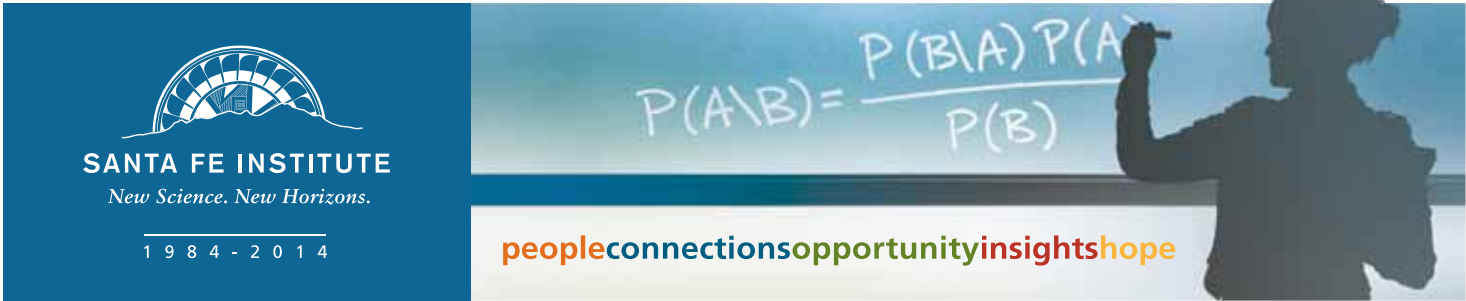
The Santa Fe Institute's Board of Trustees, which has the fiduciary responsibility for the Institute, oversees SFI's operations through its biannual meetings and its active committees that offer advice and support to SFI's leadership. ■

theoretical entity: Agent_Zero. Grounded in contemporary neuroscience, this software individual, or "agent," is endowed with distinct emotional/affective, cognitive/deliberative, and social modules. When multiple agents of this new type move and interact spatially, they collectively generate a range of dynamics spanning the fields of social conflict, psychology, public health, law, network science, and economics.



Aid on the Edge of Chaos: Rethinking International Cooperation in a Complex World (Oxford, 2013) by Ben Ramalingam looks at the implications of complex systems research for international develop-

ment and humanitarian work. Ramalingam draws on and synthesizes the work of numerous SFI scientists and spent time at the Institute researching the book. ■



Above: Bayes' Theorem

Three decades of complexity science

In 2014, SFI celebrates 30 years of insights on the horizons of science. We'll look back at the visionary scientists, scholars, and philanthropists who have made the Institute a world hub of complexity science. And we'll look forward to all that we can accomplish as we continue to explore society's most pressing challenges through collaboration, conversation, and education.

In the coming months we'll share stories from our first three decades – from the small group of scientists who conceived of SFI in the days and months leading up to our founding in 1984 to the many innovators who since have built a new approach to science around complex adaptive systems.

The words at right, which anchor our **New Science. New Horizons.** celebration for 2014, I think perfectly capture the spirit of SFI and our commitment to pushing the boundaries

of scientific understanding. SFI is its own complex system that brings together people, connections, opportunity, insights, and hope.

As we mark this important milestone, we are also launching the public phase of a comprehensive fundraising campaign that will touch every aspect of the Institute and provide a sustainable and solid financial footing for our next 30 years. We can do this because

of the loyal support that we see each year from so many of you who read each issue of the *Update*. We look forward to sharing our memories and our opportunities with you in the coming months.

Best regards,

Nancy Deutch, Vice President for Advancement

"As SFI turns 30, we reflect on our first three decades in which a signature approach to science was born, a **new science** based on a revolutionary spirit and a dedication to inquiry without boundaries. We also look ahead to the next 30 years in which we will behold **new horizons** gained through a renewed commitment to the history and precepts that have shaped SFI and made it the intellectual hub of complex systems research worldwide. At SFI's core are exceptionally curious and talented **people** — some of the great scientific minds of our day. The **connections** that our scientists make — connections that link fields, ideas, and each other — result in a distinctive **opportunity** for innovative thinking about some of our most pressing problems. Our transdisciplinary approach gets to the heart of these issues, helping us gain fresh scientific **insights** — insights that, if used wisely, offer **hope** for improving the human condition.

SFI@30

MY STORY

David Pines
Co-founder in Residence,
Santa Fe Institute

Present at the creation

"In early 1983, Nick Metropolis, one of the original Manhattan Project physicists and a future SFI Science Board member, invited me to join the 'Cowan Collaborative,' a group of Los Alamos senior fellows led by George Cowan that was trying to found a new kind of educational institution in Santa Fe. A defining moment was a suggestion by Herb Anderson, one of those senior fellows, that we convene a group of distinguished colleagues to explore initial research directions and test our game plan. We agreed, and George asked Herb, Murray Gell-Mann, and me to organize what became 'Emerging Syntheses in Science,' the founding workshops that launched SFI in 1984."

New Science. New Horizons. THE CAMPAIGN

As part of SFI's 30th anniversary, the Institute is launching a comprehensive \$30 million fundraising campaign that will support every aspect of SFI's mission. We call this campaign **New Science. New Horizons.** From education to science, and from our Santa Fe campus to our new outpost in Tesuque and our virtual impact through online outreach, this campaign will help ensure that our impact continues for the next 30 years and beyond. As of November 30, we raised more than \$19,460,600 in the "quiet" phase of the campaign, which began in 2012. Some of the campaign gift opportunities are:

President's Circle Member
\$1,000 per year – Annual giving club with special programming for members.

Send a Child to CAMP (Complexity and Modeling Program)
\$3,500 per scholarship – Funds tuition and travel expenses for one high school student to participate in an SFI summer complexity and computation program held at Groton School, Groton, Massachusetts, in summer 2014.

Visiting Sabbatical Scientist Fund
\$10,000 – Funds scientific visits to the Institute

Name a Faculty Office
\$25,000 and up – Yes, we will introduce you to the great mind in the office you select!

There also are opportunities to establish a permanent legacy, from building and open-space namings to endowed funds supporting science, education, and outreach. We welcome multi-year commitments and gifts of appreciated assets to fund your chosen program. Please contact the Office of Advancement at 505.946.3678 to discuss how you can help us attain new horizons.

1399 Hyde Park Road
Santa Fe, New Mexico 87501
505.984.8800

www.santafe.edu

January / February 2014

UPDATE

SANTA FE INSTITUTE

> Sabloff Q&A continued from page 7

status of the presidential search, and what do you think are the most important qualities for an SFI president?

Sabloff: Originally I was asked to come to SFI for a three-year term as president, and then in 2012 the Board asked if I would stay for a second three-year term. I agreed, but with the understanding that I would step down in the summer of 2015, which I intend to do. That will give me a chance to continue my research and writing, which haven't been my top priority in light of the challenges the Institute has faced during my term.

I'm very optimistic about the search. I think the SFI presidency is a terrific position. The Board has put together a strong search committee headed by [SFI External Professor and Science Steering Committee member] Walter Fontana of Harvard Medical School. I think they're poised to find the best person available.

It's not an easy job. In terms of qualities, first and foremost the next SFI president needs to have strong scientific credentials. He or she will have to be widely accepted by the scientific community, both within SFI and beyond. Candidates obviously need to have an interest in the study of complex systems. In addition, the new president needs to be someone with administrative experience, who at least has been a department chair, a dean, or a provost at a university, or who has in a variety of ways gained experience in running an organization. At the same time, SFI needs someone who has had significant success and experience in fundraising, because that's a key part of the job. And then I think, more intangibly, we need someone who has the people skills to energize a very diverse community of scholars and staff here at the Institute and also in our much broader community. Finally, there are a lot of strong egos in science, and that's a good thing, but

we need someone whose ego is harnessed to the success and development of the Institute. Essentially, it has to be someone who believes we is much more important than I. That's a tough combination, but as I said, I'm very optimistic that the Board, the faculty, and the staff are committed to finding the best person available to lead us as we begin our next 30 years.

Update: Why is a place like the Santa Fe Institute important in today's world?

Sabloff: More and more we find ourselves today focused on short-term, and increasingly shorter-term, linear thinking that says if we do A, we're going to get result B. In the complicated world that we live in, we need a more complex, nonlinear way of thinking. We hear popularly about black swans and tipping points and all kinds of other phenomena that come out of complex systems thinking. In business and government and public policy the focus, instead of being on years or decades, is on time horizons of months or weeks and quarterly reports and so on. As a society we need to take a longer-term view. As SFI's scientists have argued for years, we need to recognize that if we do A, we might or might not get B, but we also might get unintended consequences C and D and F, and some of those results we might not want. New emergent phenomena arise constantly. The system changes. This way of thinking, I believe, is essential in our world today.

SFI has been an important stimulus for complex systems thinking for 30 years. Many of our theoretical advancements can have, and have had, important ramifications in both science and public policy. Because of the challenges we face, that role is more important today than it ever has been. This is the way of thinking we're celebrating this year, our 30th year. I'm proud to be a part of it. ■