SANTA FE INSTITUTE

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UPDATE

How complexity restored Bali's rice yields

In Bali, rice is so intrinsic to the culture that its indigenous name, *nasi*, is also the word for "meal." For 1,000 years farmers on the Indonesian island province determined planting and irrigation schedules for Bali's curving rice terraces in ritualized water temple ceremonies.

By the 1960s, however, rapid population growth forced Indonesia to begin importing rice from abroad, and in the mid 1970s the Asian Development Bank and the Indonesian government introduced modern agricultural methods to boost crop production. In Bali, this meant new high-yield varieties of grain and the use of chemical fertilizers and pesticides.

The new rice – dubbed "miracle rice" – and chemicals increased Bali's rice production exceedingly well – for a short time. The bumper crops began to wane in less than two years.

SFI External Professor Steve Lansing, an anthropologist, happened to be in Bali at the time studying its temples. He suspected that the decline of the rice harvests could be related to the abandonment of the centuries-old farming methods.

In the traditional system, farmers met frequently at local water temples to coordinate their irrigation schedules and their fallow periods, and representatives met annually at Bali's supreme water temple to coordinate and pay homage to the goddess of the waters.

The modern approach, on the other hand, required each farmer to plant rice as often as possible, which made it easier for rice pests to migrate across adjacent, continually planted fields, and it caused the supply of irrigation water to become less predictable.

Steve believed the water temples had enabled Balinese farmers to strike a balance between water sharing and controlling rice

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RESEARCH NEWS

Mayan 'collapse' was more complex than a bad drought

The collapse of Classic Maya civilization in the Central Maya Lowlands and the dispersal of 90 percent of its population in the ninth century AD has been attributed to many things: drought, epidemic, even a peasant revolt.

New research based on a multidisciplinary analysis of the Maya civilization shows that only by looking at the interactions of the complex economic and social systems the Mayans were part of – including climate, trade, and agriculture – do clues to the real history emerge.

"There is no monolithic period of collapse but a lot of variability," says SFI President Jerry Sabloff. "What we see are many variable patterns. The only way to explain the variability is to have a complex systems view."

Jerry and Arizona State University geographer B. L. Turner have woven together a complex, data-rich history of agricultural practices in the lowlands and the demands on ecosystem services that created a stressed environment ripe for trouble when one particular drought struck.

On top of that, overland trade routes had shifted to sea routes around the peninsula, isolating the interior cities. All these stresses led to conflicts, loss of control by the Mayan elite, and, ultimately, decisions by peasants to leave the Central Lowland cities and relocate on the coast or in the Northern Lowlands, where Maya civilization continued to flourish.

The analysis, published in the August 20 issue of the *Proceedings of the National Academy of Sciences*, is in sharp contrast to theories that put most of the blame on individual, catastrophic stresses.

In recent years, for example, many archaeologists have renewed their interest in the drought hypothesis, says Jerry. That interest has been fueled by more and better paleoclimate data from the region. What the data show, however, is not a simple drought/collapse relationship, he says. Even cities that were water-rich, like Palenque, collapsed.

"It is true that we go through moments when certain drivers are emphasized much more than others," says Turner. "But collapse of the Classic Maya is sometimes simplified to the point of misunderstanding." ■

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RESEARCH NEWS

Why the housing bubble burst: Model offers fresh insights

When markets crashed in 2008 and 2009, a number of competing hypotheses cropped up as to how it happened and what the major contributors were. Some economists concluded that financial leverage in housing markets triggered the downfall, while others just as firmly ruled it out, citing interest rates as the main reason.

The assessments differed so widely, in part, because the market models most economists rely on today have shortcomings: Many use just a few variables that don't adequately represent the complexity of housing markets, and they typically run on averages and aggregate numbers to

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RESEARCH NEWS

Mayan astronomy, society, cosmology, and timekeeping

As December 2012 approaches – and with it the supposed end of the fabled Mayan Long Count calendar – popular references to a Maya-predicted doomsday will reach a crescendo. Recently at SFI, a small group gathered for a quieter and far more scholarly approach to understanding the early Maya.

The three-day SFI working group in August brought together experts in Maya archaeoastronomy to pursue questions central to both to astronomy and complex civilizations.

"With the rapid increase in archaeological knowledge about early Maya cities, their

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Nature, Science, NPR, PRI, *Science News,* and *Discover* magazine covered an August 13 *PNAS* paper co-authored by SFI External Professors Michael Hochberg and Pablo Marquet. Their study posited that ritual mummification and other complex cultural innovations that arose some 7,000 years ago in hunter-gatherer societies in the Atacama Desert (modern-day Chile and Peru) might have been a by-product of a regional population increase driven by favorable environmental changes, including a wetter climate.

In an August 7 opinion piece on CNN.com, SFI Omidyar Fellow Simon DeDeo asks whether the excitement surrounding the Curiosity rover's landing on Mars suggests that Americans are "rekindling their romance with science after what seems like a long and tepid stupor," and suggests that a new era of scientific exploration is upon us in which we might at last begin to understand the principles underlying human behaviors.

In *Nature* on August 1, former SFI External Professor Peter Turchin describes the promise of the field of cliodynamics, the quantitatively informed study of history, citing the work of SFI External Professor Herbert Gintis.

Better technology has turned cities into fountains of data that confirm known regularities and reveal striking new patterns, according to a June 23 feature in *The Economist* that cites SFI's cities and urbanization research. On July 6 *The Atlantic* also mentions SFI's quantitative research of cities. And on July 27, the *Wall Street Journal* described SFI's cities and urbanization research, noting how, on average, the creative output of larger cities more than doubles when population doubles.

SFI External Professor Jessica Green's research to understand the ecology of indoor spaces is featured in the July issue of *Discover* magazine. Green is director of the University of Oregon's Biology and the Built Environment (BiobBE) Center.

An *American Scientist* review of "The Nature of Computation" (Oxford University Press, 2011), by SFI Professor Cris Moore and External Professor Stephan Mertens, calls the book "one of the most successful attempts to capture the broad scope and intellectual depth of theoretical computer science as it is practiced today."

An interview in the October issue of *Discover* magazine features SFI Distinguished Professor Geoffrey West and SFI's cities and urbanization research, and the genesis of the work that has found surprisingly similar scaling relationships in biological and human socioeconomic systems — from cells to cities.

Technology Review, the *Daily Mail*, and *io9* covered recent research by SFI External Professor Aaron Clauset and collaborator Ryan Woodard, who examined 13,000 lethal terrorist attacks between 1968 and 2007 and calculated a 20 to 50 percent likelihood of another 9/11-magnitude catastrophic attack in the next decade.

More SFI news at www.santafe.edu/news.

Nonlinearities
From the editor

We recently hosted a public panel discussion in Santa Fe on why complexity is a defining feature of our universe. The event was moderated by David Krakauer (who could probably talk provocatively about cardboard if you asked him to). With big names in science like Lord Colin Renfrew, Sir Christopher Llewellyn Smith, Murray Gell-Mann, and Melanie Mitchell (who literally wrote the book on complexity), the conversation was no disappointment. Many people had to be turned away, unfortunately, because of a full house and those pesky fire codes. You can now watch it online at www.santafe.edu.

SFI President Jerry Sabloff lamented during his opening remarks that there just aren't enough jokes about complexity science. He gave two examples that went something like this. Q: How many SFI scientists does it take to screw in a light bulb? A: Three, plus or minus one. Q: How can you tell an introverted SFI scientist from an extroverted one? A: The introverted scientist looks at her shoes when she talks to you. The extroverted scientist looks at *your* shoes.

Yes, this is a dire situation. Fortunately we can do something about it. A year ago *Update* readers submitted a few dozen very good entries as part of the SFI T-shirt slogan contest, resulting in three popular T-shirts that sold quickly. Let's try again. If you have a joke – recycled or fresh – about complexity science, complexity scientists, or SFI, send it to me at jdg@santafe.edu. The winning entry or entries, judged by a semi-random group of SFI extroverts, will be announced here, and the submitter(s) will receive one of the aforementioned T-shirts. Bonus points for irreverence, as always.

Did you know you can follow SFI on Facebook, Twitter, LinkedIn, Google+, YouTube, and Pinterest? Behind SFI's growing social media presence are Juniper Lovato, who is a bit of a social media muse, and yours truly, who tries to keep up. On Twitter you can follow SFI at @sfi_news (science news) and @sfi_live (a live feed during selected SFI events). Today I'm happy to announce a third SFI Twitter feed, @nonlinearities, which is sort of like this column except more frequent and in 140 characters or less. Its mission, officially: "Revealing the behind-the-scenes, human, often humorous side of the Santa Fe Institute." I hope you'll join us.

– John German, jdg@santafe.edu

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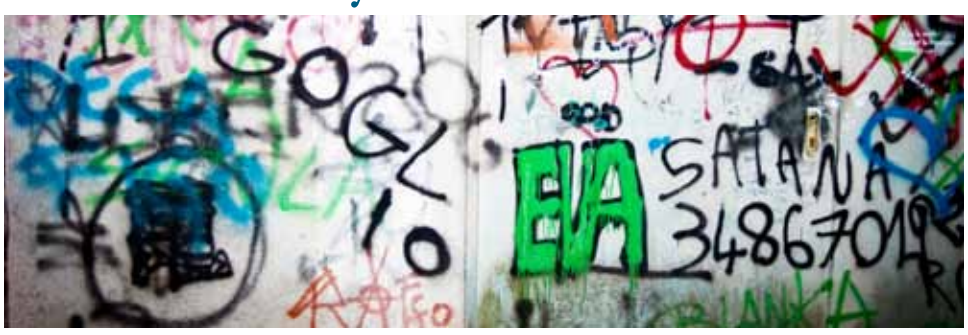
Statistical analysis that fits the crime



While many urban indicators – infrastructure, wages, patents, etc. – are known to scale predictably with city population, previous statistical analyses of cities have not examined in detail how year-to-year deviations in certain highly variable, lower frequency statistics fit with these general expectations.

Serious crime, such the number of homicides, is especially problematic for scientists studying urban dynamics because crime rates for an individual city can vary drastically from year to year. One year a city might experience a single homicide, and the next year, perhaps five. A peaceful year with no crimes is a particularly knotty statistical problem because for scaling purposes, a zero crime rate can be expected only for a city of zero population.

In a recent paper, three SFI researchers demonstrated an analysis method that – for the first time, they believe – resolves these statistical difficulties and, using homicide data from three nations with very high but rapidly changing rates of violent crime – Brazil, Colombia, and Mexico – fit real-world data to their method.

"The main issue with studying homicides and other violent crimes is that numbers are usually – and fortunately – small, and vary significantly from year to year," says co-author Luis Bettencourt, an SFI Professor. "Crime is almost always measured as a per capita rate, usually a small number per 100,000 people, which doesn't reveal much underlying truth about variations in crime between cities and over time."

Additionally, notes co-author Andres Gomez-Lievano, a graduate student at Arizona State University, scaling analyses are usually applied to large cities; the team wanted to extend the analyses to cities of all sizes, including very small ones. Applying simple scaling laws to all cities, however, typically generates false conclusions, especially with data from small places where zeroes are more probable. Their new statistical framework corrects this shortcoming.

Their work shows that although population is a poor one-for-one predictor of homicide rates, homicides are, indeed, statistically entangled with population size. Moreover, they show that when using their statistical method, the distribution of homicides is much more predictable than previously believed.

"The deeper level of understanding made possible with our new method might, if considered by policy makers, contribute to making real progress in fighting crime, especially in taking into account its variability and helping unveil its underlying dynamics" says Luis.

Next the researchers plan to use data from many urban systems around the world to examine how crime rates and their statistics evolve over time, and shed light on successful strategies to fight crime and detect impending crime waves.

The paper, "The Statistics of Urban Scaling and Their Connection to Zipf's Law," by Gomez-Lievano, SFI Postdoctoral Fellow HyeJin Youn, and Luis, was published in *PLoS One* on July 18, 2012. ■

An SFI public panel discussion August 6 in Santa Fe included (from left) SFI External Professor David Krakauer, Sir Christopher Llewellyn Smith, Lord Colin Renfrew, SFI External Professor Melanie Mitchell, and SFI Distinguished Fellow Murray Gell-Mann. The wide-ranging conversation, which attracted a standing-room-only audience, covered new SFI research supported by the John Templeton Foundation, including major SFI projects on the evolution of complexity on earth, hidden laws in complex biological and social systems, and the emergence of complex societies.

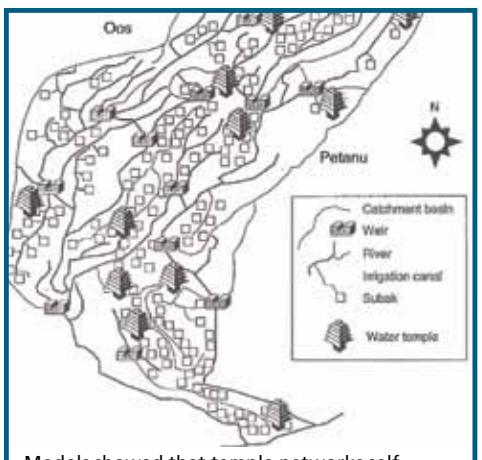
> *Bali's rice* continued from page 1

pests with synchronized fallow periods, tending towards a global optimum in each valley. Furthermore, the temple rituals were just flexible enough to allow the farmers to adjust to changing conditions. The modern methods, he believed, had inadvertently revealed the functional role of the temple networks.

Steve explained the problem to the Asian Development Bank in a 1983 unsolicited report. Its planners were unconvinced, so he and ecologist James Kremer devised a computer model to explore the effects of temple coordination on irrigation flows, pest outbreaks, and rice harvests for 172 farming communities, called *subaks*, operating along two rivers.

In the simulations, each *subak* began with a random cropping pattern and irrigation schedule. After every harvest, the *subaks* compared their yields to those of neighboring *subaks*. Each *subak* would then adjust its crop patterns and irrigation schedules to match those of its neighbor when the neighbor's rice yields were higher.

No matter what "external" conditions the researchers changed in their model – rainfall, water flow, rice growth, pest biology – over several "modeling years" the virtual *subaks* adjusted their cropping patterns and irrigation schedules such that synchronized planting and fallow patterns emerged, and rice yields for the overall model were optimal. Moreover, the simulations formed a near match of the *subaks*' actual practices.



Models showed that temple networks self-organize, creating a globally optimal scale of water use.

"As we repeated these simulations," says Steve, "we found that it is almost impossible *not* to grow a water temple system."

Based on the modeling results, the Bank conceded in 1988. In Bali, after the return to temple management, water was used more effectively, pest populations declined, and Balinese farmers once again became the most productive in Indonesia. This summer Bali's water temple network was selected by UNESCO for recognition as a World Heritage site.

This, says Steve, was a real-world example of a complex adaptive system with emergent properties, whose existence had gone unnoticed until modeling revealed its processes. "Without the complexity perspective, this system would very likely have gone unrecognized," he says. ■

SFI Online

Multimedia content available at ***www.santafe.edu***

Video: Microsoft's Duncan Watts, drawing from examples and ideas from physics to sociology, explores how we get duped by shared assumptions and demonstrates how learning to suspect our own common sense can lead to better solutions. Source: SFI 2012 Community Lecture

Video: SFI Omidyar Fellow alumnus Dan Hruschka searches for clues to the origins of human friendship – how it develops, how it varies across cultures, and how it compares to social ties in other species. Source: SFI 2012 Community Lecture

Video: SFI Distinguished Professor Murray Gell-Mann joins screenwriter Danny Rubin to give the comedy classic movie "Groundhog Day" a novel spin: Can Bill Murray help us understand the essence of scientific practice? Source: 2012 SFI-CCA Science on Screen series

Video: SFI External Professor Scott Page discusses the myriad roles diversity plays in complex systems. Source: National Science Foundation video

Audio: SFI Omidyar Fellow Scott Ortman explores the critical role metaphor and conceptualization play in human history. Source: Santa Fe Radio Cafe interview

Audio: Author Pamela McCorduck discusses her latest novel, "Bounded Rationality," the second in a planned trilogy whose characters and storyline are entangled with SFI and complexity science. Source: Santa Fe Radio Cafe interview

Audio: Former SFI Omidyar Fellow Nathan Collins draws on science to ask whether democratic societies can make good decisions. Source: Santa Fe Radio Cafe interview

Video: Five of the biggest thinkers in science explore why and how complexity is a pervasive feature of our universe — in systems from genes to societies. Source: SFI public panel discussion

Audio: SFI Professor Jennifer Dunne on food webs, what they are, and why a better scientific understanding of the structure of interactions between species is important for a more stable planet. Source: Santa Fe Radio Cafe interview

RESEARCH NEWS

Next steps in art and science collaboration

Art and science often intersect, but true collaborations that bring art and science together for a specific purpose have been few and far between.

In mid September, SFI is hosting the Scientists/Artists Research Collaborations (SARC) Working Group. The meeting will include short presentations of current projects by SARC participants, who include visiting artists and collaborating New Mexico scientists. Participants will explore the future of art-science collaborative research and development.

SFI Professor Jennifer Dunne says most previous art-science collaborations have been limited to either artists using or critiquing technology and scientific methods, or scientists acquiring compelling visualizations of data.

"While these types of 'science serves art' or 'art serves science' projects can be very fruitful, what have generally been missing are collaborations that truly advance both art and science, and society," she says. "An extended, deep, critical discussion about the potential opportunities for science and art collaboration and exchange is urgently needed."

SARC is organized by Richard Lowenberg, director of the 1st-Mile Institute, and Jack Ox, associate research professor in the University of New Mexico College of Fine Arts. It is part of the 18th International Symposium on Electronic Art, which takes place in Albuquerque, Santa Fe, and Los Alamos September 19-24, 2012 (http://www.isea2012.org). ■

In his Auto Immune Response (AIR) series, artist Will Wilson addresses the relationship between a post-apocalyptic Diné man and the beautiful but toxic environment he inhabits. Auto Immune Response Laboratory 2, seen here, is a hogan-shaped metal greenhouse that will cultivate Indigenous food and dye species. The greenhouse will be installed at the Navajo Nation Zoo in Window Rock, Arizona. (Courtesy: Will Wilson)

RESEARCH NEWS

Defining archaeology's biggest questions

What is the relationship between agricultural production, population, and innovation in human history? How do humans respond to abrupt environmental changes? How does the organization of human communities emerge from and constrain the actions of their members?

During a workshop at SFI in August, participants asked and began to hammer out answers to these and other big questions in archaeology.

The National Science Foundation funded the workshop, with an objective of defining the key scientific questions that will drive archaeological research over the next decade, says Keith Kintigh, the workshop's organizer. The archaeologists who participated sought to articulate challenges that are both relevant to human experience (now and in the past) and capable of being addressed through archaeological data.

Many of the grand challenges they proposed dealt with emergence, complexity, scale independence, and other themes that figure prominently in SFI's research.

The participants agreed that to progress toward solving the grand challenges, archaeologists generally will need to adopt new approaches that will allow them to synthesize and analyze large data sets.

"Attacking many of these grand challenges will involve building expertise for modeling how societies work," says SFI Science Board member and External Professor Tim Kohler, who has pioneered the use of agent-based modeling for understanding archaeological data.

"We've been doing empirical work in archaeology for over a hundred years, and we need to continue to do so," he says. "But to understand social and environmental processes, we need to be able to compare the outputs of models with archaeological data sets. That, along with new techniques for visualization, will be critical to making progress in the next couple of decades."

The workshop also highlighted the need for a cyber infrastructure for archaeological information that would enable transformative synthesis and modeling.

A followup meeting is planned for next spring in Washington, D.C. to begin the development of such an infrastructure. ■

RESEARCH NEWS

Taking stock of Darwin's theory

Two centuries ago, a young Charles Darwin puzzled over the birds of the Galapagos Islands while gathering the inspiration for his theory of natural selection. Today that theory is getting a fresh look through the lens of information theory.

In essence Darwin's theory is the process by which living things with traits favorable for reproduction in particular environments succeed in doing so. On a planet where complex biological and physical pressures are always – to some degree – in flux, natural selection leads to a steady evolution in the contest between organism and environment.

"Although the theory of natural selection is simple, it remains endlessly contentious and difficult to apply," says Steven Frank, an SFI External Professor and professor of ecology and evolutionary biology at UC Irvine. He is publishing a series of articles in the *Journal of Evolutionary Biology* called "Topics in Natural Selection," addressing the fundamentals of the theory.

"My goal is to make more accessible the concepts that are so important, yet are either mostly unknown or widely misunderstood," he wrote.

For instance, instead of looking at just how individuals of a species change over time, natural selection can be seen as a way information about the environment is captured by populations of living things.

"I'm primarily looking at mathematical relationships," he says. "The point is that the mathematical expressions of natural selection and the mathematical expressions of information theory are exactly the same, which, for some reason, has never been said explicitly, as far as I know."

The failure to recognize that connection might arise from the history of Darwinian theory, Steven says, in which the math followed statistical theory instead of information expressions.

"The mathematical connections between natural selection and information theory are valuable because we can now see more precisely how to understand the workings of selection," he says. ■

> ***Mayan astronomy*** **continued from page 1**

architecture and urban forms, new information from hieroglyphic decipherment, and recent advances in understanding ancient Maya iconography, the opportunity for new insights into the role of astronomy in the development of ancient Maya civilization could not be better," says SFI President Jerry Sabloff, who participated in the meeting.

"This working group brought the rising stars in the field [of Mayan archaeology] together with very accomplished archaeo-astronomers," says Maya iconographer and Washington University professor David Freidel, who organized the event. Participants exchanged data and met at SFI to discuss the significance of celestial worship in emerging, pre-classic Mayan cities.

The ancient Maya developed a complex society in the Central American rainforests starting around 800 BC. They flourished there until about AD 900 (although Maya civilization continued in neighboring regions until the 16th century Spanish Conquest). The sun was a major part of their cosmology, and the Mayans erected solar observatories that were central to both religious and political activities.

The working group's discussion focused on the origins of Maya solar cosmology, and on the architectural structures and early calendars used to tie religious ceremonies to civic gatherings.

With more than half of the world's population now living in cities, says Freidel, it is more important than ever to understand the religion, politics, and economics of ancient urbanites.

"The Maya built and sustained an urban civilization in a rainforest environment for more than 2,000 years," he says. "We modern civilizations have managed to almost completely destroy that rainforest in less than 50 years. We have a lot to learn from what the Maya did right." ■

RESEARCH NEWS

Online 'social petri dish' offers insights about real-world human mobility


Scene from Pardus

New research started during SFI's 2010 Complex Systems Summer School suggests that player-interaction data from online games such as Pardus are surprisingly useful for understanding how and why people physically move in the real world.

Large amounts of data on human mobility are readily available thanks to studies of mobile phone records and location-based online social networks. But a rich understanding of the mechanisms behind the individual decisions people make – based on socio-economic factors, spatial constraints, and temporal considerations – has been elusive.

CSSS participants Michael Szell, Roberta Sinatra, Giovanni Petri, and Vito Latora, working with SFI External Professor Stefan Thurner, used the vast amounts of data on players' social interactions and economic activities generated by Pardus to study the patterns and mechanisms of player mobility. Pardus is a multiplayer online game in which gamers explore a virtual universe, where they make friends and enemies and communicate, trade, and interact with one another.

"What I like most about this work is that human mobility in the real world and in virtual worlds are not all that different," Stefan says. "One could – if one is a bit generous – interpret this to mean that the processes of traveling basically happen in our imagination, and the way mobility is finally executed is somehow secondary; we don't necessarily need the real world to understand how we move."

The team's results were published in June 2012 in *Scientific Reports*, an online, open-access journal by the Nature Publishing Group. ■

DONOR PROFILE

Mickey & Jeanne Klein: Supporting creativity

For creativity to thrive, it must be nurtured. Mickey and Jeanne Klein have long nurtured the creative spirit through their longtime support of contemporary art. Recently they discovered that the same creative spirit is alive and well at SFI.

"It struck me how much I'd like to support not only arts but creative thinking…to honor the creative spirit no matter the discipline," Jeanne says. "At SFI, they acknowledge that the creative spirit crosses disciplinary lines."

Jeanne used to think of science in terms of its disciplines – astronomy, biology, nuclear science, and the like. That changed last September when she and Mickey attended their first SFI public lecture. SFI External Professor David Krakauer's Ulam Memorial Lectures on the co-evolution of biological intelligence and machine intelligence opened their minds to creative thinking that transcends and unites traditional scientific disciplines. Even more impressive, Jeanne says, was how David spoke in a way that was engaging and understandable to nonscientists.

The Kleins move comfortably in the world of contemporary art. They find that people who are new to art are often interested in what they see but afraid to discuss it. Science can have a similar effect; people without a science background are often curious but intimidated.

Jeanne says she and Mickey have appreciated the way SFI has opened its doors to the uninitiated public. Its researchers are not only willing to share their work but they are eager to explain it in a way that nonscientists can understand and get excited about.

"I love that they've reached out to people," she says. "Great minds attract great minds, no matter the discipline." ■

ACHIEVEMENTS

SFI Omidyar Fellow alumnus Nathan Eagle has received a 2012 Global Economy Prize from Germany's Kiel Institute for the World Economy, conferred for advancing creative discourse on world economic matters and for initiatives that meet globalization challenges using labor, financing, and commodities markets. Eagle, founder and CEO of the mobile phone research and marketing company Jana, shares the 2012 prize with two Nobel laureates: former Finnish President Martti Ahtisaari and economics professor Daniel Kahneman.

The American Association of Physics Teachers (AAPT) has selected SFI Science Board member David Pines with the John David Jackson Award for Excellence in Graduate Physics Education. The award is presented to physicists and physics educators who have made outstanding contributions to curriculum development, mentorship, or classroom teaching in graduate physics education. David will receive the award at the AAPT's January meeting in New Orleans. ■

> ***Housing bubble*** **continued from page 1**

find coarse patterns rather than apply the full range of possibilities.

"There are millions of homeowners with widely different tastes and wealth," says SFI External Professor John Geanakoplos, an economist at Yale. "Aggregating them into a simple average misses the behavior in the tails that causes the big swings up and down like we saw from 1997 to 2009."

In a recent paper published in *American Economic Review*, John, SFI External Professors Rob Axtell and Doyne Farmer, and Peter Howitt of Brown University questioned weaknesses in the current models and asked whether forecasters were using the most telling variables. Their own agent-based model of the U.S. housing market, they wrote, better captures the heterogeneity of agent behaviors.

Their model adds new loan features and incorporates data on household demographics, economic conditions, and housing market behaviors. Starting at the level of the individual homeowner, it follows each through the various costs, likelihood of prepayments and turnovers, and other factors. Its simulations neatly fit housing prices and other housing market indices from 1997 to 2010.

Consequently, they say, manipulating the model (by holding certain variables constant) offers a means to pinpoint the major causes of the 2008-2009 crash. Freezing interest rates, for example, simply reduced the intensity of the boom and bust, but holding leverage (down-payment percentages) constant greatly shrank the boom and wiped out the bust.

"Knowing that mortgage lending with very small down-payments was the primary cause of the 1997-2006 housing boom, and that the sudden spike in required down-payments in 2007 and onward was a primary cause of the housing crash, suggests that the federal reserve ought to rethink its obsession with interest rates as the unique tool for maintaining financial stability," says John. ■

Upcoming events

Santa Fe Institute-Museum of Contemporary Native Arts event: "Chaos to Complexity: Artists and Scientists Share Insights into the Creative Process," September 29, 4 p.m., Museum of Contemporary Native Arts (108 Cathedral Place, Santa Fe) – The Museum of Contemporary Native Arts and SFI kick off a new lecture series exploring the creative process in art and science. SFI Distinguished Professor Geoffrey West and native artist Mateo Romero discuss how creativity influences and inspires their work, how it compares and differs across art and science, and how the discovery process – whether it be in painting, photography, or mixed-media art or the study of scale in physics or social systems – can produce bursts of manic, creative energy that drives innovation. Moderated by SFI's Valerie Plame Wilson.

SFI's Stanislaw Ulam Memorial Lectures: "The Many Faces of Complexity," three lectures, three nights, October 2-4, 7:30 p.m., James A. Little Theater (1060 Cerrillos Road), Santa Fe. Renowned scholar, science activist, zoologist, and complex systems pioneer Robert May, Baron May of Oxford, considers the complex systems that matter most to humanity's future. May is a professor of zoology at Oxford University and Imperial College, the former president of Britain's Royal Society, the former Chief Scientific Advisor to the U.K. government, and a member of SFI's Science Board.

Lecture I (October 2, 7:30 p.m.): "Beauty and Truth in Mathematics and Science" – May explores the extent to which beauty has guided, and still guides, humanity's quest to understand how the world works, with a brief look at the interactions among beliefs, values, beauty, truth, and our expectations for tomorrow's world.

Lecture II (October 3, 7:30 p.m.): "What Is Stability in Today's Complex Financial Systems?" – The economic crisis prompts May to explore how we might design financial services that satisfy their purpose of efficient distribution of capital in a free-market system but without the fragility and (hidden) costliness of our current systems, with emphasis on what ecology can teach us about banking.

Lecture III (October 4, 7:30 p.m.): "People and Tomorrow's World" – What having more people on Earth, with each of them having a longer life span and greater per-person impact on our environment, means for the world's climate and ecosystems and the services they deliver (with emphasis on how little we know about these questions).

Support for SFI's 2012 lecture series is provided by Los Alamos National Bank. ■

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UPDATE

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