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# UPDATE



Image: Gabriel Garcia

## Big Data meets big theory at annual symposium

As our abilities to acquire, store, and analyze mountains of data have grown in recent years, so too have questions about Big Data's true abilities and limits. Proponents tout Big Data as a means to improve the quality of almost any process we can measure. But data alone, without accompanying theory, may not lead to the best questions and hence may not be generating the best answers.

SFI's annual Business Network and Board of Trustees Symposium will explore both the promise and the limits of Big Data, as well as the value of theory in the Big Data context.

"The fundamental hope of Big Data proponents is that it can provide a tool to help them substantially answer their questions," says Symposium organizer, neuroscientist, and SFI Business Network Director Chris Wood. "But perhaps the biggest misconception is that we can answer all our scientific, business, government, or political questions if we only have the right data."

Often the true usefulness of Big Data is uncertain, Wood points out. Social scientists are now using data from social networks such as Twitter and Facebook to make inferences about social interactions in general. Whether or not the conclusions from online network data generalize to other forms of interaction is an important empirical question, he says, but that question cannot be answered from the online data alone.

Sometimes Big Data can be the right resource. Symposium speaker Dan Wagner's analytics during the 2012 Obama campaign used a variety of commercial and political data to identify those voters likely to favor Obama's messages, then helped find ways to reach them electronically or face-to-face. The strategy contrasts markedly with more traditional "voting bloc" techniques.

Problems with the digital economy – particularly people's willingness to give away data about themselves that ad companies will pay dearly for – are the subject of a recent *New York Times* op-ed by the Symposium's

keynote speaker, author Jaron Lanier.

Other Symposium participants include Alexander Szalay, a cosmologist at Johns Hopkins who was among the first to build a very large-scale scientific database; SFI External Professor Cosma Shalizi, a professor of statistics at Carnegie Mellon who offers cautionary tales about incorrect inferences and bulky models; and author James Bamford, a leading scholar on the U.S. National Security Agency, which is perhaps the biggest "Big Data" organization of them all.

In any case, it is essential to question and test assumptions about Big Data and its applications, Wood says. A familiar example is the use of search histories to target online ads. Are all search terms equally valuable to advertisers? Such questions are part of the "arms race" between companies providing online services and seeking to deliver the best "eyes" to their advertisers.

The invitation-only Symposium runs October 31-November 2 in Santa Fe. ■

### RESEARCH NEWS

## Workshop: How far can Big Data about cities really take us?

Big Data's potential to provide a quantitative basis for addressing familiar urban problems has prompted several universities and corporations to launch programs dedicated to urban informatics and policy.

But the use of extensive data in urban management is not new, which poses questions about what specific qualitative leaps are achievable in the near future, and what data those advances require.

For a few days in September, urban researchers, city planners, and representatives from international organizations and major corporations are meeting at SFI to explore how Big Data can help them better understand, plan, and manage cities.

Some Big Data enthusiasts believe "if we can measure everything we can solve everything, without knowing or caring about underlying constraints," says meeting co-organizer and

SFI Distinguished Professor Geoffrey West. The workshop will explore under which specific conditions this may be true.

In that view's favor, some pressing urban problems – such as effective public transportation or even crime reduction – might be tackled using relatively simple approaches enabled by more and better data. But "we still don't know how such solutions play out

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### RESEARCH NEWS

## Searching for smarter algorithms

For many of the complex systems we care the most about, "simply relying on the fact that computers are bigger and faster isn't enough," says SFI Professor Cris Moore.

Intel co-founder Gordon Moore's law about the doubling of computing power every few years is of little significance compared to the astronomically greater improvement in computing power achieved through smarter algorithms, Cris says.

An SFI workshop in early August for physicists and computer scientists sought to prompt collaboration on new algorithms for solving problems and modeling nature.

A primary source of smarter algorithms is statistical physics. Physicists use their insights into a system's structure to design algorithms and collect empirical evidence of their validity. Of particular interest are algorithms that "skip over the steps that nature takes," as Cris puts it, bypassing what's called the "critical slowing down."

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### RESEARCH NEWS

## Building a theory for 'sustainability'

It's a word being attached to products, businesses, fisheries, farms, and more – but what does "sustainable" really mean? And if you can find a definition that everyone agrees on, how do you know whether you are attaining it?

"The problem is that the term has been used in many ways," says SFI Professor Luis Bettencourt. To some it means quick fixes to crop yield or water quality problems, with little consideration of the ecosystems services that support those fixes or the shifts they require in other human demand or consumption. To others it's a useful, but general, aspiration.

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The *Daily Beast* on August 23 notes that the movie *Elysium*’s depiction of the future gets one thing right: such an economically disparate society would likely feature an abundance of “guard labor,” as noted in a 2005 SFI working paper by SFI Professor Sam Bowles and col-laborator Arjun Jayadev.

Michael Crow’s July 31 SFI Community Lecture, during which he proposed a new kind of academic institution designed to adapt to tomorrow’s complex challenges, was covered in the *Santa Fe New Mexican* and the *Albuquerque Journal*, and in an interview on the Santa Fe Radio Café.

In an August 5 article in the *Santa Fe New Mexican*, SFI’s Maureen Psaila-Dombrowski explores ways educators can engage U.S.

students in computer science. The column is part of a series of SFI-written “Science for a Complex World” articles.

Several publications noted on August 1 that the White House announced that President Barack Obama intends to nominate France Cordova to lead the National Science Foundation. Cordova is an SFI visiting professor.

Econophysics and the “Santa Fe stock market model” are getting another look in the wake of recent financial crises and market downturns that classically trained economists failed to foresee, according to a column in the *Wall Street Journal* on July 10.

# SFI Online

Multimedia content available at [www.santafe.edu](http://www.santafe.edu)



**Audio: SFI Distinguished Fellow Murray Gell-Mann** discusses what it means to think like a scientist, the value of rejecting orthodoxy, theoretical beauty and simplicity, complex systems science, and intelligent life on other planets, among other topics. Source: Santa Fe Radio Café interview



**Video: Steven Pinker and Rebecca Newberger Goldstein** ask whether human moral progress is a gift of empathy and emotion or of reason and logic. Source: SFI Community Lecture



**Video: Arizona State University President Michael Crow** proposes a new kind of academic enterprise that will help us cope with tomorrow’s complex challenges. Source: SFI Community Lecture



**Video: Glenn Loury of Brown University** explores a formal economic model of “collective reputations” (a.k.a. stereotyping) and describes how observed agents can have control over their perceived identities. Source: SFI lunchtime seminar

## Nonlinearities From the editor

As expected, Steven Pinker and Rebecca Newberger Goldstein packed the house for their recent SFI Community Lecture, during which they asked, from scientific and philosophical perspectives, what aspect of our humanity – reason or emotion – is most responsible for the moral progress of our species. When the Q&A portion of the evening began, something unexpected happened: maybe one person left the auditorium. Usually at that point two-dozen people get up and go on to the next thing. But this duet made the whole audience yearn for more.

The Institute regularly brings to Santa Fe some of the world’s most compelling thinkers. It would be a shame if these talks were not available outside the James A. Little Theater. Fortunately, they are, and I want to be sure you know this. We don’t have a fancy set or worldwide marketing team – TED, I’m “talking” to you – but we are streaming all 2013 Community Lectures live on SFI’s YouTube page. Our remote audience hails from as far as New Zealand, where the lectures begin at 1:30 p.m...the next day.

As an added bonus, you can watch an SFI lecture *and have a discussion about it* on Twitter at #sfi\_live. Juniper Lovato and I are there, Tweeting up a storm, and we enjoy the perspectives of regulars like Phil Moyer (@hukuzatuna) from Delaware. Why don’t you say “hi” during Stephanie Forrest’s first Ulam Lecture Tuesday night, September 10 (see page 3).

Every workplace has its own shorthand. At SFI we have tea, of course, every day at 3 p.m., when we converge for an infusion of carbohydrates and conversation. But the mention of a “Special Tea” always brings a pang of regret. “Special Tea” at SFI means a member of our village is leaving, moving on to the University of Such and Such or the Institute for Advanced This & That. We’ve had a lot of special teas lately. As I’m writing this I received word of a special tea for Laura Fortunato and HyeJin Youn to take place this very afternoon. I feel glad for the individuals who have left for exciting new gigs. And departures are a necessary downside of the continual renewal that makes the Institute such an idea-rich place. But still, these people are part of our lives. We’ve laughed together, lunched together, disagreed sometimes, and given each other welcome rides up a very steep hill. I speak for us all when I say we feel their absences deeply. ■

– John German, [jdg@santafe.edu](mailto:jdg@santafe.edu)

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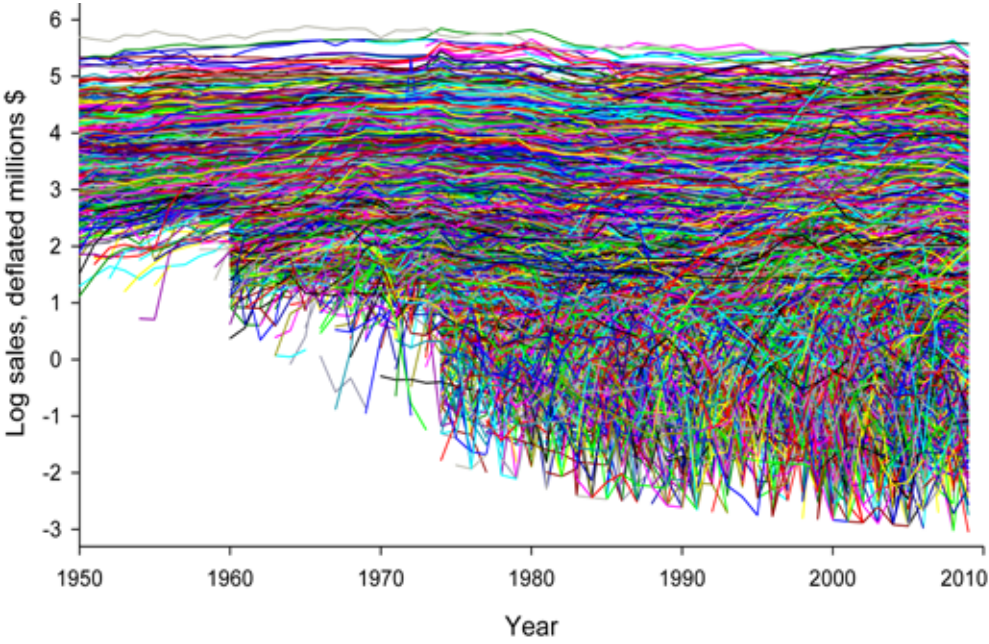
The *SFI Update* is published bimonthly by the Institute to keep its community informed. Please send comments or questions to John German at [jdg@santafe.edu](mailto:jdg@santafe.edu).



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### BUSINESS NETWORK NEWS

## Are corporate and human life cycles similar?



Sizes of some 30,000 companies traded publicly on U.S. markets from 1950-2009, measured by their sales (controlling for inflation and GDP growth). The relatively rapid growth of smaller companies near the beginnings of their lifespans account for the ragged lower portion of the chart, as well as the relatively steep initial sales increases. As companies reach maturity and as markets become saturated, their sales tend to level off. (Courtesy Marcus Hamilton and SFI’s Cities, Scaling, and Sustainability team)

Business enterprises, particularly large corporations, are closely woven into the fabric of modern society. Individual corporations go through life cycles of birth, growth, maturity, and death akin to the life cycles of people.

In its next Business Network topical meeting, The Natural History of the Corporation, SFI and BNet members will explore the evolution and historical origins of the modern corporation, along with the corporate life cycle, the impact of increasing globalization, and the relationship between corporations and other major social institutions.

The meeting takes place September 30 at the London offices of global professional and financial services company Towers Watson.

While parallels can be drawn between the human and corporate life cycles, there are also important differences. For example, corporate death is not necessarily inevitable, and corporations can experience rebirth through new technology and continual re-invention.

Business Network member Tim Hodgson, a senior investment consultant at Towers Watson, says understanding the life cycle of corporations is fundamental to his business because investment decisions are based on whether or not the market pricing of a security accurately reflects the company’s position in that cycle.

“I am expecting the meeting to confirm that corporations – statistically – do have a lifespan, but my intuition would be that individual corporate experience will be much more variable than for individual humans,” Hodgson says.

Chris Wood, SFI Vice President for Administration and Director of the Business Network, notes that this meeting provides an opportunity for SFI to engage with its UK and European members and apply the principles of complexity science to a fresh perspective on the modern corporation.

“We look forward to new insights on the life cycle of the corporation from the juxtaposition of corporate and academic viewpoints,” he says. ■

> **Big Data about cities**  
continued from page 1

over longer periods of time, when social and economic changes, which tend be slower, but crucial, in cities, come into play,” says co-organizer and SFI Professor Luis Bettencourt.

We also don’t know to what extent seemingly obvious opportunities for the use of Big Data might interfere with human behavior and the creation of productive social environments.

“It seems like a no-brainer to instrument buildings with sensors and actuators to achieve higher energy efficiency, and this is particularly appealing in big cities,” says co-organizer Jose Lobo, a senior scientist in the School of Sustainability at Arizona State University. “But often people prefer to open a window or shut the blinds, which undermines such solutions.”

Cities offer a rich interplay of human and social behavior in highly managed and instrumented spaces, Bettencourt notes. The nature of cities is at once to promote efficiencies and socioeconomic development. How this can be achieved through scientific insights, engineering solutions, and creative new policies is the central question for urban research. The meeting creates the opportunity for an exceptionally varied set of leading urban thinkers to talk openly about the future of cities in the age of Big Data, he says.

The invitation-only workshop, How Far Can Big Data Take Us Towards Understanding Cities?, runs September 19-21 in Santa Fe. ■

> **Sustainability**  
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“One important meaning is to provide improved well-being to humans without long-term damage to the Earth system,” Bettencourt says. “For a business, a city, or a nation, it’s a commitment to a path of scientific and technical improvement and ethics that speaks to improved uses of resources.”

What all notions of sustainability have in common is they are difficult to quantify, and therefore difficult to improve. A late October meeting at SFI seeks to promote the development of a theory of sustainability along with the identification of data and knowledge systems to support that theory.

SFI Science Board member and External Professor Nina Fedoroff says a science of sustainability must incorporate the impacts of economic growth and human development on the environment.

“Earth and its biological inhabitants, including people, are the most complex system we know,” she says. “We don’t yet have either a theory of complexity or an experimental approach to manage this system, our global system, wisely.”

Fedoroff is co-organizing the invitation-only workshop with Bettencourt, Molly Jahn of the University of Wisconsin-Madison, and Margaret Collins of the International Institute for Applied Systems Analysis (IIASA). ■

> **Smarter algorithms** continued from page 1

This phenomenon occurs in many natural systems near phase transitions: it takes water, for example, a long time to boil even though applying heat gets the water to the boiling temperature relatively quickly.

“So the challenge for theoretical computer scientists,” says Cris, “is to analyze the physicists’ algorithms rigorously, understand why they are so much faster than traditional algorithms – and if possible *prove* that they are – or delineate under which circumstances these algorithms work.”

During the workshop, that challenge made for an intense two-way flow of ideas between the physicists with their intuition and algorithmic experience and the computer scientists who would like to prove theorems about these smarter algorithms.

“We’re trying to strengthen the bridges between physicists and computer scientists and have them learn as much from one another as they can,” Cris says. “Participants walked out of here both with new algorithms to try and new conjectures to prove.” ■





## The 2013 Stanislaw Ulam Memorial Lecture Series: Complexity and the Biology of Computation

It's hard to go anywhere today without encountering software – in our cell phones, banks, restaurants, schools, gas stations, cars, and, of course, at our desks. Our computerized world has grown so complex, dynamic, and sometimes hostile, computers now confront challenges akin to those faced by living organisms trying to survive and thrive in an ecosystem.

In a series of three lectures over three nights, SFI's Stephanie Forrest reveals surprising commonalities between computers and organisms, and between networks and

ecosystems, and describes new research that blurs the distinctions further.

Forrest is a professor of computer science at the University of New Mexico in Albuquerque; a Jefferson Science Fellow on assignment to the U.S. State Department in Washington, D.C.; and an External Professor and member of the Science Board of the Santa Fe Institute. The lectures take place at the James A. Little Theater in Santa Fe.



**Lecture I - Tuesday, September 10, 7:30 p.m., Software Engineering: Evolving Computer Programs**

**Lecture II - Wednesday, September 11, 7:30 p.m., The Complex Science of Cyberdefense: Computer Immunology**

**Lecture III - Thursday, September 12, 7:30 p.m., Modeling Computer Networks from Chips to the Internet**

### Next SFI Community Lecture

**Wednesday, November 6, 7:30 p.m., Turing's Cathedral: The Origins of the Digital Universe.** The two most powerful technologies of the 20th century – the nuclear bomb and the computer – were

developed in New Mexico at the same time and by the same group of young people. But while the history of the Manhattan Project has been well told, the origin of the computer is relatively unknown. In his book *Turing's Cathedral*, historian George Dyson (who grew up among these proto-hackers in Princeton, New Jersey) tells the story of how Alan Turing, John von Neumann, and a small band of other geniuses not only built the computer but also foresaw the world it would create. Dyson is an author and historian of technology whose publications broadly cover the evolution of technology in relation to the physical environment and the direction of society.

## PEOPLE

### Physicist Sid Redner to join SFI in 2014

External Professor Sidney Redner will join the Institute's resident faculty next summer, SFI Chair of Faculty Jennifer Dunne announced on August 13. Redner now chairs the Department of Physics at Boston University.



Redner says he's looking forward to the working style and academic freedom SFI affords, opportunities he says are hard to come by. He first tasted life at SFI during visits in 2004 and 2005, when he was an Ulam Scholar at

Los Alamos National Laboratory working on opinion formation.

He hopes to continue work on quantitative social science, but "I couldn't even predict what I'd be doing six months from now. I'd really like to reinvent myself at SFI," he says.

Redner earned an A.B. in physics from UC Berkeley in 1972 before moving to MIT with plans for a career in high-energy experimental

physics. Following a few years studying high-energy theory and mathematics, Redner began working on statistical physics, focusing on phase transitions and renormalization theory with advisor H. Eugene Stanley.

After earning his Ph.D. in 1977, Redner spent a year at the University of Toronto before joining BU's physics department in 1978. Over the past three and a half decades, he has worked on a variety of topics related to statistical physics, including polymer physics and the theory of random walks, in addition to more recent work on complex networks and on social dynamics such as voting and opinion formation. He has been chair of BU's physics department since 2011 and joined SFI as an external professor in 1997. He is the author of more than 200 academic papers and book chapters as well as two books on statistical physics.

"Redner is an outstanding addition to the resident faculty," says Dunne. "His rigorous and creative approaches to a wide range of research topics complement ongoing work at SFI, and he will add new dimensions to the intellectual and institutional life here." ■

## ACHIEVEMENTS



At its 2013 commencement ceremonies, Harvard University bestowed an honorary degree on SFI Science Board member Robert May, Baron May of Oxford. May's citation reads: "A prodigious poly-

math and peerless peer whose mind conceives models that sustain life and whose voice resounds in support of enlightened inquiry."



The "Village Ecodynamics Project (VEP) in the American Southwest," a research program directed by SFI Science Board member and External Professor Tim Kohler, was honored by the 2013

Shanghai Archaeology Forum Selection Program for individuals and organizations that have achieved distinction in innovative, creative, and rigorous works with significant relevance to the contemporary world. SFI Omidyar Fellow alum Scott Ortman is a senior researcher on the project.



SFI External Professor Ole Peters is co-founder and fellow of The London Mathematical Laboratory (LML), an independent institute for basic science, located in Central London and funded by charitable

donations. LML's three fellows have backgrounds in mathematical physics and, with their network of collaborators, currently do work in ergodic theory, stochastic processes, extreme value theory, economics, and the history of science.



A recent paper by Anargyros Papageorgiou and SFI External Professor Joseph Traub, "Measures of quantum computing speedup" (also published as an SFI working paper), has been selected as an "Editors' Suggestion" by *Physical Review A*.

SFI External Professor Brian Arthur's book *The Nature of Technology: What It Is and How It Evolves* was selected as one of *Nature's* top reads for summer 2013. ■

## INSIDE SFI

### SFI welcomes four new Omidyar Fellows for 2014, says goodbye to seven postdocs

This fall, the Institute welcomes four new postdoctoral researchers to SFI's Omidyar Fellowship program. Omidyar Fellows spend up to three years in residence in Santa Fe, where they pursue their own research interests. For more information and to meet the fellows, visit [www.santafe.edu/omidyar-fellowship](http://www.santafe.edu/omidyar-fellowship).



**Ben Althouse** brings a computational background to the study of infectious disease epidemiology. Because infections do not spread uniformly through populations, Althouse's research simulates those aspects of the disease

transmission process that give rise to a pathogen's heterogeneous transmission patterns. He hopes his work might help explain similar phenomena in other fields, and he looks forward to exploring these applications from within SFI's interdisciplinary community. He holds degrees in biochemistry, mathematics, and biostatistics and has recently completed his PhD in epidemiology at Johns Hopkins University.



**Ruben Andrist** is exploring the future landscape of quantum computing. As a researcher and a programmer, he investigates the stability of various quantum codes by determining how well they could retain information in the presence of external noise. Andrist's cur-

rent research draws from the distinct fields of quantum information theory and statistical mechanics, and he expects to develop a wealth of new applications in collaboration with SFI researchers from other disciplines. He holds a PhD in computational physics, statistical mechanics, and quantum information processing from the Swiss Federal Institute of Technology in Zurich (ETH Zurich).



**Eric Libby** is exploring a critical and not-well-understood phase in evolution – the transition from single-celled to multicellular life. As a quantitative biologist, he models the environments and pathways that could

lead single-celled organisms to emerge as multi-celled individuals. He works in close partnership with experimental evolution researchers, and he looks forward to exploring topics such as self-organization. He is completing a postdoctoral fellowship at the New Zealand Institute for Advanced Study. His PhD is in mathematical biology from McGill University.



**Sam Scarpino** tracks infectious disease epidemics. The epidemiology of pathogens is directly affected by the complex, dynamic landscape of human and animal populations. Sam believes epidemic models must inte-

grate quantitative techniques from fields such as economics, genetics, ecology, and statistics. The interdisciplinary nature of his work makes SFI an ideal place to advance his research, he says. Sam recently earned his PhD from the University of Texas at Austin, where he worked with public health officials to improve influenza surveillance.

### Departing Fellows

Seven Postdoctoral Fellows and Omidyar Fellows have recently left the Institute for positions in academia.

SFI Omidyar Fellow **Rogier Braakman** has joined the Department of Civil and Environmental Engineering and the Department of Earth, Atmospheric, and Planetary Sciences at the Massachusetts Institute of Technology as a postdoctoral fellow.

SFI Omidyar Fellow **Laura Fortunato** has joined the Institute of Cognitive and Evolutionary Anthropology in the School of Anthropology and Museum Ethnography at the University of Oxford as a university lecturer. She also has joined the Evolutionary Anthropology Depart-

ment at Magdalen College at the University of Oxford as a tutorial fellow.

SFI Omidyar Fellow **Anne Kandler** has joined the School of Mathematical Sciences at City University London as an assistant professor.

SFI Omidyar Fellow **James O'Dwyer** has joined the Department of Plant Biology in the School of Integrative Biology at the University of Illinois as an assistant professor.

SFI Omidyar Fellow **Scott Ortman** has joined the Department of Anthropology at the University of Colorado Boulder as an assistant professor.

SFI Omidyar Fellow **Charles Perreault** has joined the Department of Anthropology at the University of Missouri-Columbia as an assistant professor.

SFI Postdoctoral Fellow **HyeJin Youn** has joined the Institute for New Economic Thinking, Oxford Martin School, University of Oxford, as a senior research fellow. ■



### The application period for the 2014 SFI Omidyar Fellowship is open.

Interested postdoctoral researchers should apply before October 25, 2013. For eligibility requirements and to apply, visit [www.santafe.edu/ofellowship](http://www.santafe.edu/ofellowship). Please email questions to [ofellowship@santafe.edu](mailto:ofellowship@santafe.edu).



# Learning Lab coalesces K-12 ed programs

As a relatively recent branch of science, the study of complex systems is nearly nonexistent in K-12 science curricula. Yet complexity today touches nearly every other scientific discipline and has informed many recent innovations, says Irene Lee, a longtime education researcher in SFI’s Education and Outreach group.

In August, Lee was named director of SFI’s new Learning Lab, created this summer to support an important component of the Institute’s mission: inspiring the next generation of scientists. The Learning Lab will help translate SFI’s research for the general public, with an emphasis on students in kindergarten through 12th grade.

“The problems our world is facing – hunger, climate change, conflict – are going to be best addressed and solved by people who understand complexity,” Lee says. “The ability to consider all the interrelated factors that contribute to these problems will be a critical skill needed in designing solutions.”

Until now, SFI has addressed the community’s need for complexity science education with programs targeted for specific audiences. The Learning Lab will create a more global and strategic approach to sharing SFI research outcomes, conducting research on best practices in teaching complexity science, evaluat-

ing current education efforts, and creating new models for complex systems education.

Significantly and symbolically, its staff now resides under one roof, having recently moved to SFI’s Gatehouse near the entrance to the Cowan Campus.

The ability to effectively disseminate outcomes is an important component of all SFI research. The Learning Lab will maintain close relationships with local schools and universities that provide students access to this science, and work closely with researchers to make sure their research is accurately presented and the pedagogy is age-appropriate.

The Learning Lab encompasses all of SFI’s current and future educational programs for local students in kindergarten through 12th grade, including Project GUTS (Growing Up Thinking Scientifically), GUTS y Girls, and the New Mexico Computer Science for All program, as well as professional development programs for teachers.

The goal, says Lee, is to share the excitement and relevance of complexity science with a new generation of young scientists and, ultimately, support efforts to encourage students to pursue careers in STEM (science, technology, engineering, and math) disciplines. ■



## Now seeking applications/nominations for SFI’s Cowan Chair

The Institute is seeking nominations for and applications from individuals conducting research in the social and behavioral sciences for the **SFI Cowan Chair in Human Social Dynamics**. This is a full-time resident faculty position at the equivalent of the assistant or associate professor level. Applications are due by November 1, 2013. More at [www.santafe.edu/cowan](http://www.santafe.edu/cowan).



Image: Cretia Prout

### INSIDE SFI

## Science symphony merges math & music

Sound is vibration. Rhythms have ratios. Octaves are fractions of one another. For centuries, musicians have used the mathematical relationships among scales and harmonies to pluck our emotions. Composers lull us with patterns and then surprise us with asymmetries. Even the planets play unheard songs in revolutions and orbits.

On Saturday evening, November 2, SFI and The Santa Fe Symphony present a unique symphony of science. The event features an expansive multimedia presentation and remarks by SFI Professor Cris Moore, a mathematician and computer scientist, interspersed with musical selections by The Symphony.

“Mathematics can help us understand why we love the music we love and how to create new music that no one has ever heard before,” says Moore.

### November 4 special concert brings math and music to area students

On Monday, November 4, several hundred northern New Mexico 7th-9th grade students will attend a version of the “Majesty of Music and Mathematics” event designed just for them. SFI VP for Education and Outreach Ginger Richardson says the field trip/concert at The Lensic will form the basis of an ongoing educational website with learning tools for teachers and students, to be available at SFI’s Complexity Explorer ([www.complexityexplorer.org](http://www.complexityexplorer.org)).

Greg Heltman, The Symphony’s Founder and General Director, says: “Throughout history there has been much conjecture on the commonality of music and mathematics, and this project is an effort to explore through the language of mathematics the nature of rhythm, symmetry, and harmony.”

The program takes the audience on a journey, from the rhythms of molecules and planets to the harmonies of dolphins and the dissonances of the “devil’s interval,” from the music of Strauss to the theme song of *The Simpsons*, from the earliest bone flutes 40,000 years ago to the soundtracks of modern cinema.

The Symphony’s performances span the musical spectrum, from demonstrations on the harp and flute to movements from Strauss, Brahms, Prokofiev, Handel, Holst, Wagner, Bach, Adams, and more.

The November 2 concert, “Voyages of Discovery IV: The Majesty of Music and Mathematics,” takes place at 7:30 p.m. at the Lensic Performing Arts Center. Tickets range from \$22 to \$76 and are available through The Symphony box office at (505) 983-1414 or (800) 480-1319, and through The Lensic Box Office at (505) 988-1234. Tickets are also available online. Visit [www.santafesymphony.org](http://www.santafesymphony.org) or [www.lensic.org](http://www.lensic.org)

“The Majesty of Music and Mathematics” is the fourth in a series of “Voyages of Discovery” events co-organized by SFI and The Symphony.

This year’s Voyages is generously underwritten by the Andrew and Sydney Davis Foundation. ■



### SFI SCIENCE BRIEFS

#### It’s time for transdisciplinary electric power grid science

As climate change increases weather disturbances, as increasing demand tests power supplies, as smart grid and renewable energy technologies make the grid more complex and distributed, and as planners improve responses to inevitable power failures, a transdisciplinary understanding of power grid reliability and complexity informed by modeling becomes more critical, according to a July 23 opinion piece in *PNAS* co-authored by SFI Professor Cris Moore, SFI External Professor Raissa D’Souza, and collaborators.

“Validated models enable the next grand challenge: improve and transform power grids to meet 21st century pressures. Reliable electricity must reach more people demanding more energy in more places... These challenges span engineering, physics, complex networks, computational science, economics, and social sciences,” plus ecology, they conclude.

#### Hierarchy in networks could have emerged at random

From river systems to electrical grids, most networks exhibit some degree of hierarchy, but researchers have been slow to understand why. In a July 6 paper in *PNAS*, SFI External Professor Ricard Solé and colleagues at Pompeu Fabra University argue that much

of the hierarchy in the world could have emerged at random.

The team began by constructing three measures of hierarchy: how clear the “chain of command” is, how prevalent circular chains are, and how high up the network those circles are. Using those measures, they identified four distinct types of hierarchy, corresponding to software and electronic circuits; language, metabolic, and neural networks; gene regulation networks; and food webs.

Simulations showed all but gene regulation networks and food webs shared similar structures with random networks, suggesting hierarchical networks can form without anything guiding them there.

#### How network theory is informing cognitive science

Networks have long played a key role in cognitive science, from studies of artificial neural networks to modeling of semantic memory. Today, the inclusion of network theory in the cognitive sciences and the expansion of complex-systems science promise to significantly change how the organization and dynamics of cognitive and behavioral processes are understood, according to a recent paper co-authored by SFI External Professor Morten Christiansen. The paper was published May 30 in *Trends in Cognitive Science*.

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UPDATE

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