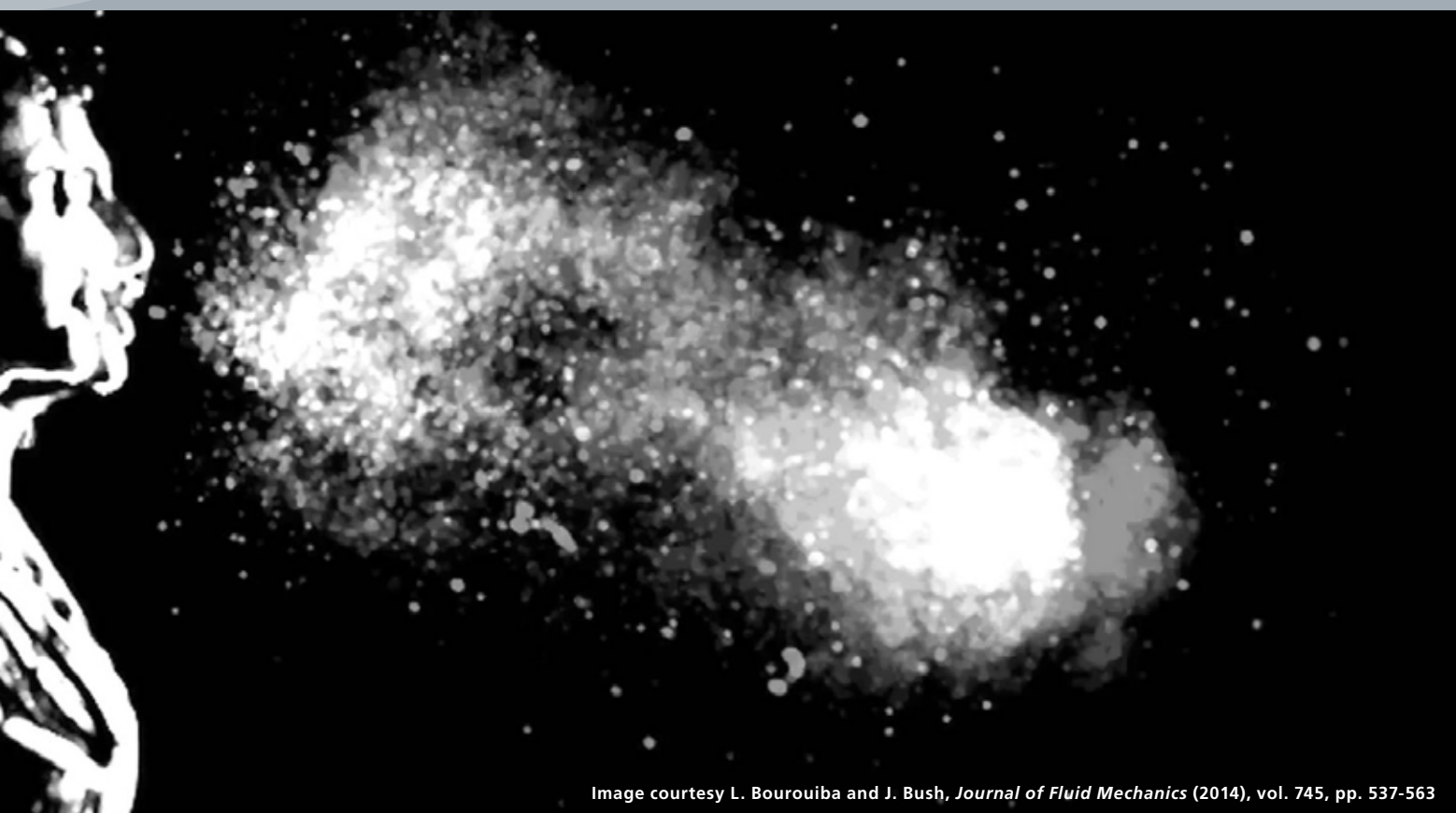




July / August 2015

# UPDATE

Image courtesy L. Bourouiba and J. Bush, *Journal of Fluid Mechanics* (2014), vol. 745, pp. 537-563

## Is current vaccine behind whooping cough resurgence?

Whooping cough has made an astonishing comeback, with 2012 seeing nearly 50,000 infections in the U.S. (the most since 1955), and a death rate in infants three times that of the rest of the population. The dramatic resurgence has puzzled public health officials, who have pointed to the waning effectiveness of the current vaccine and growing anti-vaccine sentiment as the most likely culprits.

But that might not be the whole story, suggests a new study published in *BMC*

*Medicine* by SFI Omidyar Fellows Ben Althouse and Sam Scarpino. Their research points to a different, but related, source of the outbreak – vaccinated people who are infected but who do not display the symptoms of whooping cough. Their research suggests that the number of people transmitting without symptoms may be many times greater than those with symptoms.

In the 1950s, highly successful vaccines based on inactivated pertussis cells (the

bacterium that causes whooping cough) drove infection rates in the U.S. below one case per 100,000 people. But adverse side effects of those vaccines led to the development and introduction in the 1990s of acellular pertussis vaccines, which use just a handful of the bacterium's proteins and bypass most of the side effects.

The problem is, the newer vaccines might not block transmission. A January 2014 study in *PNAS* by another research team [> more on page 7](#)

### INSIDE SFI

## Q&A with outgoing SFI President Jerry Sabloff

After six years at the Institute's helm, including a three-year extension at the request of the Board of Trustees, SFI President Jerry Sabloff retires July 31. On the eve of his departure, he gave the *Update* his thoughts on the Institute's status and trajectory.

**Update:** Has the Institute changed in any significant way during your tenure?

**Jerry Sabloff:** I don't think it's changed in a significant way. For me, the bottom line is that today we feel the same excitement about new theoretical understandings of complex systems, particularly through true transdisciplinary approaches, as we did six years ago, and that SFI's nonlinear, open systems view of the world is as important as it was six years ago for suggesting solutions to major problems.

One of my favorite examples of the value of this perspective for solving real-world problems was having Bill Frej from USAID

here for a year, and the related workshop we hosted on Afghanistan as a complex system. With Afghanistan, you had people in government trying to solve problems with all due diligence, presuming that if they took Action A they would get Result B. They were doing everything right, except they assumed the system was in some sort of static equilibrium. When they acted on the system, by providing monetary aid to a village, for example, they found that the system changed, and they saw unanticipated emergent behaviors that in some cases exacerbated the problems. In the village example, the monetary aid changed the local power structure, which resulted in power struggles and, ultimately, more conflict rather than less. It's not that anyone can necessarily predict all emergent behaviors, but we should be well aware that when we act on a complex system we should expect a range of outcomes or probabilities of [> more on page 5](#)



## David Krakauer to become SFI's 7th president Aug. 1



David Krakauer becomes SFI's seventh president on August 1, 2015.

Krakauer has led the Wisconsin Institute for Discovery (WID) at the University of Wisconsin-Madison since 2011. Previously he spent nine years as a researcher at SFI, including three years as SFI's faculty chair.

He earned degrees in biology and computer science at the University of London and earned his D.Phil. in evolutionary theory from Oxford University, where he remained as a postdoctoral fellow and later as a Wellcome Research Fellow. He also spent three years at the Institute for Advanced Studies at Princeton University before joining SFI in 2002.

At WID, he sought to re-imagine the standard, siloed university research model in favor of a more freeform collaborative mash-up of disciplines.

Watch for news about the presidential transition and Krakauer's plans for SFI in the next *Update*. ■

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The *New York Times* on June 30 featured new research by SFI Omidyar Fellows Ben Althouse and Sam Scarpino suggesting that vaccinated, asymptomatic people might be a major source of whooping cough transmission.

CNBC on June 12, *USA Today* on May 28, and *The Atlantic* on April 12 featured recent research by SFI’s Marcus Hamilton, Madeline Daepf, Geoffrey West, and Luis Bettencourt finding that publicly-traded firms on average die at the same rate regardless of their age or economic sector.

*The Guardian* on May 17 reviewed SFI External Professor W. Brian Arthur’s SFI-affiliated work on technology and how it evolves and spurs innovation.

## Nonlinearities

From the editor

If you somehow missed it, we are in the midst of a leadership transition. Jerry Sabloff steps down as president on July 31 and David Krakauer takes the helm August 1. SFI Professor Paula Sabloff transitions to the external faculty August 1, as does Jerry Sabloff. Jessica Flack rejoins the resident faculty August 1. Ginny Greninger, who has managed the president’s office since 2005, retired on July 8 (see her My Story on page 8). Tim Taylor, a longtime SFer before going to Wisconsin in 2011, has already stepped in as the new maestro of the president’s office. We are in good hands.

Jerry and Paula, by the way, aren’t using the word “retire.” Both plan to continue rather busy, and blissful-sounding, research schedules. I have to say, I know very few people who actually retire these days in the traditional sense. Is retirement an old fashioned notion? Is “failing retirement” the new norm? Does anyone retire, or do people just move on to the activities they’ve always wanted to spend their time doing? I’m attached to the latter notion.

On Saturday, August 1, a couple dozen volunteers are to gather at SFI to help with a unique preservation project. Roughly 150 endangered Santa Fe cholla (*Cylindropuntia viridiflora*) will be planted on SFI’s main campus in hopes they will thrive and reproduce. If you’re not from around here, cholla are tall, spindly cacti, and they’re quite beautiful when they flower for a few weeks in mid summer (which many New Mexico cholla are doing as I write this). SFI’s cholla stands will be located in two spots on the Cowan Campus, including the area between the upper and lower parking lots where other cactus species now thrive.

The transplant is part of the Cactus Rescue Project, a nonprofit-driven effort to grow the rare plants in private gardens at numbers equal to or exceeding the number of plants found in the wild. SFI was asked to host the endangered cholla because the Institute is a few miles from their wild location at the Cross of the Martyrs Park, and because the hillside we occupy has the just-right soil composition and orientation to the sun. State botanists will monitor the plants. If you’re here after August 1, take a stroll in SFI’s new cholla preserve... I suppose I don’t need to ask you not to touch ‘em. ■

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

### CREDITS

**Editor:** John German  
**Contributors:** Jenna Marshall, Nathan Collins, Krista Zala, Katie Mast, Deb Trevino, Connor O’Neil  
**Design & production:** Michael Vittitow  
**VP for Science:** Jennifer Dunne

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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Matthew O. Jackson has been named to the National Academy of Sciences. Members are elected in recognition of their continuing achievements in original research. Jackson, an SFI external professor since 2007, is the William D. Eberle Professor of Economics at Stanford University.

Katelynn James and Meghan Hill, former participants in SFI’s Project GUTS (Growing Up Thinking Scientifically), won first place in the 2014-2015 Supercomputing Challenge. Both are students at Monte del Sol Charter School in Santa Fe. GUTS is a middle school after-school program for New Mexico students.



SFI Professor Paula Sabloff will become an SFI external professor on July 31 after six years on the Institute’s resident faculty. During her tenure she completed two books: *Does Everyone Want Democracy? Insights from Mongolia* (Left Coast Press, 2013) and *Mapping Mongolia: From Geologic Time to the Present* (University of Pennsylvania Press, 2011). She also contributed to SFI’s Emergence of Complex Societies research and led an ongoing project to apply the anthropological concept of status and role to archaeology as a way to compare and contrast early societies, among other ongoing research.

### RESEARCH NEWS

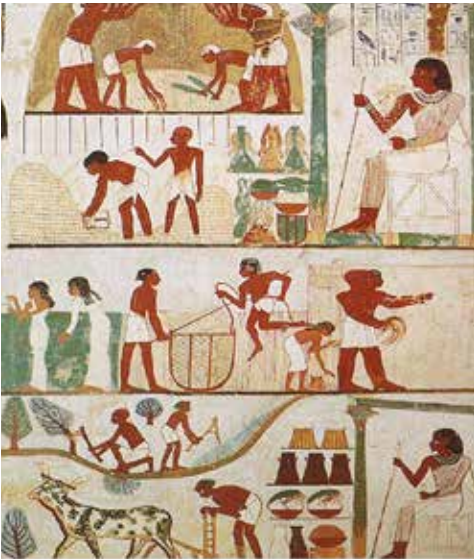
## What can status and role tell us about archaic states?

The famed soliloquy in Shakespeare’s *As You Like It*, beginning “All the world’s a stage, and all the men and women merely players,” could serve as a poetic primer on “status and role,” a time-honored concept in anthropology.

A research project led by SFI Professor Paula Sabloff is, for the first time, applying the concepts of status and role to archaeology as a way to compare and contrast early societies, from Old Kingdom Egypt and Early Dynasty Lower Mesopotamia to the Classic Maya and Aztec.

“The definition of ‘statehood’ is still being debated,” says Sabloff, a political anthropologist. “By comparing a core set of statuses and roles across societies, we hope to find patterns that will tell us more about what it means to be an early state.”

The multidisciplinary work builds on anthropologist Ralph Linton’s 1936 *The Study of Man*, which proffered that all people have statuses (president, father, or consumer, for example) and each is expected to perform roles (defined as rights, duties, and behaviors) appropriate to those statuses.



An Egyptian tomb relief depicts workers plowing fields, harvesting crops, and threshing grain under the direction of an overseer. (The tomb of Nakht, 15th century BC)

To apply Linton’s concept to complex archaic societies, Sabloff paired the statuses observed in a society with social rank. Rulers held the top rank, for example, while slaves were at the bottom. “Rank ordering is the only way to understand that a royal father has different behaviors and duties toward his children than a slave does,” she says.

She also needed to expand Linton’s list of ways people obtain statuses, adding “imposed” to Linton’s “ascribed” (given at birth) and “achieved” statuses. That small addition revealed a range of decision-making freedoms in the society.

Gathering a team of interns and SFI volunteers, Sabloff set to work building a database of statuses and their appropriate roles from the archaeological and historical literature. (In addition to helping Sabloff and the team find patterns of early state organization, the database will be linked with the Evolution Institute’s new Seshat database so anyone can use it.)

The data are still being collected, but insights and patterns related to status and role are already emerging. A recent statistical analysis by SFI Cowan Chair Mirta Galesic and External Professor Henrik Olsson, for example, suggests that Early Dynasty Lower Mesopotamia and the Classic Maya societies might be considered the prototypical early states. New network analyses reveal that pre-conquest Hawai’i has to be considered an early state, contradicting many archaeologists but supporting leading Oceanic archaeologist Patrick Kirch.

Working with former SFI Research Fellow Skyler Cragg, Sabloff also found that archaeologists who credit warfare as a major enabler of complex societies might be seeing only half the picture. “By studying status and role in the early societies, we see that long-term alliances are a critical part of warfare – either to prevent it or to ensure success in battle by having more troops than an opponent,” she says. “High-rank women help build such alliances through the roles they

play as spouses of foreign rulers – spying, advocating, and cementing relations.”

The work supports SFI’s Emergence of Complex Societies project, initiated in 2011 with funding from the John Templeton Foundation. ■

### PEOPLE

## Jessica Flack to re-join resident faculty



Jessica Flack will rejoin SFI’s resident faculty on August 1, 2015, as a professor.

Flack, an evolutionary biologist specializing in collective behavior and natural computation, spent five years at SFI

on the resident faculty and three years before that as a postdoctoral fellow prior to leaving for the University of Wisconsin-Madison in 2011. Since then, she ran, as co-director, UW-Madison’s Center for Complexity and Collective Computation (C4).

Her research focuses on coarse-graining and collective computation in nature and their role in the evolution and development of new levels of biological and social organization. Her approach is highly empirical, beginning with rich, fine-grained behavioral data, including network time series data gained from model systems in neuroscience, animal behavior, and human social systems. The goal is to find common algorithmic principles underlying the emergence of novel, functionally significant organization at a variety of spatial and temporal scales.

Flack’s transition to Santa Fe prompts moving C4 to New Mexico, where it will become the Collective Computation Group. ■

### RESEARCH NEWS

## Working group: What T cells have in common with ants

Theory and experiment in immune research have developed largely independently, but recent advances in each are presenting new opportunities. Two-photon microscopy tracks immune cells in vivo in exquisite detail, for example, and the resulting new data have furthered computational and mathematical modeling of cell movement.

Such promising progress has prompted SFI researchers to explore means of linking the fields. Computer scientist and SFI External Professor Melanie Moses and immunologist Judy Cannon, both of the University of New Mexico, are co-organizing a late-July working group, Motility in the Immune System, at SFI.

The participants will focus on methods of study-

ing the emergence of immune response from the complex motility patterns of T cells. Attendees include immunological modelers and SFI External Professors Alan Perelson (Los Alamos National Lab) and Stephanie Forrest (UNM); Mark Miller (Washington University), a pioneer in studying T cell movement; and physicist Nitant Kenkre (UNM), a mathematical modeler of animal movement and epidemiology.

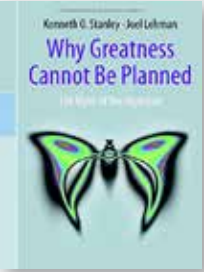
In considering various systems as a basis for modeling immune cells, Moses and her colleagues have looked to well-studied communication and movement in ants, as they have “intriguing similarities,” Moses says. Both ants and T cells move stochastically: ants when foraging and T cells in their search for infected cells. Both rely heavily on chemical

communication: ants draw a line to crumbs on your picnic blanket using pheromone trails, and T cells recognize molecular markers on infected cells to initiate the adaptive immune response. Both are evolved to cooperate in the service of a larger entity rather than to survive as individuals.

Building on the primary goal of understanding and predicting T-cell movement in a range of conditions, the participants plan to explore the broader concept of search efficiency and how agents adapt to varying stimuli across the biological domains.

“The driving question is how relatively simple agents cooperate and how they do so differently in different kinds of environments,” she says. ■





*Why Greatness Cannot Be Planned: The Myth of the Objective* (Springer, May 2015), by Ken Stanley (a recent SFI sabbatical visitor) and Joel Lehman, introduces the “Objective Paradox” – the phenomenon of finding not what you’re looking for but something else entirely. The authors place the Objective Paradox in the context of both historical example and modern culture, where goals, objectives, progress reports, and measurable outcomes drive and constrain most aspects of our daily lives. The book offers a fresh historical and scientific framework for understanding the nature of innovation.



*This Idea Must Die: Scientific Theories That Are Blocking Progress* (Edge Question Series, February 2015), a book of concise, big-idea essays, leads off with a piece by Geoffrey West on “The Theory of Everything.” Other SFI-affiliated authors and their must-die topics include Seth Lloyd (“The Universe”), Nigel Goldenfeld (“Individuality”), Rebecca Newberger Goldstein (“Science Makes Philosophy Obsolete”), and Dan Dennett (“The Hard Problem”). Each year John Brockman, publisher of Edge.org, asks top thinkers to answer a provocative question crucial to our time.



**Audio: SFI External Professor Stephanie Forrest** explores how computer software and hardware systems might benefit from a studied imitation of living systems. Santa Fe Radio Café interview



**Video: MIT’s Alex “Sandy” Pentland** describes how the mathematical analysis of social networks is fertile ground for understanding human behavior. 2015 SFI Community Lecture video



**Video: University of Michigan statistician Susan Murphy** shows how health care decision rules that adapt treatment to each individual’s response over time



can suggest interventions that maximize treatment efficacy. 2015 SFI Community Lecture video



**Video: MIT humanist and physicist Alan Lightman** on timeless topics such as God, science, the universe, and religion. 2015 SFI Community Lecture video

**Video: SFI sabbatical visitor Ken Stanley** describes research that reveals the folly of focusing on single-minded objectives and the benefits of freeform intellectual pursuits that more often lead to innovation. PBS “Report from Santa Fe” talk show interview

Developing a *lingua franca* for linguistics

Over time, English has swirled into dialects so different that speakers from the same country cannot always understand each other. Similarly, linguists – as they have catalogued words, spellings, pronunciations, and meanings – have stylized their individual academic databases to suit the needs of their own research.

In an age of computational linguistics, that can be a problem. Computers offer vastly improved capabilities for finding patterns and connections. But while human brains are good at smoothing over minor inconsistencies, computers tend to be very literal. And data that can’t be understood can’t be part of the conversation.

“Because of the large quantities of data that can be brought to bear on a problem, for many studies occasional data quality issues are not fatal,” explains SFI Professor Tanmoy Bhattacharya, who leads SFI’s linguistics program. But, he says, “the next advance in linguistics will need to understand weak signals or complicated histories deep in the data, and in these situations data issues will be very important. We will need to understand how the data being used are selected,

curated, and presented.”

Further, language databases will need to adopt coding conventions that allow them to talk to one another. “We need to develop a *lingua franca* for all linguistics databases to speak,” he says. “Whatever way databases organize their own data, or speak their own internal dialect, we should be able to translate them all into something universally understandable and answer queries using the same code all others use.”

Bhattacharya, SFI Distinguished Fellow Murray Gell-Mann, and longtime SFI collaborator George Starostin are organizing a mid-August working group at SFI to address this challenge. Conventional and computational linguists will evaluate existing relevant online and offline databases, explore optimal data formats, and discuss – perhaps even establish – the most useful programmed analysis tools for historical linguistics research.

“What is going to come of this is the preparation to enable the next big advance in computational linguistics,” Bhattacharya says. ■

Workshop to ready teachers to think and teach computationally

To prepare the next generation of computer scientists, educators need opportunities to learn and practice emerging computational skills. SFI’s Learning Lab is developing an online training workshop for high school teachers who wish to teach the new Advanced Placement (AP) Computer Science Principles course.

The SFI workshop, Computer Science Principles-Aligned Integration of Modeling and Simulation, will leverage SFI’s expertise in modeling toward the goal of building the community of educators versed in these techniques, says Learning Lab Director Irene Lee.

The workshop is being developed under a \$35,000 grant from the Tides Foundation on the recommendation of the Google Education and University Relations Fund.

Computer science is the fastest-growing cluster of occupations, according to U.S. Department of Labor projections, but data from the National Science Foundation show that only 2.4 percent of college students graduate with degrees in computer science. Of these computer science degrees, women earn only 18 percent, though they claim 57 percent of total bachelors degrees.

The new online workshop aims to train 500 high school and college teachers in computer modeling and simulation while also preparing them to use best practices for engaging and retaining students from underrepresented groups in science, tech-

nology, engineering, mathematics, and computing.

“Modeling and simulation have been shown to have broad appeal and to provide students from diverse backgrounds and educational needs with opportunities to successfully engage in modern scientific practice,” says Lee. “Students have been able to incorporate their own realities into scientific investigations through computer modeling and simulation, resulting in deep engagement in both science and computer science content and practices.” ■



Painting of a Sierra Miwok encampment, Yosemite Valley, by Albert Bierstadt, ~1872

Study: Social learning best explains span of human behavior

The behavioral variation exhibited by the human species is unmatched in the animal world. Scholars have debated whether this span of behavior is due to the unusually wide range of environments we humans inhabit or to our unique reliance on social learning. In a recent paper in *Proceedings of the Royal Society B*, SFI Omidyar Fellow alum Charles Perreault and Sarah Mathew (both with Arizona State University) ask whether the behavioral variation among 172 Native American tribes was due to the varied environments they lived in or their different cultural histories.

They demonstrate that behaviors can persist in cultural lineages for millennia, suggesting that a large part of human behavior results from cultural inertia. The richness of our behavioral repertoire may thus be due to our capacity for culture, not our intelligence and cognitive flexibility, they conclude. They speculate that the capacity for cultural learning might explain why modern humans were able to thrive in virtually every terrestrial habitat on the planet.

Sustainability is a job for complex systems science

Technology alone cannot solve the problem of sustainability, note SFI Professor Luís Bettencourt and Postdoctoral Fellow Christa Brelsford in a recent article for the *Journal of Industrial Ecology*. Sustainability is in a class of problems – along with such challenges as economic growth and human development – featuring circular objectives, multi-dimensional causality, and evolving horizons that place it beyond the scope of engineering. The decentralized nature of sustainability demands an approach inherently different from centralized optimization problems that characterize traditional engineering. Multidisciplinary, combinatorial approaches from complex systems science are better suited to the sustainability problem, they say. ■

Complex Systems Summer School 2015

On day three of SFI’s 2015 Complex Systems Summer School, two of its 66 participants – Maria Pereda Garcia, a postdoctoral researcher at the University of Burgos, Spain, and Juan Carlos Castilla, a PhD student at the University of New South Wales, Australia – explore a nonlinear dynamics model created by school lecturer Joshua Garland. Shortly after, students conversed about their research interests during a session called “intellectual speed dating.” The summer school, which began June 7, brings together students from diverse geographic and academic backgrounds for a month of lectures and projects in complexity science.





## Marion Dumas

### Democracy, capitalism, and sustainability



How to engender a sustainable society might be the most pressing question of our time. For new SFI Omidyar Fellow Marion Dumas, part of the answer lies in the political and economic institutions that shape our lives.

“The challenge, as I see it,” she says, “is to collectively create the conditions for living meaningful and ethical lives while maintaining the robustness of the social and ecological systems we depend on.”

She uses both models and large-scale datasets of social structures and behavior to understand how capitalism and democracy interact and determine our capacity to adapt to ecological constraints.

She earned her PhD in sustainable development from Columbia University and brings to SFI training in earth sciences, biogeochemistry, economics, and political science.

“The quantitative social sciences tend to focus on aggregate and static causal effects, often eschewing the quantitative study of processes,” Dumas says.

While at SFI, she hopes to discover how institutions shape processes of social change. Ultimately, she hopes to address whether our current political institutions can reconcile economic welfare and sustainability. These high-stakes questions are the kind of problems that require a complexity science perspective, she says.

She plans to join SFI in September. ■

## Justin Grana

### Game theoretic cyber security



Cyber attacks cost society billions every year, and while computer networks are becoming increasingly complex, both attackers and those who defend against them are only human. By applying tools of game theory, Justin Grana hopes to better understand how the people behind cyber attacks make decisions.

“There is literature on game theory in cyber networks, but it’s very stylized and simplified,” says Grana. “We want to go deeper.”

Grana joins SFI as a graduate fellow in September and becomes a postdoctoral fellow in January. Working with SFI Professor David Wolpert, he will explore how cyber at-

tackers, once they have breached a network, make decisions about accessing data while avoiding detection.

Grana, whose (pending) PhD from American University is in economics, says his training in decision theory – the backbone of economics – is directly applicable to understanding the interplay between cyber attacker and defender. “It’s two entities who have to make decisions while keeping in mind what the other is going to do.”

Most recently, Grana has been applying existing algorithms to the cyber security problem to illustrate that the models aren’t adequate to the task. “When you get even a little more complicated than poker, they crash and burn,” he says.

While at SFI, he will be working to develop a more robust model that will be scalable to real-world cyber networks. ■

## Chris Kempes

### Evolution everywhere



We don’t know what life might lie beyond Earth’s atmosphere, but understanding the constraints bounding life on this planet could offer clues about where to look.

“A lot of the same questions we’re interested in for ecology and evolution are what we’ll need in order to understand the possibilities for even microbial life on other planets,” says new SFI Omidyar Fellow Christopher Kempes, who explores astrobiology through his work with the NASA Ames Research Center.

With a PhD in physical biology from MIT, Kempes is interested in identifying the dominant constraints that have guided evolution on Earth, such as what

determines the minimum size for a bacterium or the maximum growth limits of larger organisms.

A better understanding of evolution on Earth would help astrobiologists develop theories about what types of life they might expect to find in certain conditions, and which types of planets might support it.

Kempes anticipates that the creative, cross-discipline discussions at SFI will help foster a richer general theory and understanding of evolution.

“If you have a general theory about something, you can predict things that you haven’t seen yet,” says Kempes, “and this type of approach is really needed in biology.”

Kempes plans to join SFI in August. ■

## Dan Larremore

### Diseases’ evolving strategies



The malaria parasite, which kills nearly a million people every year, is so successful in part because of its ability to respond to environmental changes through genetic recombination.

New SFI Omidyar Fellow Daniel Larremore, an applied mathematician with a PhD from the University of Colorado Boulder, uses network techniques and genetics to understand the evolution of both human pathogens and human neuronal networks.

“What we’re trying to figure out [with malaria] is how the virulence genes that make humans really, really sick evolved in the first place,” says Larremore.

As a postdoctoral fellow at Harvard’s T. H. Chan School of Public Health, Larremore helped develop models revealing that malaria’s modern virulence strategy evolved tens of millions of years ago, long before humans.

Today’s highly mobile human populations add complexity to understanding the evolution of malaria’s virulence. Larremore’s continued work will combine the theory of network science and dynamics with real-world biological data to develop models that may be applicable to other diseases.

“The hope is that if you’re diligent about building a realistic but generalizable model, you’ll get more out of it than just malaria,” he says.

Larremore plans to arrive at SFI in September. ■





## Eleanor Power

### Religiosity and human sociality



People invest a great deal of time, energy, and money in the name of the divine, from building Barcelona's Sagrada Familia to making epic pilgrimages. How can we explain these investments?

For new SFI Omidyar Fellow Eleanor Power, an anthropologist, understanding the social consequences of religious rituals can provide important clues to the puzzle of human sociality.

Power, who recently completed her PhD at Stanford, spent 20 months doing field work in two villages in southern India. There, she observed dramatic religious acts ranging from piercing skin with hooks and spears to animal sacrifices.

Using network analysis, Power investigated how individual religious practice impacted social standing and social capital. "While there was strong evidence that costly ritual acts led to improved reputations and greater social capital," she says, "the subtler act of attending regular worship also had a significant and often greater effect. These acts convey character and intentions toward others, helping form supportive relationships and, ultimately, cooperative, cohesive communities."

While at SFI, Power plans to continue such analyses to better understand the economic and fitness consequences of religious practice, factoring in gender and caste as well as the relationship between signal strategies and punishment.

"I undertook this project to contribute to a much broader scholarship aimed at understanding the role of religion in society," Power says. "Few places engage in the scale of inquiry attempted at SFI."

She plans to join SFI in September. ■

## Brendan Tracey

### Optimizing engineering processes



Complex machines – airplanes, for example – feature a spectrum of design variables, ranging from broad parameters like wing area and engine thrust to specific elements like a wing's interior support structure.

During the initial "conceptual design" stage, design teams typically use relatively simplistic analysis tools to determine the broad parameters. Later in the process, more precise analysis tools help set the detailed parameters within those initial constraints.

Brendan Tracey, who studies aeronautics and astronautics at Stanford University, is

looking for ways to improve the design process. He joins SFI in July as a postdoctoral fellow working with SFI Professor David Wolpert.

"Traditional optimization methods are not able to use high-fidelity analysis efficiently," says Tracey. Integrating higher-accuracy tools into conceptual design could lead to better designs, he says, but traditional optimization methods take too long.

Using an approach called Multi-Information Source Optimization, or MISO, Tracey wants to develop algorithms to allow the use of these more accurate tools earlier in the process.

MISO breaks optimization into a system of functions rather than approaching it as one large function, and allows the model to use statistical relationships and evaluate each component only as needed.

"By being judicious in when we use our analysis tools, we can save a lot of time," says Tracey. ■

### > Q&A with Jerry Sabloff continued from page 1

outcomes. The terrific book that followed that workshop, Ben Ramalingan's *Aid on the Edge of Chaos*, contains a nice example from Afghanistan.

There have been some minor changes at SFI. One is the greater emphasis on the human and historical sciences. This was one of the reasons the Board wanted to have the first non-physicist, non-biologist president in the Institute's history. Murray Gell-Mann said to me a few years ago that – given the recent work sponsored by the John Templeton Foundation and some of the research, workshops, and working groups related to archaeology, anthropology, and

history – this is what he and some of SFI's other founders had hoped for when SFI was started. That was very gratifying to me.

Another change is the increase in funding support from large private foundations relative to federal support. Six years ago, Elisabeth Johnson and I both looked at our portfolio of grant support and felt that we were too heavily tied to the federal side, particularly the National Science Foundation. In hindsight, the fact that we've had the major foundations – Templeton, Rockefeller, Gates, MacArthur, and others – supporting our work in recent years has been a plus.

Those are some of the smaller changes. But basically the place is as exciting and important as it was six years ago.

**Update:** What have been some of SFI's major challenges and triumphs during your tenure?

**Sabloff:** The biggest struggle and triumph was coming back from the fiscal challenges of the recession that began in 2008. We always hoped a recovery was a given, but it wasn't a given at every point in time. That was the worry that kept me up at night. I've joked with the Board that my major achievement was keeping the doors open. One can be lighthearted about that, but you look at other nonprofits and you can see we did pretty well.

Obviously rebuilding the resident faculty after key departures was another big one. Departures normally happen in the course of things. But it was difficult to lose so many in such a short time due to a convergence of factors. We also had to replace key staff people during this time. I think we did very well overcoming both challenges at a time when budgets were tight.

Beyond that, I'm proud of the restructuring of the Omidyar Postdoctoral Fellowship, which is now on strong financial footing. The Omidyar Fellows are the lifeblood of the Institute, and the program is now living up to the visions we had for it. Many people view this as the premier postdoctoral fellowship in the world right now. We're getting the best early career transdisciplinary scientists from around the globe to come here. We've gotten acceptances from every one of our top selections in the last two years. When we receive the final gift from Pam and Pierre Omidyar by the end of this year, we will be positioned to keep the program going at its current level for another 25 or 30 years as long as we meet reasonable matching-gift targets each year.



Sabloff helps launch the SFI-ASU Center for Biosocial Complexity in Tempe in January 2015.

Our net assets and our overall financial portfolio are stronger than they've ever been. Part of that was the generous gift [of the Tesuque Campus] from Eugene and Clare Thaw, but we also were able to pay off the mortgage on the Cowan property, so we've come out of the recession debt free. And I'm proud to say that due to the hard work of our Finance Office, we've had clean audits with no findings for the six years I've been here. It's not the stuff of headlines, but it's important because it gives our donors, our federal and foundation funders, and our trustees confidence that we're managing our finances the right way in an increasingly complex fiscal and regulatory environment.

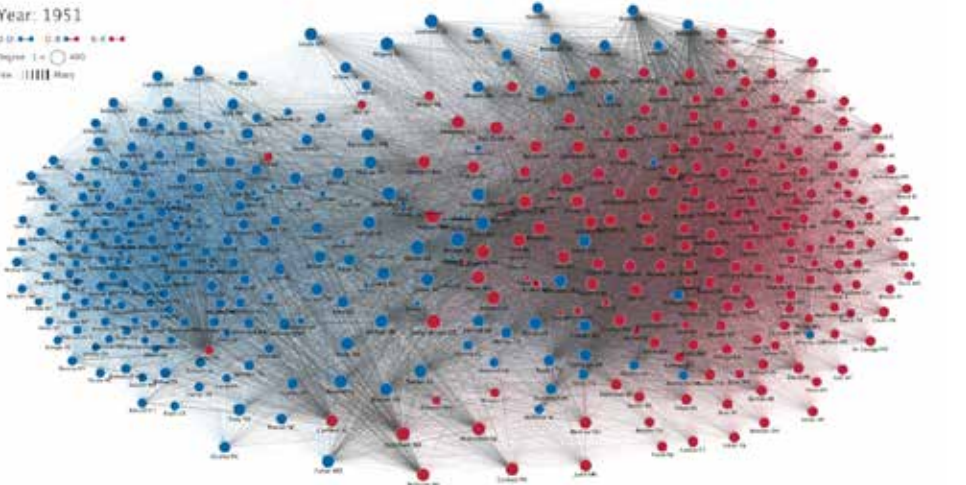
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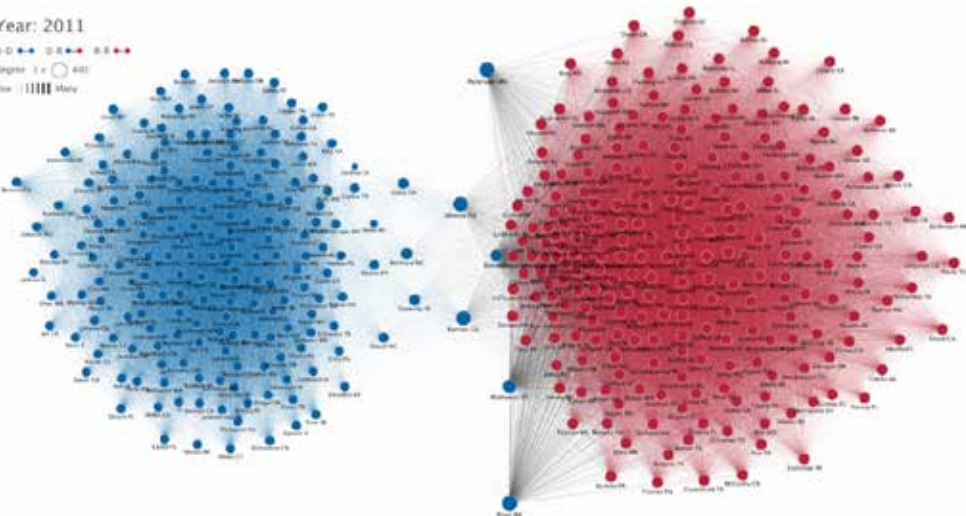
During a December 2012 luncheon at SFI honoring Eugene and Clare Thaw, Sabloff thanks Eugene Thaw for the couple's gift of the Tesuque Campus to SFI.



# Study: Worsening polarization in Congress stymies innovation



The U.S. House of Representatives in 1951 (above) and in 2011 (below, Republicans in red, Democrats in blue). Edges (lines) are a relative measure of voting cooperation. Larger nodes represent members with more voting connections. Thicker edges connect pairs that agree more often. (Image: Mauro Martino)



Party polarization in American politics has been worsening since the 1950s, according to an analysis of the U.S. House of Representatives by SFI researchers that confirms mathematically what most Americans have long suspected.

But the bigger problem, the researchers suggest, is that as cooperation has declined, Congress’s ability to come up with new ideas to solve the nation’s problems has stalled.

The project began when geographer Clio Andris, a former SFI postdoctoral fellow now at Penn State, wondered whether the interwoven House districts created by gerrymandering might actually foster cooperation. After all, with some districts practically wrapped around each other, their constituents ought to share some common interests. And where there are common interests, Andris reasoned, there ought to be cooperation.

“I found none,” Andris says. Party affiliation, not geography, seemed to be the best indicator of whether two representatives would cooperate when a bill came to a vote.

But was it always this way? Working with SFI Postdoctoral Fellow Marcus Hamilton and colleagues from MIT, Andris found that the period from 1949 until the early

1970s was marked by generally high levels of cross-party cooperation. That peaked during the 91st congress, during President Nixon’s first term in office, when members of opposing parties voted with each other nearly as often as members of the same party. By the middle of Ronald Reagan’s first term, however, that kind of cooperation had started to crumble, and since 1983, the rate of cross-party cooperation has steadily declined, while same-party cooperation has kept going up.

The team’s analysis also reveals that as cooperation across the aisle has declined, so too has Congress’s ability to get anything done. Not only has the number of House bills that pass gone down, so too has the number of bills that are proposed in the first place. That means there are “fewer ideas being explored,” Hamilton says. “It seems that congressional innovation is suffering because of partisanship.”

As a geographer, Andris says she’s most troubled by the loss of a once-rich political geography and its diversity. “Geography is just zeros and ones,” she says – whether one lives in Seattle or Atlanta, it makes no difference politically.

“That’s a problem for me, because it dulls what’s great about this country.” ■

# Ho hum. Sports are not nearly as exciting as we thought

If you’re up 18 points at the half, chances are pretty good you’re going to win a game of basketball. In fact, your lead is 90 percent safe. What’s more, if you blow such a comfortable lead, you’ll probably do it late in the fourth quarter.

Those are some of the findings of a recent paper in *Physical Review* co-authored by SFI Professor Sid Redner, External Professor Aaron Clauset (CU Boulder), and Boulder graduate student Marina Kogan.

But the really incredible insight, Redner says, “is that apart from some technical details, basketball scoring conforms to a random-walk process” – essentially, it’s a series of coin flips, with a few modifications to account for alternating possession and the teams’ relative strengths.

Redner and Clauset each has a history of slightly offbeat research. In recent years, Redner has studied such topics as the role of Luddism on innovation diffusion, sperm search dynamics (see story on this page), and the best strategy for capturing skittish lambs. Clauset has worked on everything from friendship networks in the online combat game Halo to academic hiring biases.

Relying on the wealth of data generated by professional sports, Clauset, Kogan, and Redner recently turned their attention to the dynamics of scoring in sports. As a starting point, they studied scoring in basketball and other sports as a random walk.

Remarkably, they found, all of these follow the same probability distribution: the total amount of time a team holds the lead, when during a game the leading team is



up by the most points, and the time of the last lead change.

The last lead change is by far most likely to happen very early or very late in a game, and with high probability, teams post the biggest leads either near the start of a game or near the end of a game. Similarly, chances are a team will be up for either most of the game or very little of it.

Those results line up well with scoring data from the NBA and from the NFL, MLB, and NHL, which might not be a good thing for fans. Leads, the researchers conclude, are far safer than sports experts and aficionados might think, and following anything but the start and end of a game is a little like watching ten players flip coins for 45 minutes. ■

## INSIDE SFI

# Three trustees elected to SFI’s board

SFI’s Board of Trustees welcomed three new members during its biannual meeting on May 3, 2015.

**Fred Dotzler** is a managing director and co-founder of De Novo Ventures, a firm that invests in medical devices and biotechnology. Previously he was a managing general partner of Medicus Venture Partners; a general partner with Crosspoint Venture Partners; and an executive in finance, marketing, sales, manufacturing, and business development for a variety of medical, technology, and biotech companies.

**Jacques Dubois** retired from Swiss Re Group in 2006, having served the global re-insurance provider as a member of the Swiss Re Executive Board in Zurich and as chairman and CEO of Swiss Re America Holding Corporation, among other roles. Since retiring, Mr. Dubois has been a consultant to financial institutions on matters related to acquisitions, insurance coverage litigation, collateralized debt obliga-

tions, and credit default swaps.

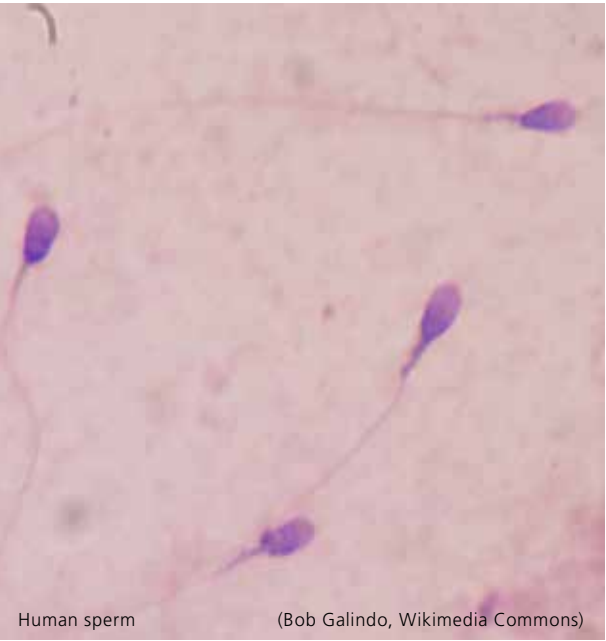
**Josh Wolfe** is co-founder of Lux Capital, where he focuses on investments in the physical and life sciences. Previously he worked in investment banking at Salomon Smith Barney, in capital markets at Merrill Lynch, and in municipal finance at Prudential Securities. He is a columnist with *Forbes*, editor for the *Forbes/Wolfe Emerging Tech Report*, and host of a program on the *Forbes Video Network*.

Detailed bios are available at [www.santafe.edu](http://www.santafe.edu).

SFI also bid farewell to **Reese Jones**, with gratitude for his many contributions to the board and to SFI over his three years of service.

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

# Why so many sperm? Probably to overcome their high mortality rate



Human sperm (Bob Galindo, Wikimedia Commons)

It’s one of the true miracles of life, that moment when hundreds of sperm make it all the way to an unfertilized egg and one breaches its walls. But what of all those other spermatozoa, the hundreds of millions of little guys that never make anything of themselves?

Why are they even there?

Perhaps, says SFI Professor Sid Redner, it’s because “sperm are moving through an incredibly hostile environment,” and the best way to compensate for their high mortality rate might be sending out a very large search party.

Redner, a physicist, had been

interested in search problems for a while when he came across a research paper that asked a simple question: why so many sperm?

“The title and qualitative presentation piqued my interest,” he says. So he and fellow physicist Baruch Meerson (Racah Institute of Physics, Hebrew University of Jerusalem) decided to probe the matter quantitatively. Starting from a simple diffusion model, in which abstract “searchers” start from one point on a line and spread out until one reaches a target, they looked at two cases: one in which the searchers lived forever, and one in which they didn’t.

Though the model is obviously a “caricature” of the process of fertilization, Redner says, it did yield some intriguing conclusions. First, immortal searchers don’t gain much by arriving in massive numbers. Changing from one million to two million searchers, for example,

reduces the average search time only by about five percent.

Mortal searchers are another matter. When the mortality rate is sufficiently high, it is a lucky sperm that makes it, Redner says. In other words, if sperm don’t live very long, the probability that any individual sperm gets lucky is very low.

Fortunately, there’s a way to compensate: increase the sperm count – by a lot. The number needed for a decent shot at fertilization grows exponentially with the mortality rate. That may help explain why it takes 250 million sperm, each with a lifetime of a few days at most, just to have decent odds of fertilizing an egg.

Their paper, “Mortality, Redundancy, and Diversity in Stochastic Search,” appeared May 15 in *Physical Review Letters*. ■



# The language of invention: Most innovations are rephrasings of past ideas

Most new patents are combinations of existing ideas and pretty much always have been, even as the stream of fundamentally new core technologies has slowed, according to a recent paper in the *Journal of the Royal Society Interface* by Hyejin Youn, SFI Professor Luis Bettencourt, and Arizona State University collaborators Jose Lobo and Deborah Strumsky.

Youn, a former SFI postdoctoral fellow now at Oxford, and her colleagues reached those conclusions sifting through the records of the United States Patent and Trademark Office. Dating back to 1790, the records feature an elaborate system of technology codes – a vocabulary of sorts, in which any new invention is a phrase.

The researchers found that throughout the Patent Office’s history, about 40 percent of patents have been refinements of existing patents that leave the “phrase” unchanged. The

rest are either new words or new phrases – and the balance between those has changed.

The vocabulary of invention grew exponentially until 1870. Afterwards the expansion slowed, but by that time there were so many basic technologies that inventors could keep up the pace of new patents only by combining old words in new ways.

Youn says there are a number of avenues for future research. In one project, she and colleagues are examining the grammar of technology – the different ways individual ideas are combined or not – and how that grammar has changed over time.

She adds that this research, and the notion of studying combinatoric invention, is a good example of the collaborative nature of the Institute, which is itself deeply combinatoric in terms of both researcher expertise and home institution. ■

## > Q&A with Jerry Sabloff continued from page 6

The major gifts we’ve received have been very important triumphs: the gift from Ian and Sonnet McKinnon to endow the position of vice president for education; the gift from George Cowan to support the Cowan Chair for Human Social Dynamics; the Miller Scholars Program and the journalism fellowship, both sponsored by Bill Miller; the gift from the Thaws, which was among the largest single gifts in the Institute’s history.

We achieved and exceeded our 30th anniversary campaign goal of raising \$30 million thanks to the hard work of our Advancement staff and others, and especially the trustees. We have evidence all around: the Michael and Sandy Collins Conference Room, the Bill and Stephanie Sick Presidential Suite, the Melton Library at the Thaw House, and so on. These are some visible examples of the campaign’s success.

Most important, across the board, our science is flourishing. Through the hard work of our past three science vice presidents – David Krakauer, Doug Erwin, and Jennifer Dunne – we’ve been able to recharge our workshop and working group activities. Visits are up. Seminars and colloquia are up. Our experimental partnership with Arizona State University is realizing important benefits in the form of shared postdocs and research. All that is in terrific shape, and that’s just the broad stroke.

**Update:** Any regrets or missed opportunities?

**Sabloff:** The main one is that in the six years I’ve been here, I’ve had little or no discretionary funds to support the exploration of new ideas – for example, if I had had some seed money to explore the kind of idea where, if we just put in a little thought and early research, then we could put in a grant proposal to the NSF or a foundation to study it. We just have not had that freedom. George Cowan said to me when I came here, “you know, you don’t have to say ‘no’ all the time.” Saying “yes” to the exciting or risky idea is in the Institute’s DNA, so not always having that freedom is both a regret and a missed opportunity.

**Update:** What are the Institute’s biggest challenges?

**Sabloff:** The finances still loom very large. We’ve come back, but we’re not out of the woods. We have restored some of the expenses we had to cut, such as the salary reductions and the retirement plan match, but unfortunately our operating budget remains exceedingly tight. And the key objective remains raising additional unrestricted funding, which would give us the flexibility to move money toward the Institute’s most critical needs or fund the study of new ideas.

Related to that, making sure we take risks is a major challenge today, at a time when most of science and academia seem to be pulling in the opposite direction. We’ve been extremely fortunate that the John Templeton Foundation has seen the value and the potential of some of our higher risk, more speculative theoretical science.

Finally, continuing to attract the best scientists remains a major challenge.

**Update:** Any messages for SFI’s people as you depart?

**Sabloff:** The biggest message I have is “thank you.” Given the hard times we’ve been through, the morale and the unbelievable loyalty to the Institute have been remarkable to me. People put in a huge amount of energy and effort in all departments, staff and faculty and postdocs alike, to keep the enterprise going.

At the Board dinner last month, I was asked whether the last six years have been enjoyable, and I said that’s the wrong question. The answer to that question is “no.” A better question would be whether the job of president has been exciting. The answer to that question is “yes,” and it really has been fun to come to work every day. You never know who you’re going to meet, what ideas you’re going to discuss. I don’t think anybody who works at a university would say it’s fun to come to work every single day. It’s the people that make SFI such a stimulating environment. So thank you.

**Update:** Any thoughts for incoming president David Krakauer?

**Sabloff:** He’s well aware of the challenges facing the Institute, so he’s going to be able to hit the ground running. And he clearly wants to make the Institute

## > Whooping cough continued from page 1



Quarantine sign, Montana, 1943

(Credit: Montana Historical Society)

demonstrated that giving baboons acellular pertussis vaccines prevented them from developing symptoms of whooping cough but failed to stop transmission.

Building on that result, Althouse and Scarpino used whopping cough case counts from the CDC, genomic data on the pertussis bacteria, and a detailed epidemiological model of whooping cough transmission to conclude that acellular vaccines may well have contributed to – even exacerbated – the recent pertussis outbreak by allowing infected individuals without symptoms to unknowingly spread pertussis multiple times in their lifetimes.

“There could be millions of people out there with just a minor cough or no cough spreading this potentially fatal disease without knowing it,” said Althouse. “The public health community should act now to better assess the true burden of pertussis infection.”

What’s worse, their model shows that if the disease can be spread through vaccinated, asymptomatic individuals essentially undetected, the level of vaccination needed to protect those that are unvaccinated (so-called “herd immunity”) is over 99 percent, impractically high at a time

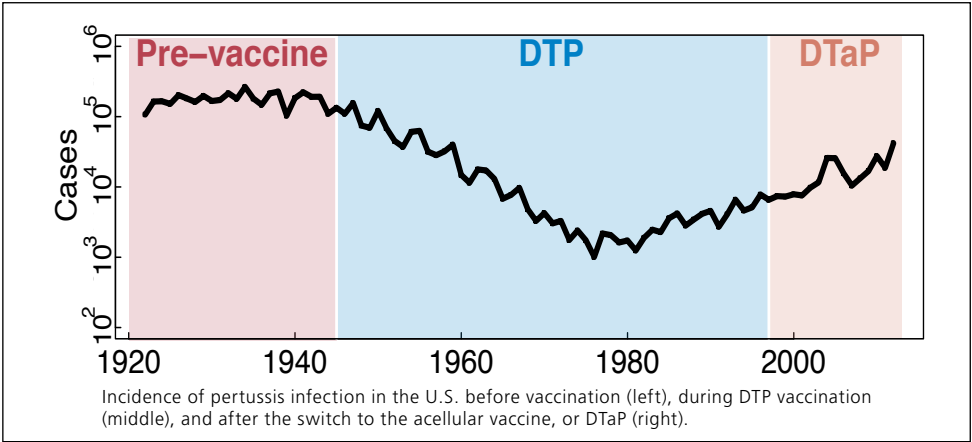
when anti-vaccine campaigns are turning people away from vaccination.

Their results also suggest that a practice called cocooning, where mothers, fathers, and siblings are vaccinated to protect newborns, isn’t effective. “It just doesn’t work, because even if you get the acellular vaccine you can still become infected and can still transmit. So that baby is not protected,” Althouse says.

Does this mean the current vaccine is useless? Not at all, the pair says. Until researchers can develop a new pertussis vaccine that blocks transmission, the protection the acellular vaccine offers to individuals is vital.

“It’s the symptoms of pertussis infection that kill people,” Scarpino says, “and the existing vaccine prevents these most debilitating effects of whooping cough.”

In that sense, the research underscores the importance of getting vaccinated, especially for children. “There are lots of people out there who may be transmitting pertussis unknowingly,” Scarpino says. “Not vaccinating your own child puts her or him at increased risk of severe disease, even death.” ■



even more visible. In terms of both deep knowledge of SFI and temperament, in every sense, really, SFI is very fortunate to have him.

**Update:** What are your own plans?



Sabloff kicks off SFI’s Business Network Symposium in November 2012.

**Sabloff:** As of August 1, I’ll become an external professor, and Paula and I will be staying in Santa Fe, which will give me the excuse to come up regularly for lunch and events and so on. And I want to write. The publisher of my book *Archaeology Matters* has been after me for a long time to do a new edition because there has been so much important new work in archaeology that is relevant to the modern world, so that should be fun. I want more time to read and catch up on all the exciting stuff going on pertaining to the rise of early states, in general, and the ancient Maya in particular. There are some ideas in the back of my head I want to have the time to develop.

I continue to serve on several nonprofit boards, particularly the National Museum of Natural History at the Smithsonian, so I want to keep those activities alive. I’ll be a visiting scholar for Phi Beta Kappa for 2016 and 2017, so that will give me a chance to visit several college campuses a year. All this will certainly keep me busy, I hope! ■





# Shaun Swanson: Making sense of big socioeconomic data



Complex systems science is a compass for navigating the digital trails of our modern world, according to Shaun Swanson, a data scientist at Radius.

com in San Francisco. At the fast-growing startup, he applies machine learning to enhance and grow a massive, monthly-published dataset of more than 25 million U.S. businesses.

With a background in thermostatics, Swanson believes complexity will help make sense of the socioeconomic datasets that expand every day through our digitized social transactions on computers, cell phones, and social media.

“[Data science] is heavily skewed toward socioeconomic datasets,” he says, “and under the hood, these complex technology and socioeconomic networks are producing the data. We’re about to see a really big rise

in the importance of complexity science, because many of these growing datasets are complex.” Swanson, something of a self-taught complexity scholar, supports SFI because, he says, “anytime you read anything about complexity science, the Santa Fe Institute pops up all over the place.” He is particularly intrigued by the work of SFI’s cities and urbanization research and sees potential for finding similar scaling phenomena in the small business data he works with.

“I donate a monthly amount – not a huge amount – because I think it makes the most sense,” he says. “I’ve got this great job, and I get a paycheck regularly, so I can put a little of it toward this institute I really believe in.” ■

## Monthly Giving

- Recurring gifts make it easy to maintain your commitment to SFI’s science.
- Set up a monthly gift using your credit card. Your payments are processed securely.
- For more information about giving to SFI, visit [santafe.edu/support](http://santafe.edu/support) or call us at 505.946.3678.

# One teacher, ten Santa Fe students honored with SFI’s high school prize

On May 13 at SFI, New Mexico School for the Arts chemistry and physics teacher Dave Brooks received SFI’s 2015 Prize for Outstanding Teacher. Brooks joined ten Santa Fe-area high

as up to date as yesterday.”

His students have used Google Earth to study dams and fluid dynamics, watched videos of MIT scientists exploring alternative energy power storage, and chatted with Mark Levinson, director of the documentary film “Particle Fever,” via Skype.

“There aren’t a lot of tangible rewards for teachers,” says Brooks. “[This award] means a great deal.”



Dave Brooks (right) and the winners of SFI’s 2015 High School Prize for Scientific Excellence. (Credit: Gabby Beans)

school seniors in receiving the Institute’s High School Prize for Scientific Excellence, awarded each year to one local science teacher and one senior from each of Santa Fe’s high schools.

Brooks relies on digital technology and online media to keep his curricula both fresh and relevant. “It’s a great time to be a teacher,” says Brooks. “The information you can present...is

The ten winning high school seniors are: Alexander Ortiz, Santa Fe High School; Alma Valdez Garcia, New Mexico School for the Arts; August Honnell, The MASTERS Program; Bridget Bohlin, Santa Fe Preparatory School; Brooke Reiche, Santa Fe Waldorf High School; Charelle Brown, Santa Fe Indian School; Isaac Fischer, Desert Academy; Isabel Chavez, St. Michael’s High School; Meghan Hill, Monte del Sol Charter School; and Randall Pietrocci, Academy at Larragoite. ■



# MY STORY

**Ginny Greninger**  
Manager (retiring)  
Office of the President  
Santa Fe Institute



After moving to Santa Fe from the Los Angeles area in 1998, I was fortunate to find a position at SFI in my favored sphere – education and outreach. After six months of processing applications, it was always so gratifying to meet those impressive applicants in person on the first day of Complex Systems Summer School. Later, in 2005, Geoffrey West recruited me to manage the president’s office, and that gave me the chance to interact with so many remarkable individuals in a wonderfully unstructured and often chaotic, but fun, environment. Weaving SFI experiences into my life has led me down a much more imaginative path.



## Upcoming community events

**SFI Community Lecture, Wednesday, July 15, 7:30 p.m., James A. Little Theater (1060 Cerrillos Road) – Understanding Genius: The Neuroscience of Extraordinary Creativity.** How does one define extraordinary creativity? Is creative genius a product of nature or nurture? And how can we become more creative? Nancy Andreasen draws from neuroscience to analyze the connections between extraordinary creativity, intelligence, the social environment, and mental illness, providing fascinating insights on human potential and the creative mind. Andreasen is a neuroscientist and psychiatrist and the Andrew H. Woods Chair of Psychiatry and director of the Neuroimaging Research Center and the Mental Health Clinical Research Center at The University of Iowa Carver College of Medicine. She is the author of three widely praised books, including *The Creating Brain: The Neuroscience of Genius*.

**Stanislaw Ulam Memorial Lecture Series, Tuesday & Wednesday, September 15 & 16, 7:30 p.m., James A. Little Theater (1060 Cerrillos Road) – The web of life and the ecological human.** Life has a hidden order. In two lectures over two nights, ecologist Jennifer Dunne will reveal surprising characteristics shared by ecosystems in radically different environments, comprising different species, and across time. By highlighting patterns in the architecture of how species, including humans, interact, she reveals new ways to understand the sustainability of ecosystems past, present, and future.

**Lecture I - Tuesday, September 15, 7:30 p.m. The hidden order of complex ecosystems.** Dunne shares surprising findings from her research of food webs, the networks of who eats whom in nature. After revealing hidden ecological order, she explores the underlying forces that constrain and organize ecosystems across hundreds of millions of years, from the explosion of biodiversity in the deep-time Cambrian period, long before the dinosaurs, to the deteriorating condition of ecosystems in the present day. She then describes characteristics that can fortify ecosystems against species loss and environmental change.

**Lecture II - Wednesday, September 16, 7:30 p.m. The ecological human.** Traditionally, most ecological research has studied ecosystems as separate from humans. In her second lecture, Dunne shows how humans fit into and impact ecosystems through their myriad interactions with other species. She then explores how the science of ecological networks can help meet the pressing need to understand the roles of humans in ecosystems, particularly in terms of resource use and consumption. With examples from pre-industrial hunter-gatherer and agricultural societies, she will explore potential lessons for modern humans in fostering a more sustainable future.

Jennifer Dunne is the vice president for science at the Santa Fe Institute. Her research interests are in analysis, modeling, and theory related to the organization, dynamics, and stability of ecosystems that include humans.

SFI’s 2015 Community Lectures are made possible through the generous support of Thornburg Investment Management. Lectures are free and open to the public, but seating is limited. To watch a lecture as it happens, visit SFI’s YouTube page; participate in the discussion live on Twitter at @SFIlive. ■

July / August 2015

# UPDATE

SANTA FE INSTITUTE



1399 Hyde Park Road  
Santa Fe, New Mexico 87501  
505.984.8800

[www.santafe.edu](http://www.santafe.edu)