SANTA FE INSTITUTE

March / April 2016

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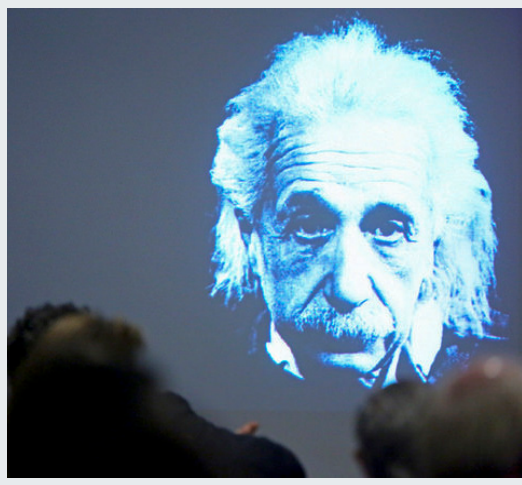


IN THIS ISSUE

INSIDE SFI

Krakauer: 2016 is the year of conversations, experiments, and partnerships at SFI

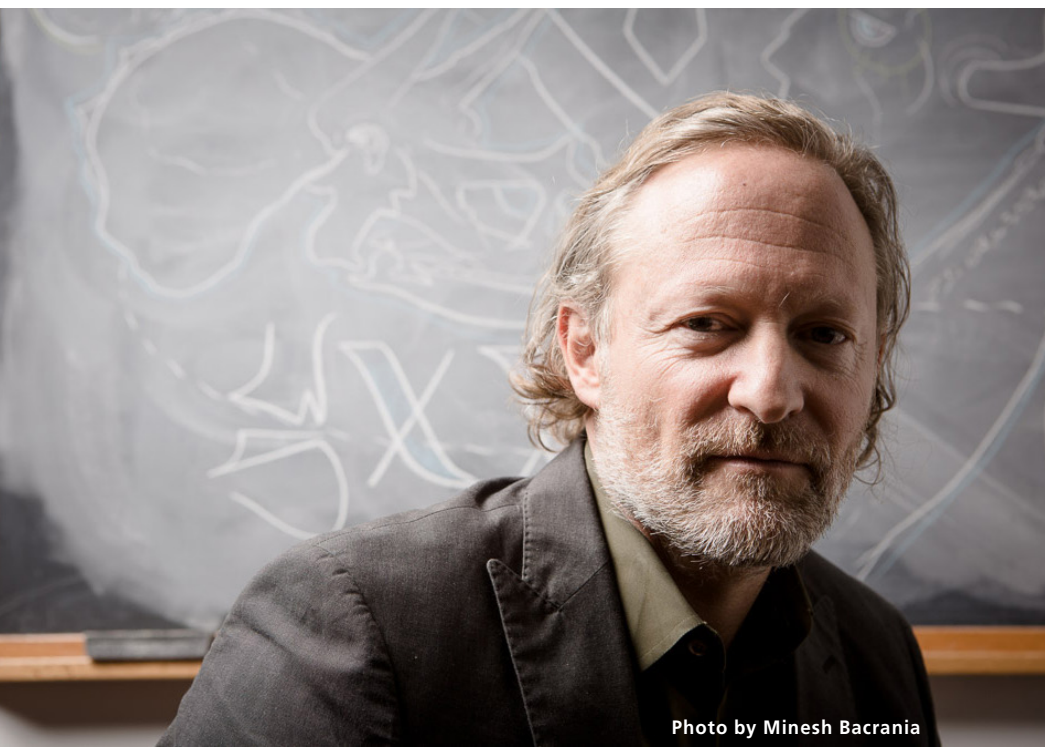


Photo by Minesh Bacrania

SFI President David Krakauer has launched a number of initiatives intended to put the Institute's intellectual thrusters into hyperdrive and amplify the impact of SFI's science.

His vision comes in three parts: conversations, experiments, and partnerships: "We're going to have more, and more interesting, conversations with a greater diversity of people. We're going to try some exciting new things that invite incredible opportunity…and skirt failure. And we're going to partner. This is the year of partnerships at the Santa Fe Institute."

The new Strategic Partnerships group at SFI, which combines the previous functions of Advancement and the former Business Network, is responsible for developing and maintaining all of the Institute's high level partnerships. On March 1, Krakauer announced the selection of Will Tracy to lead the new unit as VP for Strategic Partnerships. (See article on page 5.)

> more on page 4

RESEARCH NEWS

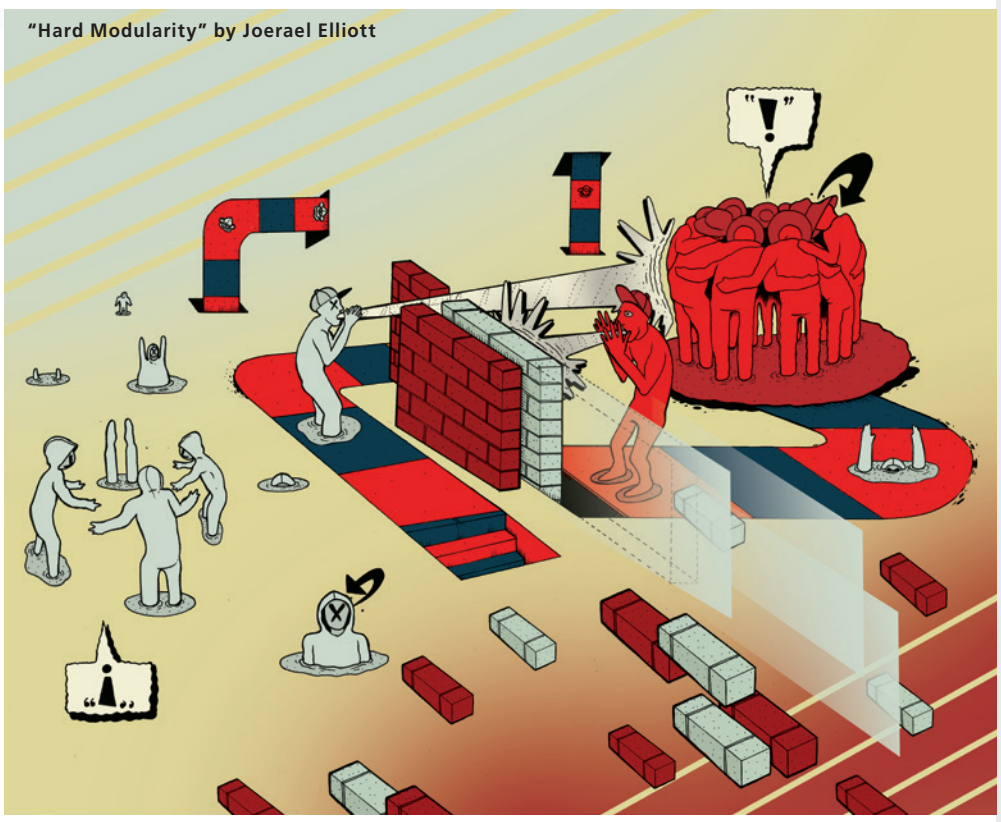
The influence of modularity on networks

In large systems, from biology to politics, like attracts like. Individuals in social systems connect and form factions based on common interests or behaviors, such as a voting populous that divides by candidate. A biological model of malarial transmission may divide its constituents into parasites (mosquitoes) and hosts (humans), with each group playing fundamentally different roles.

Understanding groupings, or "modules," is a key problem in network theory. Traditional clustering models assume many modules will pop up in a large population. But that approach is limited, says Laurent Hébert-Dufresne, an SFI postdoctoral fellow. Recent findings suggest that a small, finite number of tightly knit modules – those whose components play by the same rules as the system evolves – emerge in many systems, and this "hard modularity" can influence network processes.

To better explore the impact of hard modularity on networks, Hébert-Dufresne organized a five-day working group at SFI in January. His collaborators included three physicists, Antoine Allard (University of Barcelona), Jean-Gabriel Young (Université Laval in Québec), and Pierre-André Noël (UC Davis), as well as evolutionary biologist Eric Libby, an SFI Omidyar Fellow.

"Hard Modularity" by Joerael Elliott



Modularity is typically regarded as a structural property of a network, but this group took a different approach. "We studied modularity instead as a strategy," says Hébert-Dufresne. "Do you look for people like you, or different from you?"

Scrawling on a whiteboard and on paper, the network theorists thought through a number of simple strategy games to test the influence of hard modularity: for example, to win an election, how much effort should

> more on page 8

RESEARCH NEWS

Bluebird's conundrum: Shack up now or hang out on mom's couch for a while

For a young male western bluebird, it might be better to live with one's parents as a helper for a year before starting a nest of one's own, according to a recent study in *Behavioral Ecology*.

It's a unique and somewhat counterintuitive interplay of evolutionary tradeoffs that makes this kind of cooperative breeding advantageous for species like bluebirds, says Caitlin Stern, an SFI Omidyar Fellow and lead author on the paper.

Female western bluebirds show an age bias, preferring to mate with older males. And bluebirds have high rates of extra-pair paternity, or EPP, where a female's social mate may not be the father of all her offspring. This means a young partnered male often shares more genetic material with the younger siblings in his parents' nest than the young of his own nest.

In addition, behavioral ecologists know that helping behavior often results in longevity. By sharing the workload, each individual in a cooperative system has a survival advantage.

Young birds who stay at home as helpers may increase both their parents' and their own lifespans, on average. For long-lived species like bluebirds, which can survive eight years, males may thus increase their reproductive fitness – the representation of their alleles in the next generation – over their lifetimes by delaying breeding and helping instead.

> more on page 7

Deploying ideas and tools from complexity science could help economists foresee market interdependencies that cause global market instabilities, wrote a group of researchers in *Science* on February 18, including SFI External Professor Doyne Farmer and Science Board member Robert May.

Bloomberg on February 11 featured SFI Board of Trustees Chair Emeritus Bill Miller and his new investing algorithm, influenced by complex systems science and a computer model developed with SFI External Professor John Rundle designed to predict earthquakes and other natural disasters.

Nature on February 11 highlighted a recent study – co-athored by Hyejin Youn, Tanmoy Bhattacharya, Cris Moore, D. Eric Smith, and Jon Wilkins – in which the researchers used a new methodology to reveal that for many universal concepts, the world's languages feature a common structure of semantic relatedness. The *CS Monitor* covered the paper on February 3.

SFI's essay series with the *CS Monitor* continued with "Beehives and voting booths" by SFI External Professor John Miller on February 11; "Why people become terrorists" by SFI Professor Mirta Galesic on January 21; and "Engineered societies: Can science help orchestrate social outcomes?" by SFI Professor Jessica Flack and External Professor Manfred Laubichler on January 7.

New Scientist on February 10 reviewed SFI External Professor John Miller's new book, *A Crude Look at the Whole*. *Slate* reviewed the book on January 19.

Forbes on February 10 covered a paper by SFI's Hyejin Youn, Luís Bettencourt, José Lobo, Deborah Strumsky, and Geoffrey West that examined the diversity, distribution, and patterns in the types of companies that arise in cities of different sizes.

The *Wall Street Journal* on January 29 explored the implications of a 2015 paper by Madeleine Daepp, Marcus Hamilton, Geoffrey West, and Luís Bettencourt revealing that a typical firm lasts about 10 years before it gets merged, acquired or liquidated, and that a firm's mortality rate is independent of its age, how well established it is, or what it does.

Articles in the *New York Times'* Stuff We Like column and *The Atlantic's* CityLab on January 29 featured a study co-authored by SFI Professor Luís Bettencourt and former postdoctoral fellow Marcus Schläpfer that finds universal patterns, and limits, in the heights of buildings in major cities.

PBS Nova on January 13 and *Wired* on January 4 quoted SFI Professor Luís Bettencourt in an article on the range of possibilities – utopian to dystopian – the urban transportation networks of the future might realize. ■

Nonlinearities

From the editor

Intellectual thrusters to hyperdrive! In March, nine science meetings take place at SFI. The Applied Complexity Network (now known as ACtioN) is announcing a host of new membership perks (see page 4) and holding a exciting meetings on topics like financial regulation and ecosystem dynamics (with a little population genetics for good measure).

The Education office is gearing up for one crazy summer, with a global sustainability summer school to augment its already rich lineup of schools and residential programs, new online courses at ComplexityExplorer.org, and new short courses. Our community lecture series this year moved to The Lensic, an auditorium of 800+ seats (twice the size of the previous venue) — and we're still routinely near capacity.

The Broken Symmetry Society was inaugurated in February, with Cormac McCarthy, James Drake, Joerael Elliott, and a half dozen other creative types in the house; read more about it in the article that starts on page 1.

A new art exhibition just went up in our main building. It features paintings, a photocopied map and pages from a couple of short stories, and several office doors with stenciled titles like "Seldom Little-Seldom" (a real town in Newfoundland), "Museum of Dark Forces," and "Library of Babel" — the latter a reference to a short story by Argentine author Jorge Luis Borges. The unifying theme of the exhibition might be *Dietrologia*, an Italian word (some say it's an Italian worldview) that the surface or official explanation for something can rarely be the real one. Maybe.

Hidden behind the deceptively stoic title "History, Networks, and Evolution" is one science meeting not covered in this issue. The organizers, Manfred Laubichler and John Padgett, wanted to do some deep thinking about thinking: what is thinking, who (or what) is capable of thinking, etc. To get there, they posed thought experiments: "How do chemicals think?" "How do ecologies think?" "How do cities think?" We'll let you know what they come up with…in the next issue. ■

– John German, 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*.

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How hunter-gatherers preserved their food network

A new study of humans on Sanak Island, Alaska and their historical relationships with local species suggests that despite being super-generalist predators, the food gathering behaviors of the local Aleut people were stabilizing for the ecosystem.

The findings provide insights into how human roles and behavior impact complex ecological networks and offer new quantitative tools for studying sustainability.

With a team of ecologists and archeologists, SFI's Vice President for Science Jennifer Dunne wanted to understand the niche humans filled in Sanak's marine ecosystems by compiling and analyzing local food web data.

"It's the first highly detailed ecological network data to include humans, which allows us to ask questions about how they compare in their roles to other predators," says Dunne. "Unlike most ecological studies that ignore humans or consider them as external actors, our analysis includes them as an integral part of the ecosystem."

For roughly 7,000 years, the Sanak Aleuts hunted marine mammals and fishes in the nearby open water and gathered shellfish and algae closer to shore. Dunne and her colleagues put together a precise picture of the local marine food webs by studying the bones and shells left behind in middens (trash heaps), oral histories gathered from Aleut elders, and ecological data.

Then, through analysis of the network structure of these food webs, they discovered that in both the intertidal and nearshore food webs, humans fed on approximately a quarter of the species present, far more than other predators in the systems. This varied diet, ranging from primary producers like algae to top carnivores like sea lions, puts humans in a niche similar to other super-generalist predators like Pacific cod.

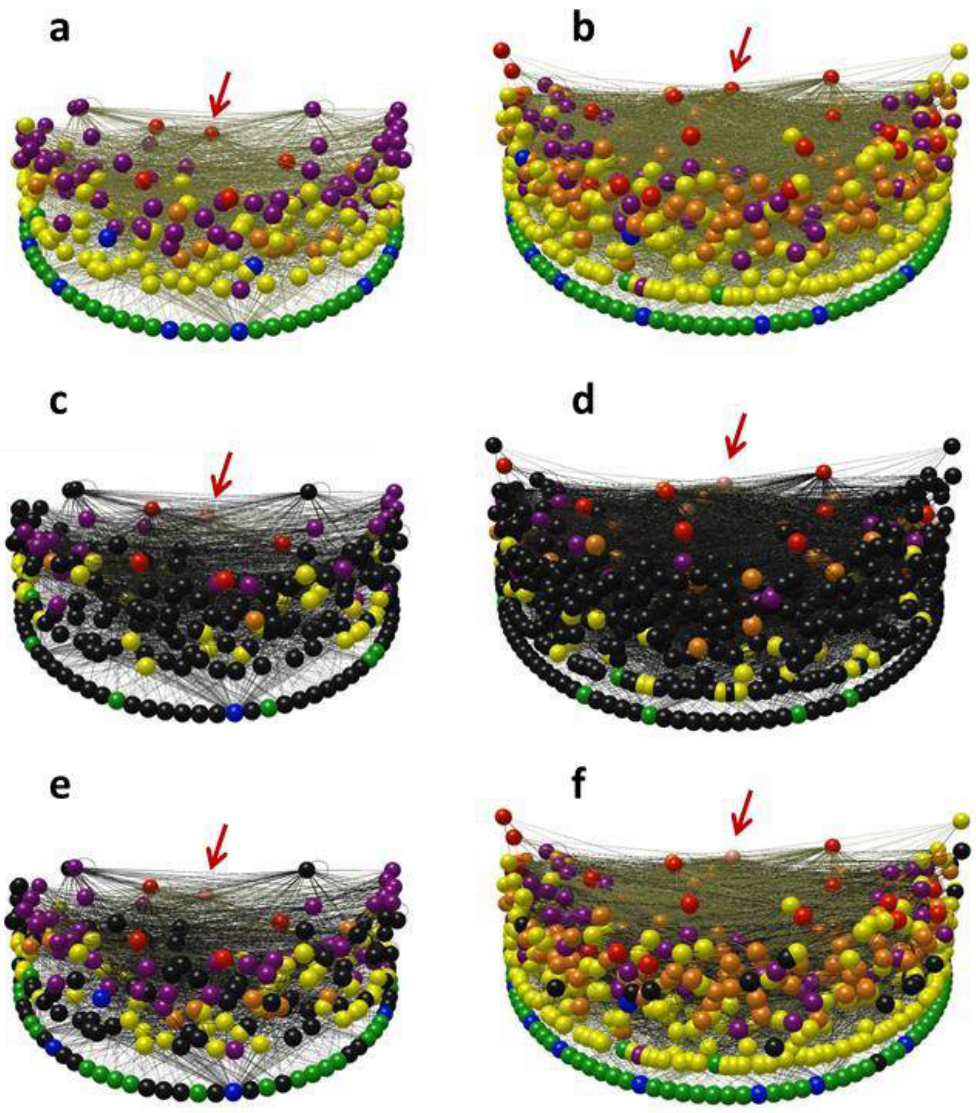
And, like other generalists, the Aleuts prey-switched. As a favored prey species became difficult to find due to population decreases or unfavorable environmental conditions, the Aleuts chose alternative food sources. In food webs where predators prey-switch, dwindling prey populations can bounce back and extinctions are rare.

"It's a very stabilizing behavior for the system," says Dunne.

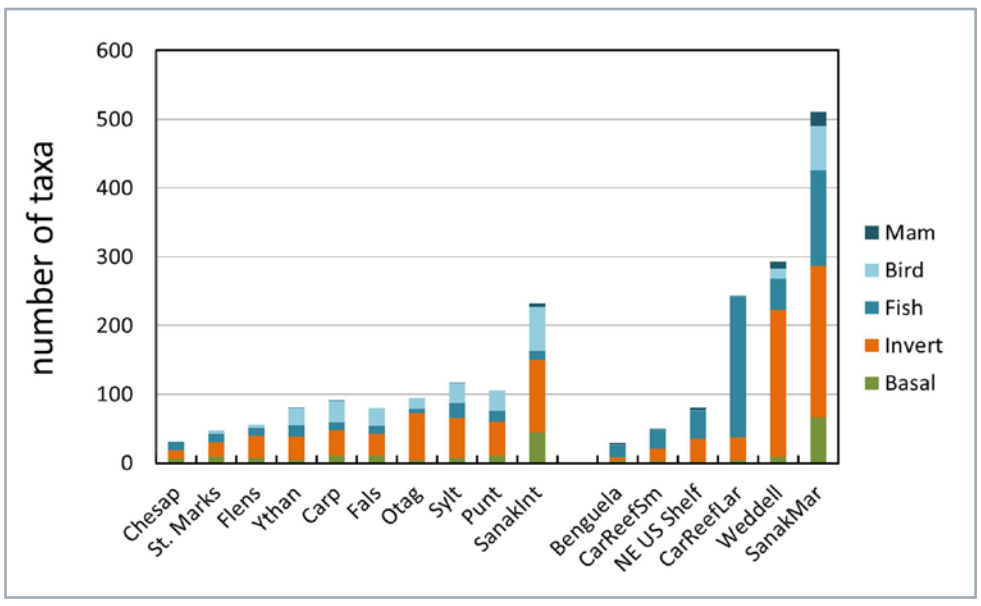
In addition, while simple technologies like fish hooks, spears, and kayaks helped the Aleut hunt some of their prey more intensively than expected for non-human predators, Dunne's analysis of the dynamics of model food webs suggests that as long as such intensive hunting was limited to a few prey species, it would cause few extinctions.

Modern fisheries can put a very different pressure on food webs, she notes. Advanced technology allows for highly intensive fishing, and in many cases as a resource becomes scarce, its value goes up. In these cases, such as with Bluefin tuna that are a highly prized sushi fish, "increased rarity increases economic value, leading to increased harvesting pressure at just the wrong time," says Dunne. "You're not only driving those populations to extinction, you're also introducing a destabilizing dynamic into the system."

The paper appeared February 17 in *Nature Scientific Reports*. ■



Vertical axes indicate trophic level. Sphere color indicates type of taxon: green = algae, blue = miscellaneous (e.g., detritus, protozoa, bacteria, biofilms, lichen, seagrass), yellow = invertebrates, orange = fishes, red = mammals, purple = birds. Red arrows point to *Homo sapiens*. Six networks are represented: (a) Sanak intertidal web, (b) Sanak nearshore web, (c,d) Sanak intertidal and nearshore webs showing resources of *Homo sapiens* in color, (e,f) Sanak intertidal and nearshore webs showing taxa within two links of *Homo sapiens* in color.
(Images created with Network3D, available freely by request to jdunne@santafe.edu.)



Data for ten intertidal (left) and six marine (right) webs in order of increasing species richness. Data shown for trophic species versions of webs, where taxa with the same set of consumers and resources are aggregated into a single node.

Tomorrow's grid: Keeping the lights on

The big utilities are getting nervous. A century ago, the North American power grid was an unfolding technical marvel rooted in a nation's way of life and delivering a clear public good.

Today, innovation in energy technology, regulatory changes, and shifting social values are de-centralizing the power supply. As more consumers install rooftop solar and home batteries, fewer draw from the power grid. Some states have enacted regulations to stop or slow certain disruptive changes. Others have viewed the progress as a prompt to re-think the utilities' business models.

"What's happening with the electric utilities in North America and around the world has a lot in common with what happened to the telecommunications companies at the advent of cell phones," observes Seth Blumsack, an energy expert who recently spent a sabbatical at SFI.

Blumsack (Penn State) is co-organizing an April SFI workshop with SFI External Professor Jessika Trancik (MIT) and SFI Professor Cris Moore to parse the complex nature of this transition in the electric power industry.

The workshop – The Nature of Technological, Social, and Industrial Innovation and Transition in Power Generation and Delivery – will bring scientists, historians, technology experts, engineers, and policy experts to SFI in early April to discuss creative ways to manage the ongoing and potentially disruptive transition.

Unlike two previous SFI workshops on the power grid, which focused on engineering power delivery systems, the April workshop will explore social and regulatory issues and the role of innovation in our shifting electricity landscape.

"Energy conversion and storage technologies are evolving rapidly, and new low-carbon technologies are being installed in a rather uncoordinated way," says Trancik. "Electric utilities are being forced to adapt, and in this workshop we hope to step back and understand the rate and characteristics of this transformation. We also plan to look at these changes within the context of history and other sectors of the economy."

"In some cases, new technologies can enter disruptively, simply because they are cheap and popular," Moore observes. "In other cases, there are significant barriers to entry based on how we have built our infrastructure, written our regulations, trained our engineers, and so on. It also depends on society's default assumptions: for instance, why did my home come with a refrigerator but not with solar panels? Why will my mortgage company help me buy a bigger house, but not a more energy-efficient one?"

SFI provides a unique opportunity to bring together scholars from disparate areas to begin to explore these complex, interrelated questions.

"What I'm hoping will come out of this workshop are ideas for modeling or research that capture how these technical and social and regulatory systems can become more coordinated," Blumsack says. "I also hope we arrive at a more firm understanding of how all those systems impact one another." ■

Modeling an ancient people

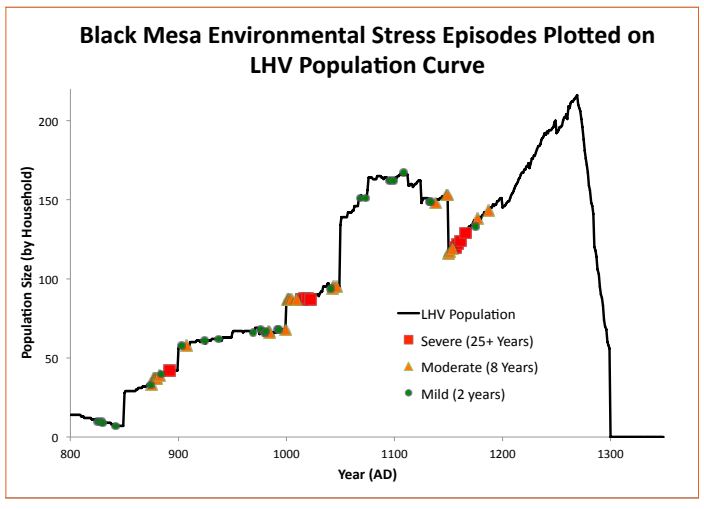
Drawing on the richness of data and questions that arose out of agent-based simulations of the Artificial Anasazi Project that originated at SFI in the mid 1990s, SFI External Professor George Gumerman and Alan Swedlund (UMass Amherst) have taken their simulation one step further in a revised model they call the Artificial Long House Valley model.

Developed in collaboration with Lisa Sattenspiel and Amy Warren (both of the University of Missouri), the Long House Valley model, with its disaggregated, individual-level demographic processes, will lead to a better understanding of human-environment interactions and deeper insight into population structure in the Anasazi settlement in today's northeastern Arizona.

"This second model focuses on individuals," explains Swedlund, "so we're able to address complex demographic processes in more dynamic ways."

The researchers will be at SFI March 28-30 to discuss and refine the new model as part of an SFI working group.

The first Artificial Anasazi simulation relied on empirical archaeological and paleo-environmental/climatological data to chart human population, distribution, growth, and decline in the Long House Valley region of the Colorado Plateau from 800-1350 AD. It provided a means for combining abundant multivariate data and testing scenarios with theoretical models for population growth and land abandonment under climatic stress.

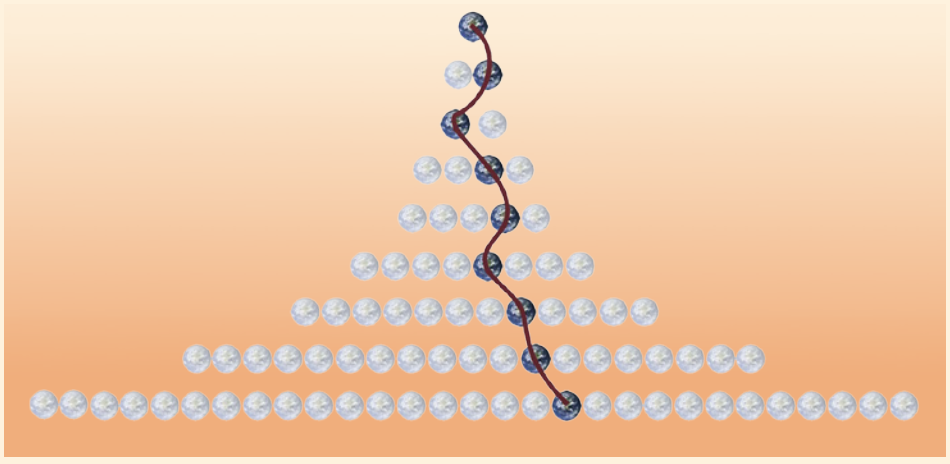


Long House Valley (LHV) model plots of environmental stress and population growth in the Long House Valley, suggesting intense migration into the valley at times of high environmental stress.

By building households from realistic probabilities based on individual-level data, the researchers aim to provide a more accurate and generalizable model for predicting outcomes in this and other archaeological populations.

It's also a model they hope to share with other researchers. "We believe our continued efforts will help to address some of the grand challenges in archaeology, as outlined in a recent SFI workshop," says Swedlund, "and that this individual-level, agent-based modeling approach will have real world applications in addressing questions about human responses to environmental stress."

It might even offer the ability to better track processes such as disease risk, selection, and migration, he adds. ■



Parallel worlds branching into the future, with reality selecting one trajectory through the space of possibilities. (Image: Ole Peters & Murray Gell-Mann)

A fundamental flaw in economic theory

Simple gambles extend through all major branches of economic theory. And, according to a new paper by SFI External Professor Ole Peters (London Mathematical Laboratory) and Murray Gell-Mann, we've been wrongly conceptualizing them for some 350 years. The paper, published February 2 in the journal *Chaos*, presented two approaches for evaluating gambles – expectation values and time averages. The authors demonstrated through a simple thought experiment that the time averages approach, which "hasn't been fully appreciated in economics so far," is superior for evaluating risk.

What makes cities unique…and the same

At a basic level, cities share some remarkably similar patterns, according to a new paper in the Royal Society's *Interface* co-authored by SFI's Hyejin Youn (Oxford), Luís Bettencourt, and Geoffrey West. Assessing data from urban areas across the United States that included 20 million business establishments, the authors could identify trends across cities of different sizes and with different dominant industries. They discovered that while the particular variety of industries and businesses may vary from one place to another, as cities grow, the general ratio of business establishments and workers also grows at a predictable relative rate.

Roots of gender disparity in computer science

SFI External Professor Aaron Clauset (CU Boulder), SFI Omidyar Fellow Daniel Larremore, and CU-Boulder PhD candidate Samuel Way recently examined the persistent gender imbalances in university computer science departments, where women hold just 15 percent of all tenure-track faculty positions. Their paper, published on arXiv.org, suggests that while overt gender bias in hiring practices might not be the primary cause of the disparity, more subtle contributing factors like documented productivity, publication rates, and ability to relocate to take new positions do correlate with gender in computer science faculty hiring networks.

Human vulnerability key to managing climate change

Our historic vulnerability to climate change can inform the way we manage climate-induced disasters today and tomorrow, according to newly-published research in *PNAS* conceived during a series of SFI working groups. Cross-disciplinary teams of archaeologists, historians, and geographers examined social and environmental variables that affected historic and prehistoric peoples in the American Southwest and North Atlantic Islands. The researchers discovered that social factors, like limitations on networks and mobility, were the primary contributors to vulnerability to food shortage following a climate disaster. ■

Is social science built on WEIRDness?

There's something odd about social science: namely that our generalized understanding of broad swaths of humanity is based on a startlingly narrow subset of that humanity. Many social science studies have, in fact, been based on sample groups of wealthy college students from industrialized countries.

Psychologists and anthropologists plan to convene at SFI to try to figure out what to do about what's called, appropriately, the WEIRD problem.

"The vast majority of scientific theory on human thought and behavior is derived from easily accessible populations in Western, Educated, Industrialized, Rich, and Democratic, or WEIRD, nations," says evolutionary anthropologist Dan Hruschka, co-organizer of a March working group that tackled WEIRDness. "In fact, those people are often extreme outliers, which raises questions about the generalizability of contemporary theories in the social and behavioral sciences."

The issue isn't that scientists can't learn anything from looking at one group of people. Darwin, after all, made great strides by examining just Galapagos finches. On the other hand, the recognized symptoms of heart attacks were for decades based entirely on studies of men – and women, it turns out, don't experience the same heart-attack symptoms. That led to a big blind spot in clinical knowledge.

The same issues crop up in social science, says Hruschka, an associate professor at Arizona State University, an ASU-SFI fellow, and a former SFI Omidyar Fellow. "Working in diverse settings outside the US or Europe," he says, "you begin to realize the importance of culture and the local environment in shaping not just what people think, but how they think." If scientists want to understand the full diversity of humanity, Hruschka says, they need to take WEIRDness seriously.

The working group, Combating Sample WEIRDness in the Social and Behavioral Sciences, took some of the first steps to tackle the problem. With funding from the National Science Foundation's Developmental and Learning Sciences and Cultural Anthropology programs, the group outlined the key barriers to research in more diverse settings, as well as some solutions. In future meetings, Hruschka says, they'll work on developing recommendations and tools so that others can more easily fight WEIRDness. ■

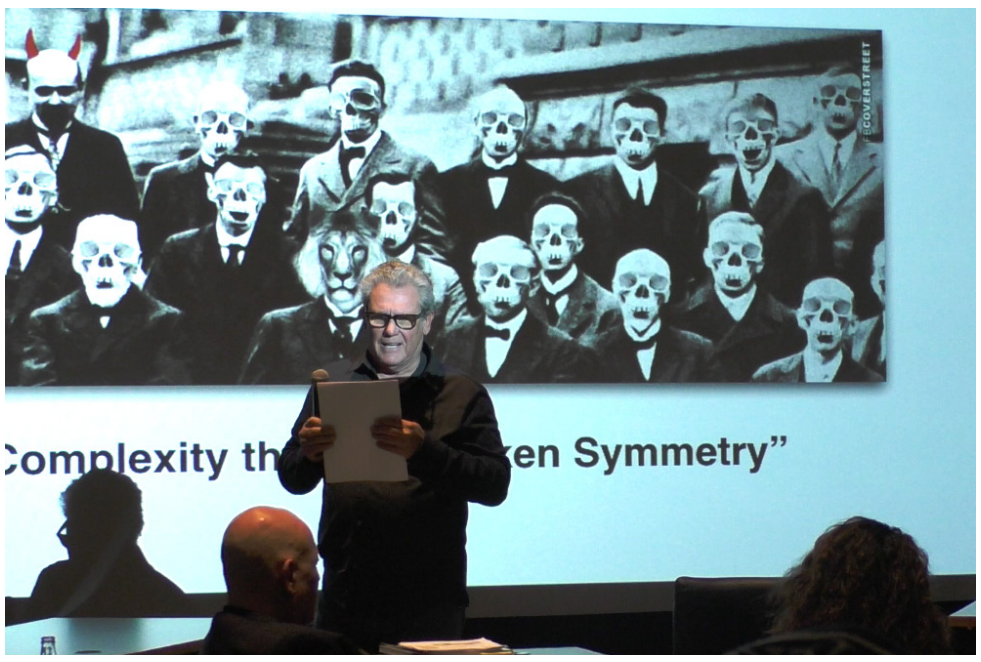
> *Krakauer* continued from page 1

Meanwhile, the flagship SFI partnership venue, the former Business Network, gets a new name and an amped up mission.

ACtioN, for the Applied Complexity Network, offers enhanced membership benefits as well as opportunities for members to engage more deeply in SFI's science through an offering of premium bespoke programs, ranging from corporate think-fest retreats at the new SFI Studio on the Cowan Campus to short courses custom-curated at an ACtioN member's request. (See "Introducing ACtioN" below right.)

ACtioN's focus expands to include foundations, government agencies, think tanks, and nonprofits in addition to companies that had been greater than 90 percent of the network's membership.

Photo by Minesh Bacrania



Santa Fe artist James Drake delivers "Drake's Proposition" during the inaugural meeting of SFI's Broken Symmetry Society.

The new ACtioN also aims to accelerate the extension and application of the Institute's scientific insights, says Krakauer.

"This is now hands-on engagement and collaboration," he says. "We're learning from members and members are learning from us, and together, we're creating something new. ACtioN is about applying complexity insights to real problems. Our members are in a position to take these ideas the rest of the way."

Krakauer's "multiversity" concept, which entails partnering with a half dozen or so elite, graduate-degree-granting academic institutions, is in the planning stage. Generally, it involves an exchange of top graduate students and postdocs with multidisciplinary backgrounds whose participation results in certificates in complexity from SFI.

In the conversations category, much is under way.

"One feeling I've had is that the Santa Fe Institute has always been about individuals," he says. "Let's see what happens when we also start having conversations with creative, smart, productive organizations – spirited organizations like the Institute."

He has had exploratory discussions with NASA, Red Bull, Spaceport America, and

> more on page 5

RESEARCH NEWS

What regulates what's living where and in what numbers?

Nature walks can inspire serenity and, for the inquisitive mind, questions. Why are maples and ferns flourishing here together? Do they get along somehow? Why are there no maples on the other riverbank, where it's mostly alder trees?

Such questions lie at the heart of ecology. Every biological system, whether a cell, an organism, a forest, or a society, can replicate and does so using resources collected from its environment. Population regulation – what's living where and in what numbers – is a principal outcome of such interactions. The attempt to understand it has arguably been the organizing principle of the science of ecology.

"Almost every group in nature has some process involved in regulating its numbers," says Stanford ecologist and SFI Science Board member Deborah Gordon, who specializes in collective behavior in social insects. Some regulation models are based on centralized control or decentralized resource depletion, but scientists are finding that many systems blend the two.

In harvester ant colonies, for example, the queen doesn't tell the others what to do. Rather, the rate an ant meets others and the information they exchange determine whether the ant should keep doing what it's doing or switch to, say, foraging.

"No ant really knows how much food they have or need – that's why it's so interesting," says Gordon. "They're not all working toward a known or personal goal, yet they meet the goals of the colony."

This emerging understanding of decentralized regulation prompted Gordon and University of Utah mathematical ecologist Frederick Adler to co-organize a working group, Centralized Versus Decentralized Control in the Regulation of Populations, this month at SFI.

During the meeting, researchers who study such topics social insect colonies, cancer, and the city-states of ancient Greece explored how centralized and decentralized control mechanisms interact to regulate physiological, social, and human systems. ■

Introducing ACtioN, the Applied Complexity Network

ACtioN, for the Applied Complexity Network, offers enhanced standard membership benefits for companies, foundations, government agencies, think tanks, and nonprofits, as well as opportunities for members to engage more deeply in SFI's science through an offering of premium, customizable programs.

Standard member benefits

ACtioN topical meetings: Jointly organized by SFI and member organizations, these meetings take advantage of SFI's unique convening power to bring complexity thinking to real-world business challenges.

The Vitamin events: Vitamin A, B, and C events, named for the intellectual "nutrition" they provide, give ACtioN members access to discussions on compelling, timely topics.

- **Vitamin A (Advanced)** events, occasionally open to ACtioN members where expertise permits, provide members with access to technical workshops and working groups on specific questions in complexity science designed for the SFI research community.
- **Vitamin B (Business)** events are insight-rich discussions that immediately follow, and extend, Vitamin A scientific meetings, designed to expose ACtioN members to the latest complexity insights.
- **Vitamin C (Complexity)** events, hosted annually in Santa Fe, are our flagship ACtioN meetings exclusively for ACtioN members, SFI trustees, and SFI researchers, each centered on a compelling topic at the intersection of business and science.

Recruiting events: The SFI community gives ACtioN members a unique opportunity to connect with in-demand complexity thinkers in the early stages of their careers.

ACtioN Complexity Explorer: Curated versions of SFI's popular massive open online course (MOOC), featuring timely content from topical meetings, conferences, and interviews on a variety of topics – all exploring how complexity applies to real-world challenges.

***Vertex* newsletter:** *Vertex* keeps members up to date on the latest ideas and research from SFI, with a view to how those concepts apply to ACtioN organization and how ACtioN members are tackling business challenges.

Complexity Intelligence Reports: Brief summaries of fresh new insights from SFI workshops and working groups throughout the year. The annual Complexity Catalogue aggregates these insights.

Complex Systems Summer School: Held in Santa Fe, the Complex Systems Summer School provides students and professionals with a rigorous month-long multidisciplinary program of lectures, laboratories, discussion sessions, and team projects designed as an introduction to complex behavior in mathematical, physical, living, and social systems. Five tuition-free spots are reserved for ACtioN members on a first-come, first-served basis (with additional spots available at the regular corporate rate).

ACtioN exclusive member opportunities

ACtioN members can create bespoke programs, at an additional cost, allowing them to engage more deeply with the SFI community.

Customized ACtioN topical meetings: The same convening power and expertise as the ACtioN topical meetings, but fully customized to an ACtioN organization's challenges. Member companies select topic, location, and invite list.

The SFI Studio Retreat: Part corporate retreat and part full-time immersion, the SFI Studio Retreat gives small groups a one- to two-week SFI experience at the Cowan Campus. Ideal for leadership teams and strategic planning exercises.

ACtioN Residential Fellowships: Individual ACtioN members can spend quality time at the SFI campus participating as part of the research community.

Corporate Short Courses: Design a complexity curriculum that responds to your organization's interests and challenges, with a view to real-world applications. ■

Institute names Will Tracy as Vice President for Strategic Partnerships

SFI has selected Will Tracy as its new Vice President for Strategic Partnerships. Tracy will begin work on May 11 as VP Designate on a part-time consulting basis and, beginning July 1, will join SFI full-time as VP.

The creation of a Strategic Partnerships group signals a shift toward a greater number and diversity of collaborative partnerships with companies, universities, nonprofits, and other organizations; it combines the previous functions of Advancement (responsible for relationships with SFI's donor community) and the Applied Complexity Network (known as ACtioN, formerly the Business Network) into a new leadership role responsible for developing and maintaining all of the Institute's high-level partnerships.

"We are delighted that Will will be joining us as the new VPSP," says SFI President David Krakauer. "He is uniquely qualified for this position, having a deep familiarity with business, education, and complexity science. Furthermore, he is familiar with SFI through his engagement with our international summer schools. With Will occupying this new position, our partnerships and our Applied Complexity Network will increase in reach and relevance."

Tracy has a longstanding relationship with SFI. He took part in the Institute's Complex Systems Summer Schools in Beijing from 2004 to 2008, serving as an associate director, faculty member, assistant, and student during that time.

"SFI is one of my all-time favorite communities," says Tracy. "I am thrilled to return at this exciting moment in the Institute's history. David has laid out a bold vision for the new Strategic Partnerships group and ACtioN. Partnerships will play an increasingly important role in purposefully disseminating the insights and breakthroughs that occur at SFI. I look forward to working with David and the entire SFI community to help make this vision a reality."

Tracy comes to SFI from Rensselaer Polytechnic Institute in Troy, New York, where he is the undergraduate program director for the Lally School of Management, assistant professor of strategic management, and an affiliate faculty member of the Severino Center of Technological Entrepreneurship.

He is also a guest research faculty member of the Indian Institute of Technology in Kanpur, India; has worked for the World Bank in Washington, D.C.; and co-founded an internet advertising startup in the U.S., later establishing that firm's office in Shanghai. He holds a PhD in management with a certificate in human complex systems from UCLA's Anderson School of Management. ■

> *Krakauer* continued from page 4

others. He can't say what's in the works, yet, but stay tuned. "It won't be boring," he says.

Enhancing the conversation includes making more people more aware of the Institute's research and the insights that arise from it. Four new digital email publications are doing just that: *Vertex* (for ACtioN members), *Axiom* (for SFI trustees), *Axis* (for the education community), and *Matrix* (for SFI's extended research community). In addition, the Institute's bimonthly print newsletter, the *Update*, will continue as *Plex* and will add a monthly digital version to the mix; watch for these changes by summer.

Experiments abound. Late last year, Krakauer created the Broken Symmetry Society at SFI, which embraces Santa Fe's rich culture by actively engaging with artists, writers, poets, musicians, and other creative thinkers with compelling perspectives.

Creative, curious individuals have always looked to the Institute for inspiration and intellectual stimulation, and the Broken Symmetry Society formalizes those relationships and adds to the Institute's eclectic culture, Krakauer says. Its first informal evening get together of a half dozen artists in mid February featured a talk by Santa Fe artist James Drake.

"Broken Symmetry Society members, who we're calling 'orthogonals' for their perspectives that come from all angles, can come here and be themselves, and that's good for the intellectual environment here," he says. "We'll see where it takes us."

Inaugural orthogonal Joerael Elliott, whose background is in graffiti and public art, spent the winter at SFI creating a series of six drawings that visually interpret the Institute's scientific programs. His complexity drawings can be seen here, each with a brief description of his approach: https://slate.adobe.com/cp/qQsOj/

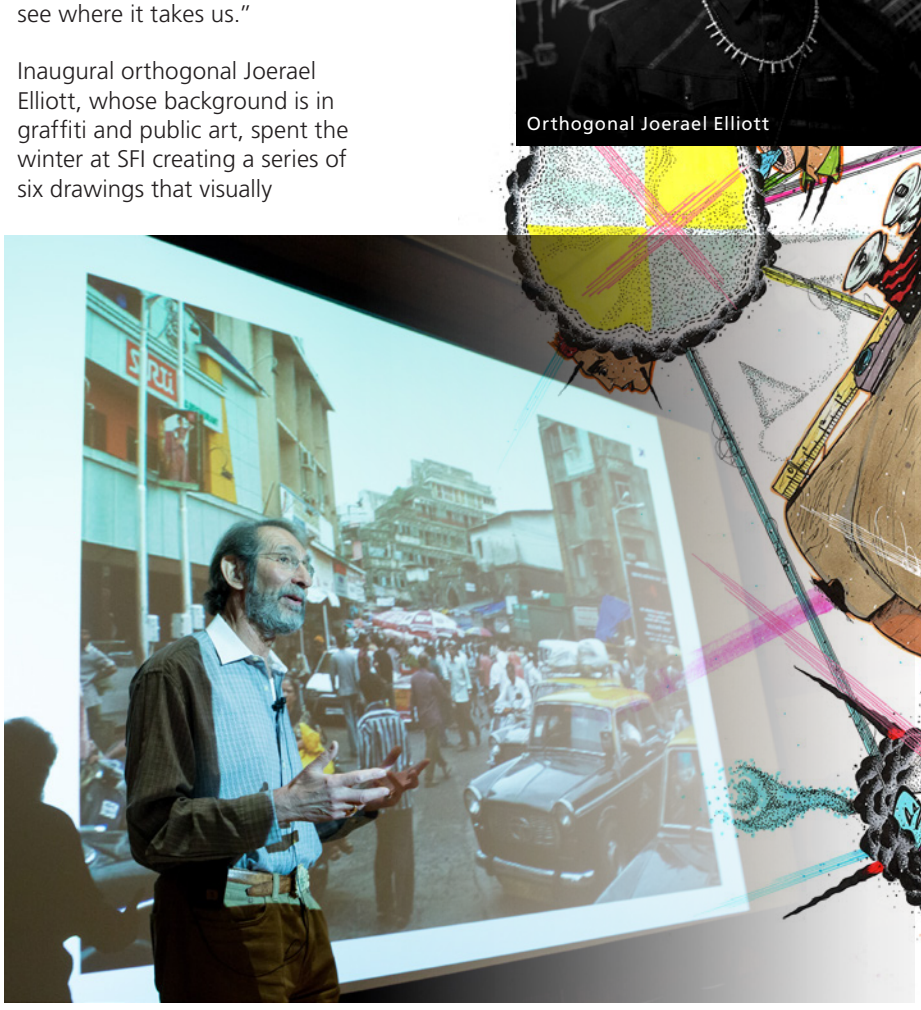
SFI Satellites, another experiment, are quarterly salon-style dinners in various cities featuring SFI supporters and their hand-picked invitees, typically in a donor's home and featuring a stimulating conversation with an Institute scientist.

SFI's education programs are experimenting too, with new executive education offerings in the works and the Complexity Explorer's massive open online courses with enhanced student interaction activities.

"An essential element of SFI has always been its ability to rigorously perform experiments on the fundamental architecture or mechanics of knowledge production," Krakauer says. "Working with the extraordinary network of SFI-affiliated minds, we are now exploring experiments at a higher energy level. And like a very high energy accelerator, we hope to discover amazing new elements of complex reality." ■

SFI VP for Science Jennifer Dunne speaks at a recent SFI meeting in Santa Fe exclusively for ACtioN members, SFI trustees, and SFI researchers – annual events now known as the Vitamin C (Complexity) events. (Image: InSightFoto)

Orthogonal Joerael Elliott



Customized short course curricula that respond to an organization's interests are among the new exclusive ACtioN member opportunities. (Image: Minesh Bacrania)

"Mental Models of Complexity" by Broken Symmetry Society member Joerael Elliott.

Aerial view of the Kibera slum, Nairobi

(Image: Kreuzschnabel, Wikimedia Commons, License: artlibre)

Making slums more disaster-resilient (and better for people)

Scientists at SFI and Arizona State University (ASU), together with Slum Dwellers International (SDI), have been selected to tackle a human development challenge: How might urban slum communities become more resilient to the effects of climate change?

In the coming decades, climate change is expected to drive more frequent extreme weather events – such as hurricanes, floods, and droughts – in many regions. Such disasters hit slum dwellers particularly hard because they exacerbate already poor access to water, health care, emergency response, and other essential services.

OpenIDEO's Amplify Program provides funding and design support for innovative human development solutions. It selected an SFI-SDI-ASU proposal from hundreds of submissions to receive support from the Global Resilience Partnership (which includes The Rockefeller Foundation and the U.S. Agency for International Development).

For many urban slums, the key to resilience may lie in a development approach called "reblocking," a process by which slum communities physically rearrange themselves to create new streets and public spaces that provide accesses to every residence and workplace, facilitating the universal introduction of modern services and giving each household an address.

The SFI-SDI-ASU team is developing an open-source digital reblocking platform that will allow slum residents to re-plan their communities with the minimum cost and disturbance. The platform allows users to map buildings, thoroughfares, and services in their communities and propose new layouts that most efficiently solve the problem of universal access.

"There are social, economic, and spatial considerations in creating a street network in a neighborhood," says SFI Professor Luís Bettencourt, who leads SFI's Neighborhoods, Slums, and Human Development project with José Lobo of ASU's School of Sustainability. "Unless you bring them all together in a single platform that everyone can use, it is very difficult to coordinate local communities, create good solutions, and collaborate with local governments. Technology and design can now help us do this much better."

"By providing a map that can be iterated to create a well-serviced neighborhood, we ensure that everyone involved is working from a common reference," says Christa Brelsford, a postdoctoral fellow of the ASU-SFI Center for Biosocial Complex Systems who has designed the Open Reblock algorithms and is helping develop the platform. ■

What can we learn from farming insects?

Farming evolved independently in humans at least nine times. The practice was among the innovations that enabled complex civilizations to develop. But we weren't the first species on the block to raise our own food: various leafcutter ants, termites, and beetles have been cultivating other organisms for millions of years.

Such analogous behavior piqued the interest of SFI External Professor Peter Peregrine, a Lawrence University anthropologist who develops datasets and tools to analyze human behavior and culture over time.

"If you can hit upon an adaptation that's a really good one, like agriculture, then you're apparently tremendously successful [as a species]," he says, pointing out that both humans and leafcutter ants live everywhere on Earth.

A "typical broad-ranging SFI conversation over lunch" some years ago uncovered farming parallels between humans and various insects, he says, enough to prompt him to propose a working group of archaeologists, entomologists, and evolutionary biologists.

The group, Convergent Evolution of Agriculture in Insects and Humans, first met in August 2014 to discuss the evolution, fundamental practices, and social effects of farming. In April the group will reconvene at SFI with empirical data on the above topic and on species' agricultural practices including managing substrates, mutations, weeds, and pests.

Leafcutter ants and fungus garden.

(Image: Alex Wild, alexanderwild.com)

Other compelling topics may also be explored. (An intriguing social note: human health is known to have declined as agriculture arose – might insects have faced similar impacts?)

Not surprisingly, comparing impacts of agriculture on or between insect species is markedly tricky. "For humans, we have a record of the way things were before agriculture and how it looks afterward," Peregrine says. "Agriculture in ants is 50 million years old." Despite the paucity of before-and-after pictures of farming insects, their success (often with mono-crops) might offer insights into how to improve our own techniques.

This working group is funded in part by the ASU-SFI Center for Biosocial Complex Systems. ■

To make sense of a mountain of food web data, give it a jolt of math

Interest in food webs, the networks of who eats whom in an ecosystem, has exploded in recent years, and it is beginning to bring with it a mountain of data – so much data, in fact, that ecologists can now ask not just how food webs are structured, but also how those structures depend on sample size, physical location, climate, or other characteristics of the habitat.

In theory, they can answer those questions. The trouble, says SFI Omidyar Fellow Joshua Grochow, is that most scientists don't really have the right mathematical tools to answer them rigorously, a problem that he, SFI Vice President for Science Jennifer Dunne, and colleagues are addressing during a March working group.

"The datasets of food webs really cry out for better analysis, to do comparison and interpolation," Grochow says, to see how food webs' structures depend on something as simple as latitude or something more complex, such as the introduction of parasites.

Right now, network science offers only somewhat crude and ad hoc ways to answer questions like that, largely because it offers mostly simple measures of food web structure – for example, the number of species each organism eats, how many feeding links away each animal is from primary producers, and how many species are omnivores, cannibals, or herbivores.

"It turns out that rigorous comparison of network structure across datasets is a very challenging, non-straightforward, problem," Dunne says. Grochow and Dunne hope to develop more sophisticated analysis approaches.

One idea is to compare the frequency of different sized motifs – smaller structures that show up repeatedly within a larger network – across different food webs, though that's just one possibility; analysis has been done of three-node motifs in food webs, but not larger motif sets.

By bringing together rich databases from ecology and rigorous new thinking from computer science, Grochow and Dunne say, they will be better prepared to search for general patterns in food webs as well as the underlying mechanisms that drive observed ecological organization. ■

Art, science, and data representation

"It's not your standard SFI science meeting," says Jennifer Dunne, SFI's VP for Science, who is co-organizing a four-day working group in March, Ecological Data Dramatization for Art and Science, with David Stout, Professor of Composition Studies and Coordinator for the Initiative for Advanced Research in Technology and the Arts (iARTA) at the University of North Texas.

Stout and four other new media artists, composers, and artist-programmers will join ecologists Dunne and SFI Omidyar Fellow Andrew Berdahl for an SFI-style exploration of the intersection of art, science, and technology.

Dunne says the group will investigate opportunities for visualizing and "sonifying" simple to complex ecological data and dynamical algorithms for a variety of purposes, including generating new art forms and creating new ways to visualize empirical and model data streams that are helpful in a scientific context.

Part of the meeting is meant to be pragmatic, focusing on exploring cutting-edge approaches and technologies for both artistic and scientific goals. But much of the meeting will entail freewheeling conversation about what art, science, and technology bring to the table and how they are similar and different.

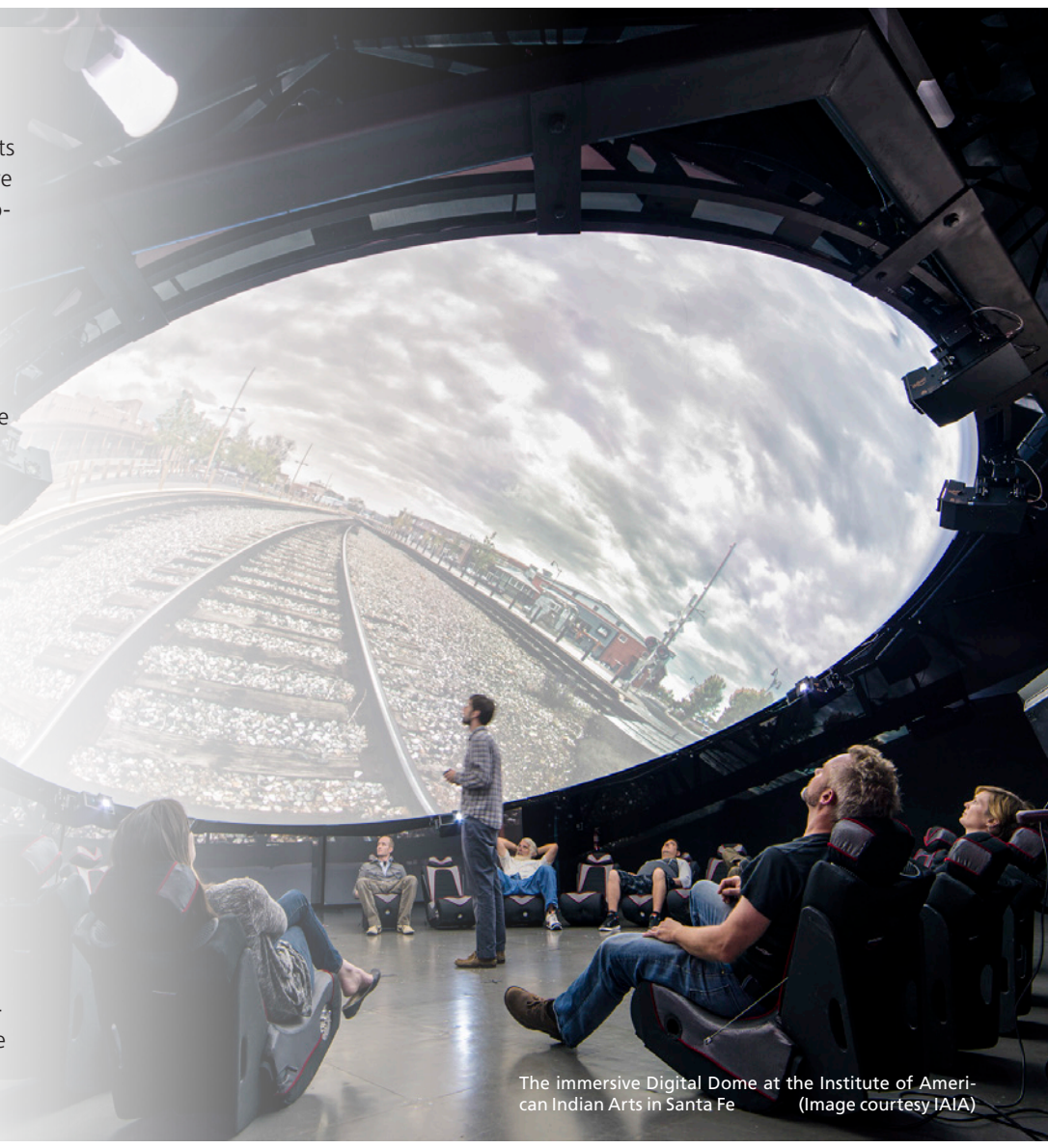
On the meeting's second day, participants will take a field trip to explore the new Digital Dome at the Institute of American Indian Arts in Santa Fe. The Digital Dome is an immersive video projection environment used for audio-visual storytelling.

The working group's members will see what the Digital Dome has to offer by way of aesthetics and creative information technology, particularly how advanced visualization and audio display technologies can foster the formulation of new ways of engaging with ecological concepts, data, and dynamics.

Dunne foresees interesting issues arising around different scales of representation. In the ecological sense, this could mean working with data on individual animals or plants that allow insight into collective behavior of populations (migration dynamics of a herd of caribou, for example, one of the species Berdahl is studying), or how populations of different kinds of organisms interact, which gets into the complex food web structures and dynamics Dunne studies.

The artists will have their own thoughts about what makes a particular type or level of representation interesting.

"Overall, there's a very creative, playful character to what we'll be talking about," Dunne says. "That's something at the heart of both art and science: creativity and the creative process." ■



The immersive Digital Dome at the Institute of American Indian Arts in Santa Fe (Image courtesy IAIA)

Artemy Kolchinsky: How expensive is information processing?

Prior to his recent appointment as a postdoctoral fellow at SFI, Artemy Kolchinsky worked with EEG and functional MRI data, looking at how highly integrated the brain is on different scales.

He says he has always been fascinated by the relationship between complexity and cognition. "The brain is the archetypal complex system," says Kolchinsky, who hopes to use novel mathematical techniques to understand ever-increasing amounts of brain imaging data.

While at SFI, Kolchinsky is working with SFI Professor David Wolpert on several projects related to optimal use of information and prediction. One is the problem of modeling and analyzing complicated dynamical systems that require large amounts of time and computational power to simulate. An example would be the propagation of disturbances and blackouts on an electrical grid. Their question: Given such a system, how can we find a compression of it that still gives us good predictions but is much cheaper to run?

Another project investigates connections between information processing and statistical physics. A longstanding notion is that to perform a computation, a minimum amount of energy is required. "David demonstrated that the amount of entropy dissipated can depend not only on the function, but what you expect the inputs to be," says Kolchinsky. "There is a certain thermodynamic cost to making the wrong predictions." The researchers are working toward generalizing and extending these results.

Finally, the two are beginning to work on understanding why different social groups develop different organizations, whether the group is a prehistoric tribe or a business firm. Here again appears the idea that information processing is a costly resource. Some types of organizations appear to use this resource to coordinate group activity more efficiently than others.

Prior to joining SFI, Kolchinsky received a PhD in informatics (with focuses on complex systems and cognitive science) from Indiana University. ■

> *Bluebird's conundrum* continued from page 1

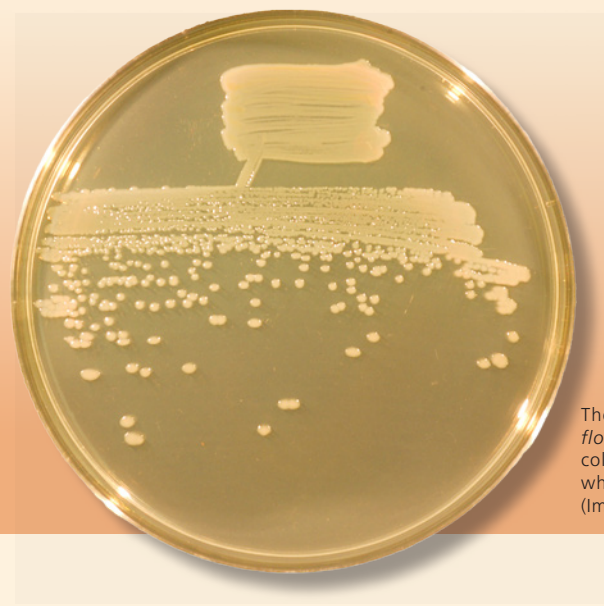
Behavioral ecologists usually expect to see helping behavior dominantly in monogamous populations with low EPP, where the helper is guaranteed a close genetic relationship to his younger siblings. However, the additional factors of age bias and longevity change the formula for bluebirds.

"If you have this combination of an age bias – such that young males are not likely to sire offspring in another male's nest but old males are – and if helpers and their parents have a survival advantage, you can get this evolution of helping behavior even in systems with high rates of EPP," says Stern.

The behavioral ecology literature is beginning to acknowledge the importance of considering a species' full life history when studying behaviors, says Stern. "Our study is a case-in-point for the need to do this," she says.

"An individual's fitness accumulates over its lifespan, and we need to take that into account when we're looking at the evolution of behavior." ■

Female and male bluebirds (Image: David Moldoff)



The bacterium *Pseudomonas flourescens* streaked to single colonies and visualized under white light. (Image: Wikimedia Commons)

Switching states a winning strategy for multicellular life

Environmental triggers may have tipped the transition from single- to multi-cellular life, according to an *Evolutionary Ecology* study by former SFI REU Emma Wolinsky and SFI Omidyar Fellow Eric Libby. The researchers simulated three evolutionary strategies that could have coordinated growth and reproduction across multiple cells of *Pseudomonas fluorescens* bacteria in a changing environment. The best strategy for multicellularity proved to be an epigenetic, external sensing scheme wherein a cell's DNA switches its phenotypic expression in response to cues from the external environment.

How organisms adapt to their own adaptations

A new paper by SFI External Professor Juan Pérez-Mercader and colleague Matthew Egbert addresses the puzzle of how organisms regulate and respond to their own adaptations. In *Nature Scientific Reports*, the researchers published a computational model demonstrating that "interoceptive" mechanisms, which regulate according to cues within the organism, outperform "exteroceptive" mechanisms that take their cues from the environment alone. The work could influence theories of how early life evolved and "could prove useful in the effort to create more robust synthetic life forms."

Scale independence, at minimum

Scale independence is a ubiquitous feature of complex systems, from protein networks to financial markets. In *Physical Review E,* SFI Postdoctoral Fellow Laurent Hébert-Dufresne and colleagues identify two dynamical properties that must both be present in order for scale-independence to evolve in networks. They validated their minimalistic model using data from "diverse spheres of human activities ranging from scientific and artistic productivity to sexual relations and online traffic."

Why and how far hunter-gatherer groups migrate

Hunter-gathers around the world often migrate when food resources become scarce. Just how far and how often they move varies widely. A new model developed by several SFI-affiliated researchers – Marcus Hamilton, Eric Rupley, Hyejin Youn, Geoffrey West, and Jose Lobo – explains and predicts the variation in observed residential mobility by understanding the evolved biomechanics of humans and the available energy in their particular ecosystems. Their study was published February 1 in *Complexity Digest.* ■

RESEARCH NEWS

Report to POTUS: Now's the time to promote urban innovation

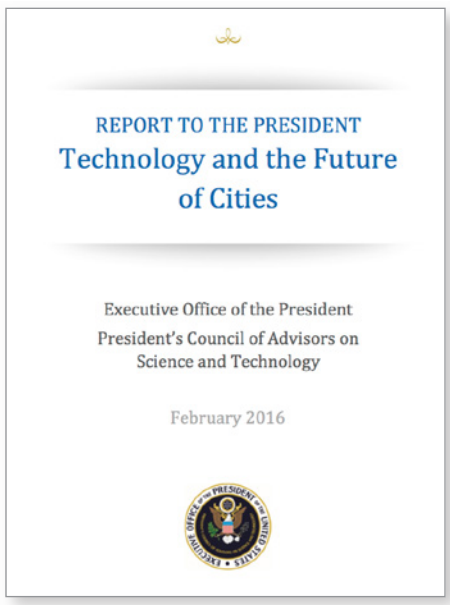
The newly-released report to the President of the United States, Technology and the Future of Cities, makes concrete policy recommendations for promoting innovation and improving lives, drawing from SFI research and insights about cities and urbanization.

A group of experts, including SFI Professor Luís Bettencourt, contributed to the report, which was issued by the President's Council of Advisors on Science and Technology (PCAST).

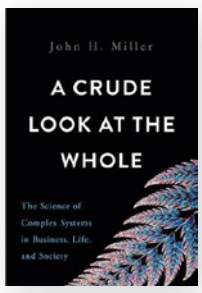
Says Bettencourt: "The main societal challenges we face today are urban and must be addressed in cities. We tried to provide a map for how the powerful integration of systemic urban science, a number of emerging new technologies, and action by city governments and other stakeholders is now poised to make a big difference. I hope PCAST's proposals for how the federal government can be a critical enabler of these processes can become a model for future integrated urban policy."

The report notes that with Big Data collection and analytics and a better understanding of urban dynamics than ever before, the time is right to promote technological innovation in cities. It makes a variety of recommendations for the federal government to engage with cities through place-based policy. And it suggests ways for individual cities to collect and share data to further innovation.

Read the full report at whitehouse.gov. ■



BOOKS BY SFI AUTHORS



A Crude Look at the Whole: The Science of Complex Systems in Business, Life, and Society (Basic Books, 2016) by SFI External Professor John H. Miller calls for a revolution in scientific perspective – from the reductionist, fragmented study of individual parts to a generalized, theoretic look at dynamical systems. This "crude look," a reference to a quote from Murray Gell-Mann, may be the only way to understand emergent patterns that link beehives to stock markets or cities to heartbeats, and otherwise tackle intractably complex problems. ■

SFI Online

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

Video: Los Alamos's Karissa Sanbonmatsu explores epigenetics and its implications for autism, addiction, depression, Alzheimer's, and even love. SFI Community Lecture

Video: A recent SFI paper finds an underlying structure uniting human languages, at least for universal core concepts. Quartz magazine animated video short

Audio: SFI External Professor Brian Arthur explains the principles and history of the SFI-inspired El Farol bar problem. Relatively Prime podcast

Video: Economics Nobel laureate Daniel Kahneman discusses with SFI Board of Trustees Chairman Michael Mauboussin why noncausal, statistical models routinely outperform intuition. SFI Business Network interview

Video: Neurophilosopher Patricia Churchland explores how the latest research into consciousness, memory, and free will can help us reexamine identity and other enduring philosophical, ethical, and spiritual questions. SFI Community Lecture

RESEARCH NEWS

Asking why pertussis is back, SFI style

Pertussis (better known as whooping cough) has made a comeback in recent years in the United States, but understanding its reemergence and global prevalence isn't a simple matter. A swath of researchers, diverse even by SFI standards, will converge to address pertussis and other reemerging infectious diseases at a workshop beginning March 21.

"It's going to be a full house," says workshop organizer and former SFI Omidyar Fellow Sam Scarpino. He and his fellow researchers will try to tackle one of the more peculiar aspects of pertussis: In some parts of the world, the disease is on the rise, while in others, it's in decline. Globally, Scarpino says, "it's not clear how one accounts for all this data."

There are plenty of hypotheses, including the possibility that pertussis evolved in a way that makes the current vaccine ineffective, or perhaps, as Scarpino and fellow former SFI Omidyar Fellow Ben Althouse recently proposed, it's because the vaccine allows the disease to spread even when people don't develop symptoms, such as the persistent coughing fits most commonly associated with the bacteria.

But, Scarpino says, "We're not looking for one mechanism. We're looking for how they work together in concert," he says. Most likely, researchers will have to look at many mechanisms and their interactions – a classic complex system challenge, making SFI an ideal place to hold the workshop, he says.

Scarpino and his fellow co-organizers, including Aaron King (University of Michigan), have invited mathematicians, public health experts, ecologists, biologists, geneticists, and even computer scientists, many of them from outside the U.S., and some who haven't studied pertussis before. Their outside perspectives, Scarpino says, could help everyone come to a better understanding of the disease.

For fresh insights, "I think you have to have all those people in the room," Scarpino says.

The broader purpose of the workshop, Scarpino says, is to understand how the various facets of infectious disease, from infection dynamics to the evolution of pathogens, work together and result – or don't result – in outbreaks. "Pertussis is how we're trying to focus that question," Scarpino says.

This working group is funded in part by the ASU-SFI Center for Biosocial Complex Systems. ■

> ***Hard modularity*** **continued from page 1**

I spend on reinforcing the opinion of my friends versus trying to convince strangers or opponents? Should my strategy differ based on the strategies of my opponents?

Surprising observations emerged. Aggressive strategies with no chance of winning, for example, affected a game's outcome by conferring more power to a different, otherwise unsuccessful strategy. Hébert-Dufresne compares this observation to the U.S. presidential campaign of Donald Trump, whose aggressive approach may steer the vote toward middle-ground candidates. (The meeting concluded just before the first Republican primary.)

Their approach is general enough to be relevant to a range of networks, from parasite transmission to marketing, but there remain questions Hébert-Dufresne would like to answer. "How extreme must a strategy be to completely change a game?" he asks. "Or to have no impact at all?" ■

Upcoming community events

SFI Community Lecture, Tuesday, April 12, 7:30 p.m., The Lensic Performing Arts Center (211 W. San Francisco Street) — Emerging Diseases, Deadly Lessons. It has been more than two years since confirmation of the Ebola hemorrhagic fever outbreak in West Africa. Now, with the end of the outbreak in sight, we have a once-in-a-lifetime opportunity to learn from the experience. The global impact of that epidemic, and recent outbreaks of SARS and influenza, offer critical insights on preventing future such crises. Mathematical biologist Carlos Castillo-Chavez illustrates the crucial role ecological, social, political, and economic factors play in the spread of devastating diseases and their implications for preventing future epidemics. This talk will be presented in both English and Spanish.

Carlos Castillo-Chavez is an SFI external professor and a Regents Professor and professor of mathematical biology at Arizona State University. He has co-authored more than 200 scholarly publications. He is a member of the Board of Higher Education at the National Academy of Sciences and serves on President Barack Obama's Committee on the National Medal of Science.

SFI's 2016 Community Lectures are made possible through the generous underwriting of Thornburg Investment Management, with additional support from The Lensic Performing Arts Center. 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.

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UPDATE
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