SANTA FE INSTITUTE

May / June 2015

UPDATE

Species' evolutionary choice: Disperse or adapt?

Dispersal and adaptation are two fundamental evolutionary strategies available to species given an environment. Generalists, like dandelions, send their offspring far and wide. Specialists, like alpine flowers, adapt to the conditions of a particular high altitude hillside.

Ecologists have typically modeled these two strategies, and the selective pressures that trigger them, by holding one strategy fixed and watching how the other evolves. New research published recently in the journal *Evolution* illustrates the dramatic interplay during the co-evolution of dispersal and adaptation strategies.

"This model helps us gain intuition for situations where multiple, interacting traits are evolving simultaneously," says SFI Omidyar Fellow Andrew Berdahl, who co-authored the paper with SFI Science Board member Simon Levin and collaborators Colin Torney and Emmanuel Shertzer.

Their model shows how even minor

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RESEARCH NEWS

2015 SFI Science Board symposium samples new ideas

Participants in SFI's 2015 Science Board symposium May 1 in Santa Fe are getting a whirlwind tour of the research of nearly a dozen new Institute professors and postdocs who have recently joined SFI. They're also hearing from four researchers whose work could prompt new ideas, and maybe new research directions, for SFI.

"Given how many resident researchers we've added recently, the May meeting is the perfect way to introduce them and their work to our broader community, including our Science Board members, some of whom were involved in the selection of the new faculty and postdocs," says Jennifer Dunne, SFI's VP for Science, who is co-organizing the event with SFI President Jerry Sabloff and Science Board co-chairs Mimi Koehl and Dan Stein.

Three new SFI professors will talk: Mirta Galesic, SFI's Cowan Chair in Human Social Dynamics who joined the Institute in January 2015, describes her exploration of how interaction of mind and environment shapes social judgments. Sid Redner, who joined SFI in July 2014, takes a look at a variety of complex systems from a physicist's perspective. And David Wolpert, who joined SFI in September 2013, discusses the thermodynamic cost of Markov chains.

Eight SFI Omidyar Fellows and Postdoctoral Fellows will give brief "lightning talks" about their research.

Guest speakers include: Christine Cassel, president and CEO, National Quality Forum, "The science of measuring quality and value in health care"; Robert Full, professor of integrative biology, UC Berkeley, "Morphological computation in complex environments: Leaping lizards, crashing cockroaches, and running robots"; Olaf Sporns, distinguished professor, psychological and brain sciences, Indiana University, "Complex systems and the brain"; and Ramanan Laxminarayan, director and senior fellow, Center for Disease Dynamics, Economics, & Policy, Public Health Foundation of India, "Transboundary problems in infectious diseases." ■

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PEOPLE

SFI selects four Omidyar Fellows

Four researchers have been selected for Omidyar Postdoctoral Fellowships and will join SFI's community this fall.

A gift from eBay Founder Pierre Omidyar and Pam Omidyar in 2008 established the Fellowship, which brings to SFI early-career scholars from the social, physical, and natural sciences. Omidyar Fellows spend up to three years delving into the major questions facing science and society in SFI's transdisciplinary, collaborative environment.

Each year, SFI selects one to six Omidyar Fellows from an applicant field of more than 200. The goal is to maintain a continuous cohort of 12 fellows. The 2015 Omidyar Fellows are:

Marion Dumas comes to SFI from Columbia University with a PhD in sustainable development. Her research centers on social structures and behaviors, and she seeks to understand how

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RESEARCH NEWS

Dipping into the well of higher math

"When mathematics and computer science come together, great stuff happens," says SFI Professor Cris Moore. He and Omidyar Fellow Josh Grochow are creating a test tube for such a combination in their May working group, "Algebra, Geometry, Pseudorandomness, and Complexity."

So far, computer science has relied mostly on relatively simple mathematics based in counting, such as graph theory and combinatorics. Recently, though, more abstract forms of math – group theory, algebraic geometry, and Fourier analysis, for example – have become important tools.

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SFI IN THE NEWS

A cover article published April 13 in *American Scientist*, co-authored by SFI Omidyar Fellow Justin Yeakel and VP for Science Jennifer Dunne, shows how recent studies of ancient and modern ecosystems suggest that food webs all share surprising structural attributes. The authors note that when redundancy in a food web is lost due to the loss of species and the roles they play in the ecosystem, the threat of additional extinctions grows.

SFI's Geoffrey West is quoted in an April 3 BBC Future article on the perils of feckless urban planning.

Fortune and *Time* magazines on April 2 featured recent research by SFI's Marcus Hamilton, Madeleine Daepp, Geoffrey West, and Luis Bettencourt finding that publicly-traded firms die at the same rate regardless of their age or economic sector.

SFI Professor Sam Bowles's "guard labor" paper figures into a March 10 article in *The Guardian* on why governments spy on their citizenries.

SFI's Andreas Wagner takes an evolutionary perspective on Platonic forms in the March 16 issue of *Aeon* magazine.

An article in the February 27 *Albuquerque Journal* on the SFI-led Computer Science for All program quotes SFI CS4All Program Manager Maureen Psaila-Dombrowski and External Professor Melanie Moses.

ACHIEVEMENTS

SFI External Professor Aaron Clauset (University of Colorado Boulder), a former SFI Omidyar Fellow, has received the NSF's prestigious Early Career Development (CAREER) award, which honors junior faculty who exemplify the role of teacher-scholars through their integration of education and research.

SFI Postdoctoral Fellow Markus Schläpfer and his collaborators have won the $5,000 First Prize and Energy Prize in the Data for Development Senegal Challenge for their proposal to use cell phone data from Senegalese mobile networks to help plan Senegal's future electrical infrastructure.

SFI Omidyar Fellow Ben Althouse has joined the Institute for Disease Modeling in Bellevue, Washington as a research scientist. He will be working on disease transmission models and vaccination programs for developed and developing countries, among other research. He continues to collaborate with SFI researchers.

Nonlinearities

From the editor

After launching a bunch of ants into orbit as part of an International Space Station experiment of how microgravity affects ant behavior, SFI Science Board member Deborah Gordon and her collaborators have launched a "citizen science for students" project. Essentially it's a lesson plan for high school teachers and their students and an online forum for gathering and discussing the data. After collecting the ubiquitous little creatures, students study how they work together to find food. The larger goal is to understand some of the collective search strategies that Earth's 14,000-plus ant species have evolved in diverse environments. It's the latest in an impressive run of ant-related education outreach by Gordon and her team. More at http://stanford.io/1Ipkkj5.

Last year, as SFI's leadership was putting down some revised operating principles, someone asked Pulitzer Prize-winning author and SFI trustee Cormac McCarthy to deliver us from this boardroom tragedy and "translate that into English." He was gracious enough to do so. His typed document is complete with strike-throughs and a couple of pencil edits, which we've reproduced on the inside front cover of our *2014 Annual Report*, now available online at www.santafe.edu. More recently SFI External Professor John Miller asked Cormac to read his SFI operating principles on camera. See the video at www.santafe.edu/mysfi. Like Cormac, it's one of a kind.

The 2014 Global Think Tank Report out of the University of Pennsylvania places SFI 20th among the world's "Top Science and Technology Think Tanks." Scholars, journalists, government officials, and donors participated in the nomination and ranking process. SFI isn't a think tank in the traditional policy-analysis sense, but we do appreciate the write-in vote.

Last issue I wrote about the mysterious Betsy Jones, the artist credited in early SFI volumes with drawing our Mimbres logo. Thanks to everyone who phoned and emailed with leads. Unfortunately, none of them panned out, but I did have delightful conversations with a couple of Betsy Joneses. The search goes on. Maybe ants can help. ■

– 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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RESEARCH NEWS

Why populations rise and fall in unison

In the 1870s, US prairie skies swelled with Rocky Mountain locusts. In its greatest swarms, trillions of insects denuded acres of farmland each minute as they swept from Texas to Colorado. Some decades later, the first recorded H1N1 flu pandemic, the Spanish Flu, arose near the end of the First World War, killing some five percent of the world's people.

During epidemics and insect outbreaks, and many other ecological processes, local oscillations in species population numbers have been known to synchronize over large geographic regions. Such extraordinary, widespread explosions and crashes in numbers were long thought to be an effect of a subpopulation's geographic range, and any concurrent rises or falls among other subpopulations were often attributed to large-scale environmental conditions, such as a continent-wide drought, that spanned the range of the species.

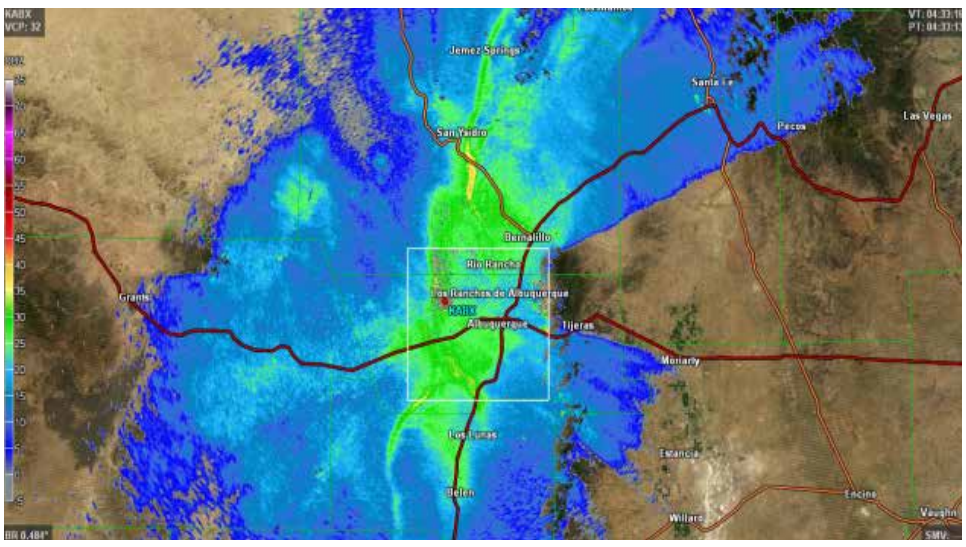
Recently, though, researchers have modeled ecological systems where long-range synchrony can emerge amid fluctuating subpopulations.

The phenomenon is well known in physics – such as when magnetic moments of electrons align, forming permanent magnets. But in physics, systems behave according to well-known laws. Ecology is quite a bit messier.

"The quality of data is often laughably poor," says theoretical ecologist Alan Hastings of UC Davis, and ecological data sets are typically noisy and spatially small compared to the tens of thousands of data points measured in material science studies.

Despite the challenge, detecting synchrony in biology is worthwhile, he says. A species is robust when its pockets of populations grow and shrink independently, but it can become significantly more vulnerable when all population levels are low – and a single event can trigger a collapse.

Hastings, SFI External Professor Jonathan Machta (UMass Amherst), and Andrew Noble (UC Davis) have organized a working group in mid-May to explore variations, measures, and early indicators of synchrony in ecology. The meeting is supported by the NSF's new INSPIRE grant program. ■



This swarm of grasshoppers surrounding Albuquerque, New Mexico, part of a region-wide summer 2014 infestation, showed up on Doppler radar. (Image: National Weather Service)

> *Higher math* continued from page 1

But Moore and Grochow believe computer scientists have barely scratched the surface of what higher math has to offer their field.

One example is in imitating randomness. Many computer science techniques use randomness to increase efficiency. An everyday use is how the Nielsen Ratings count television viewers. It would be difficult and time-consuming to track every viewer, so Nielsen randomly selects a smaller number of families, tracks their habits, and then extrapolates the results to everyone.

In a computer, though, everything is deterministic, so truly random numbers can't be found. Instead, computer scientists settle for "pseudorandom numbers," which are generated by some deterministic method so they're not truly random at all and hence have subtle patterns. But if those patterns aren't relevant for the task at hand, they can work as well as, or better than, truly random ones.

Because math is ultimately the study of patterns, it can be useful in generating pseudorandom numbers whose patterns are unproblematic for a particular task.

"I am of the personal belief that to resolve the big questions in computational complexity theory," Grochow says, "we are going to need some of these higher mathematical tools, and even some that haven't been invented yet." ■

RESEARCH NEWS

Working groups: Info machines and networked networks

SFI External Professors Jim Crutchfield and Raissa D'Souza are coordinating a pair of working groups in late June that tackle questions at very different scales.

In "Control of Interdependent Networks," invited researchers will consider interconnected networks and networks of networks. Participating experts range from nanodevice and power grid engineers to social network experimentalists. They will explore the behaviors of various heterogeneous networks and how they interconnect, evolve, and depend on one another.

Just as crucially, the group will be asking how and where to best control them. "Time and again we're caught off-guard by network failures, often because we're unaware of the instabilities we inadvertently cause by coupling different networks together," says Crutchfield, who focuses on information storage and processing in networks. "The working group's task is to come up with control schemes to tamp down these instabilities."

The tandem meeting, "Information Engines: Computing and Communication on the Nanoscale," brings together theorists and experimentalists in nanodevices, biochemistry, nonequilibrium thermodynamics, and information theory.

Taking cues from the exquisite little machines of the biological universe – cells – and how elegantly they manipulate energy and information, Crutchfield and his team are working on ways to harvest heat – disorganized energy – and transform it into useful, organized energy.

At first blush, this seems to violate the Second Law of Thermodynamics. The catch, however, is that the Second Law holds true only on average at the cellular, nanoscale level.

"If it's true only every once in a while," Crutchfield muses, "then we should be able to design sufficiently smart molecules that occasionally violate it. If so, you can grab that energy and use it."

Crutchfield and his experimental team members have already begun the process of marrying computing to nonequilibrium thermodynamics by designing smart, energy-harvesting mechanical nanodevices.

"If we're right," he says, "basic principles of information processing on the nanoscale will apply across all scales, including human-designed networked networks." ■

RESEARCH NEWS

Research finds patterns in the life and death of companies

It's a simple enough question: How long does a typical business have to live? Economists have been thinking about that one for decades without a particularly clear answer, but new research by SFI scientists reveals a surprising insight: publicly-traded firms die at the same rate regardless of their age or economic sector.

Companies come and go for a variety of reasons. Some are bought, some merge with others, and some go out of business completely. There's no shortage of theories about why.

"The theory of the firm – there are whole books," says Marcus Hamilton, an SFI postdoctoral fellow and corresponding author of a new paper published in the Royal Society journal *Interface*. Despite that, he says, "there is remarkably little quantitative work" on what economists call company mortality, and existing theory and evidence yield contradictory answers. Some researchers think younger companies are more likely to die than older ones, while others think the opposite.

"We wanted to see if there was any kind of standard behavior or if it was just random," Hamilton says.

Hamilton, SFI Distinguished Professor Geoffrey West, and SFI Professor Luis Bettencourt asked Madeleine Daepp, then an undergraduate fellow at SFI and first author of the new paper, to take the lead. "We gave her this basic idea, and she did the heavy lifting," Hamilton says.

The heavy lifting, Hamilton explains, was going through Standard and Poor's Compustat, an expansive database of information on publicly-traded companies dating back to 1950. Using a statistical technique called survival analysis, Daepp and her mentors discovered something no one had predicted: A firm's mortality rate – its risk of dying in, say, the next year – has nothing to do with how long it had already been in business or what kinds of commodities it produced.

"It doesn't matter if you're selling bananas, airplanes, or whatever," Hamilton says – the mortality rate is the same. Though the number, of course, varies from firm to firm, the team estimated that the typical company lasts about ten years before it's bought out, merges, or gets liquidated."The next question is, why might that be?" Hamilton says. The new paper largely avoids engaging with any particular economic model, though the researchers have some hypotheses inspired by ecological systems, where plants and animals have their own internal dynamics but must also compete for scarce resources – just like businesses do. ■

RESEARCH NEWS

Paper: Confirmation of geometry's least-packable shapes

If you've ever struggled to pack a bunch of suitcases into the trunk of your car, you've got some idea of a basic problem in materials science: If you put a bunch of atoms or molecules together, how do they fit together, and how densely can they be packed?

In a recent paper, SFI Omidyar Fellow Yoav Kallus takes a small but significant step toward answering those questions while at the same time addressing an old conjecture about what packs least well.

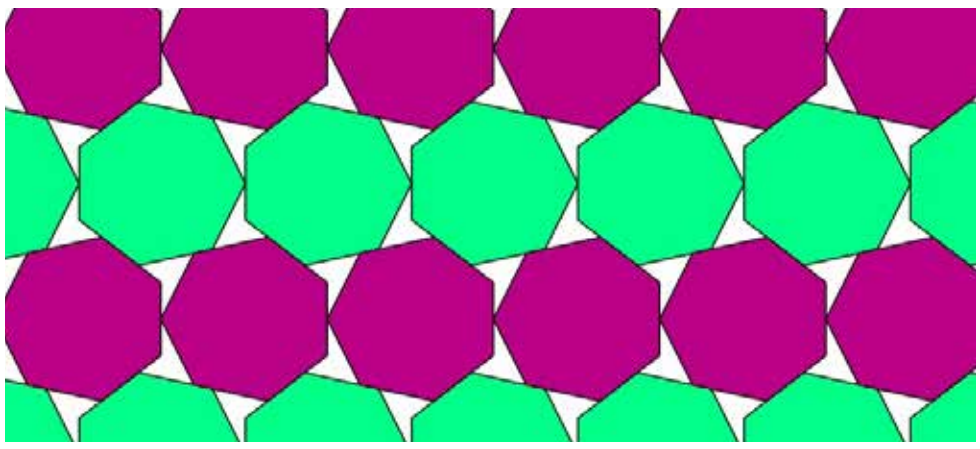
Kallus's results concern an area of mathematics known as packing problems, which range from easy ones like which shapes pack the tightest – answer: rectangular boxes – to profoundly more difficult problems. In the latter category is finding which objects pack the loosest.

For three dimensions, mathematician Stanislaw Ulam is said to have conjectured that when packed as tightly as possible, spheres leave more empty space between them than any other object, or at least any other object that has no dimples or caves on its surface.

While that remains a conjecture, Kallus shows in a paper published February 27 in the journal *Geometry & Topology* that nearly spherical objects fit together more closely than true spheres – lending new support to Ulam's idea – in three dimensions, that is. In two dimensions, Kallus says, "the natural first guess is the circle," but many shapes outdo circles. Octagons with rounded corners leave just under ten percent of the available space empty when packed as tightly as possible. Heptagons are a bit worse-fitting still, but, Kallus shows, no corner-rounding can make them even worse.

The question remains, Kallus says, "given a particular shape, can you predict its densest packing?"

Given the immense technical difficulties involved, researchers may be forced to forego rigorous mathematics in favor of computational approaches, but it may be possible to use those methods to rule out many options for the title of least-packable suitcase. ■



Heptagon packing **(Image: Yoav Kallus)**

RESEARCH NEWS

Better macrohistory through macrodata

Anthropologists and archaeologists have been doing macrohistory – the study of long-term historical processes – for ages. But macrohistorical analysis, the use of quantitative data and mathematical modeling to study long-term cultural evolutionary and historical processes, is but a decade old.

That's why SFI External Professor Peter Peregrine, who teaches anthropology at Lawrence University, wanted to host a May working group at SFI to get macrohistorians' heads around the vast quantities of data available today.

"We want to sit down with the people of SESHAT [a global history database project sponsored by the Florida-based Evolution Institute] and the Templeton Foundation and other macrohistory people and see if we can come up with a protocol to integrate large sets of data – so that we don't have to keep recreating the same data sets," he says. "Our main question is: How can we create something so people can access and employ it?"

Peregrine hopes he and his fellow macrohistory researchers can come up with a common framework for accessing all knowledge about past societies, which has not only been pretty much inaccessible to scientific analysis but inaccessible to other researchers as well – be they historians, anthropologists, sociologists, or economists.

And in line with SFI's ethos, using macrohistorical analysis to determine whether there are universal features shared by all complex societies isn't all that different from the various ways used to study physical and biological complex systems.

"These sorts of complex data sets are common – they have similar properties whether they're biological, physical, or cultural," says Peregrine. "And if we can apply this analysis to history and culture, it might be very transferable to other disciplines." ■

RESEARCH NEWS

Studying genes and language together

When a bacteria colony swells beyond a certain size, its organisms band together to produce a protective biofilm. They sense their number via chemical signaling, a simple and clear communication system that has changed little over eons.

Elsewhere on the tree of life, humans entertain a bewilderingly capricious attitude toward their communication system. Our languages grow, morph, move, dominate, and even disappear. Why all the bother? Surely if a language was hard-wired into our genes, we'd be born understanding one another and could move on to bigger things. Why is language, this cornerstone of human community, so malleable, so difficult to learn, and culturally (rather than genetically) transmitted?

These and other questions fuel an ongoing discussion between SFI Professor Tanmoy Bhattacharya, who leads SFI's linguistics program, and SFI External Professor Steve Lansing.

Bhattacharya and colleagues recently published a study on how sounds in language change. They are now researching the selective forces driving meaning change: among them the advantages of identity (setting English speakers apart from, say, French speakers) and safety (only the members of your in-group understand one another in risky circumstances where trust and cooperation are paramount for survival).

Lansing, an anthropologist and field linguist, co-directs the Singaporean Institute for Complexity Sciences at Nanyang Technological University. Some of his recent work correlates languages and mitochondrial DNA, showing how language is largely passed from mother to child but subject to social structures. This shared mechanism of matrilineal information flow raises the question: If populations of both humans and words develop similarly, should genes and language flows be studied together?

To explore that possibility, the researchers have organized a working group, SFI's first collaboration with the new Singaporean institute. For three days in late May, invited specialists in historical linguistics, genetics, and bacterial signaling will meet to discuss the co-evolution of social structure and communication in different genotypes, explore frameworks for thinking about the problem, and consider the best investigative and analytical tools for the job. ■

> *Disperse or adapt*

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changes in an environment can create feedback and trigger dramatic shifts in evolutionary strategy.

On a homogenous landscape, like a prairie or desert, dispersal is typically the favored strategy because offspring are likely to encounter a similar habitat wherever they go, the researchers show. Conversely, highly diverse, heterogeneous environments like mountainsides favor specialization because dispersing species have a lower probability of settling on an already suitable habitat.

A highly dispersing generalist species will continue to scatter even as environmental heterogeneity increases, but only to a point; at a certain threshold, patterns within a population shift to favor a number of rarely dispersing, specialist lineages, each adapted to a specific habitat.

Once a generalist population starts to specialize, the resulting drop in dispersal induces further pressure to specialize. This positive feedback loop between reduced dispersal and local adaptation often triggers a dramatic shift in the evolved strategies and creates a relative point of no return.

The researchers' conclusions have important implications.

"Environments are becoming more homogenized through [human] development," says Berdahl. "At the same time, we're also fragmenting habitats with roads and dams, which impedes dispersal. The model illustrates that there's the potential to flip states and not be able to flip back."

In other words, simply restoring environmental conditions to a previous state may not trigger a commensurate shift in a species' evolutionary strategy, he says. ■

DONOR PROFILE

‘An essential part of our cultural and intellectual life’

David and Lea Soifer are neighbors of SFI’s main campus, and they like it that way.

“With the Institute’s focus on investigating complex systems, it has become a center for interdisciplinary research, bringing together investigators from many different fields,” says David.

“This is an institution that is worthy of our encouragement and enthusiastic support,” adds Lea.

David, a cell biologist, and Lea, a pianist, go to as many SFI events as their schedules allow. In 2013, the couple joined SFI’s President’s Circle, which offers supporters chances to participate in intimate talks and gatherings with SFI researchers.

“In addition to the presentations themselves, we often find ourselves drawn into stimulating conversation,” says David. What fascinates Lea in particular is SFI’s initiative in bringing arts and sciences together in public dialogues between prominent scientists and distinguished Native American artists, a creation of Valerie Plame, SFI Director Community Relations.

They are particularly impressed with the Institute’s educational outreach in the community, especially its community lectures, its professional development programs for teachers and programs for students, online access to SFI presentations, and online courses on complexity and related subjects. SFI “has become an essential part of our cultural and intellectual life,” says Lea. ■

SFI’s President’s Circle

- Recognizes annual giving from $1,000 to $4,999
- President’s Circle donors receive invitations to Science Club conversations with scientists, breakfast talks around the country, and other events.
- For more information, call 505.946.3678.

EDUCATION NEWS

Mentor: ‘We didn’t have anything like this when I was in high school’

The mentor leans into the laptop as his protégé calls out the data points: “5, 9, 27… Montreal, Chicago, Arizona.” Their screen transforms into a colorful network map.

“It’s not like anything I’ve done before [in science classes],” says Christopher LeSueur, a high school student who meets weekly with his mentor, SFI Postdoctoral Fellow Laurent Hébert-Dufresne. “It’s more statistics, and I have a greater appreciation for working with real models.”

Mentee Christopher LeSueur (left) and mentor Laurent Hébert-Dufresne (Image: Jenna Marshall)

The two take part in SFI’s mentorship program, which is part of a city-wide program called Inspire Santa Fe. SFI joined the program in November 2014, hosting eight mentor-protégé pairs that meet at the Institute’s Cowan Campus to pursue independent research projects.

The project this pair has undertaken combines LeSueur’s passion for sports with Hébert-Dufresne’s network science acumen. They are devising a new ranking system for NHL hockey teams based on trade networks. Hypothesizing that trade networks hold promise for evaluating hockey teams (because the trades tap into the collective expertise of the team managers who are making trade decisions), the researchers are waiting to see whether their metric will predict team success more accurately than measures based on a team’s previous-year performance.

“We didn’t have anything like this when I was in high school,” says Hébert-Dufresne. “All the experiments were designed, and we knew the results beforehand. Here, we are studying, in a nonprescribed way, something that really exists.”

“All of the students are doing college-level research projects, some of which might result in co-authorship with their mentors in a scientific journal,” says Juniper Lovato, SFI’s Manager of Schools, Residencies, and Community Outreach. “On the mentors side, I think this experience has been very rewarding. It’s a chance to connect with the Santa Fe community.” ■

MY STORY

Valerie Plame
Director of Community Relations
Santa Fe Institute

“I was introduced to SFI in 2009, during a holiday tea where SFI researchers enthusiastically described their projects to the guests. How could you not get caught up in the passion and intellectual rigor with which they approached their work on ‘the big questions’? I had some experience serving as a liaison between my former CIA colleagues and the physicists at Los Alamos, and I thought I could contribute to SFI in a similar fashion while making the sparking science I witnessed here more accessible to our community. I feel fortunate to be able to help organize community programs that continually bring new people into our special SFI family.”

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> *Omidyar Fellows* **continued from page 1**

different institutions of capitalism and democracy shape a society’s capacity to adapt, particularly to ecological constraints.

Dan Larremore studies the mathematical recombination processes that shape genes and genomes to better understand the evolution of pathogens, such as malaria. He earned his PhD in applied mathematics from the University of Colorado Boulder.

Chris Kempes holds a PhD in physical biology from MIT. He seeks to understand how different physical and abstract constraints organize evolutionary and ecological structure at different scales.

Eleanor Power investigates how human social structures are influenced by religious signaling systems, and the role such signals play in establishing trusting, cooperative, and mutually beneficial relationships. She holds a PhD in anthropology from Stanford. ■

Upcoming community events

Science On Screen, Sunday, May 3, 3:30 p.m., CCA (1050 Old Pecos Trail) – ***Jurassic Park* with Liz Bradley.** “Life finds a way.” SFI External Professor and computer scientist Liz Bradley of the University of Colorado Boulder introduces Steven Spielberg’s 1993 film about scientists who clone long-dead dinosaur species and suffer the consequences. This is a special family-friendly afternoon showing, with Bradley helping place the film in its scientific context. Advance tickets are recommended. For tickets and prices, call the CCA Box Office at 505-982-1338.

SFI Community Lecture, Wednesday, May 6, 7:30 p.m., James A. Little Theater (1060 Cerrillos Road) – The Accidental Universe: The World You Thought You Knew. Can science prove the existence of God? Is this universe we inhabit the only one? Can a religious experience be scientifically proven? Novelist, essayist, physicist, and educator Alan Lightman ponders these timeless, unanswerable questions using his training as both a scientist and a novelist, always careful to include historical and contemporary perspectives. Lightman is author of the international bestseller *Einstein’s Dreams*.

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 live on Twitter @SFIlive.

Chaos to complexity: Creative collaboration in art and science, Saturday, May 30, 2:00-4:00 p.m., Allan Houser Art Park (108 Cathedral Place). SFI and the Museum of Contemporary Native Arts present the fourth annual event in the Chaos to Complexity series. SFI scientist Mirta Galesic and Albuquerque composer, performer, and installation artist Raven Chacon explore the collaborative process in both art and science in a discussion moderated by SFI’s Valerie Plame. Free with museum admission.