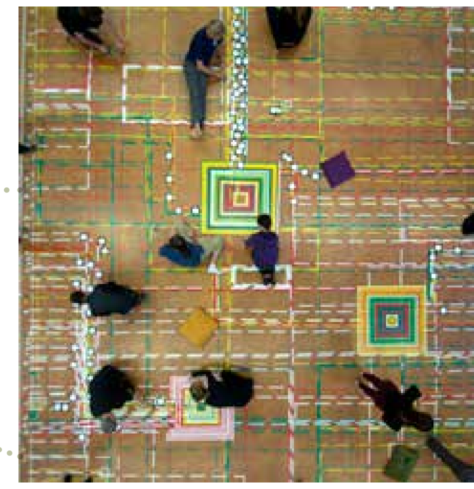
Fall 2016

Parallax

THE NEWSLETTER OF THE SANTA FE INSTITUTE



The Code of Hammurabi (left), the Babylonian code of law (~1754 BC), and digital rain (right), the computer code featured in The Matrix *series (~2000 AD). (Composite image by Laura Taylor)*

Laws and regs as society's operating system

Laws coordinate the execution of society's transactions. When new kinds of interactions emerge – sharing our airspace with private drones, for example, or algorithmic trading on financial markets – new laws are encoded to regulate those activities. Laws respond to conflicts of interest, keep criminals and cheats in check, and temper the abuse of power.

Much as Linux, Windows, and iOS coordinate the execution of computing applications, laws are the operating system of human society.

"Space law, tax law, online law, regulations for autonomous vehicles and artificial intelligence… if you think about laws and how they evolve to match the complexity of the functions they coordinate, laws become an interesting problem for complex systems science," says SFI President David Krakauer.

He is co-organizing SFI's 2016 Applied Complexity Network (ACtioN) and Board of Trustees Symposium, themed "Law OS," with SFI's VP for Strategic Partnerships Will Tracy and MITRE, a longtime ACtioN member.

The early-November meeting asks several interesting questions, Krakauer says: How bloated can our Law OS get before its starts to fail? How sure are we that present and future societal apps will run on it? Do legal systems occasionally need complete redesigns as software operating systems do? Does the complexity of our current regulatory system exceed our human capacity for attention? Can artificial intelligence help address this constraint? Where are the emerging rules and regulations in biotechnology, artificial intelligence, and autonomous vehicles taking us as a society?

Other topics include the increasing complexity of the law, new contexts for laws and regulations, the prospects for minimal laws that (like minimal operating systems) seek the smallest number of rules to encompass the maximum number of challenges, the consequences of the strategic arms race among regulatory systems, and how we might overcome the Red Queen dilemma in which the production of new laws moves ever faster, only for us to stay in the same place.

Participating experts represent diverse perspectives on law, government, computer coding, gaming, financial regulation, technology, art and copyright, physics, biology, and more.

The symposium kicks off a new research program at SFI on "Complexity and the Law," which Krakauer plans to announce during the meeting. The planned four-year program is sponsored by SFI Trustee Andrew Feldstein.

The idea for the program emerged out of a March 2016 ACtioN topical meeting on

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Nature's living circuits and how they evolve

Think of circuits, and you think of tiny resistors, transistors, and wires. But circuits are found in biology too: from genes to neurons to social interactions, living circuits crunch data to produce new outputs.

This December, a group of experts meets at SFI to explore not just how biological circuits work, but also how they evolve.

The "low bar" is to share methods among researchers who study various kinds of biological circuits, says SFI Professor Jessica Flack, who is co-organizing the event. "The high bar is the discovery of common principles of computation in biological systems and an understanding of how these principles influence the evolution of phenotypic traits and social structures," she says.

To get a sense for what biological circuits look like, consider fights among monkeys, a model system of longstanding interest to Flack and her colleagues. Each monkey is a component of the circuit, and monkeys are connected by their strategies – for instance, whether Monkey A is more or less likely to join a fight if Monkey B is already in the mix.

So-called "gates" take all of that information and compute outcomes, such as the optimal fight size – if fights are too small, they accomplish nothing, but if they get too big, conflict can spin out of control and destabilize the society. What's more, circuits can be understood at different levels of abstraction, so that a gate's outputs could serve as the inputs to a different, more macroscopic circuit, just like small circuits can be built into larger electronic devices such as stereos or computers.

The working group's first aim is to share ideas and methods for studying biological circuits – especially gene regulatory networks, neural circuits in the brain, and social circuits (like the monkey example).

But the real aim is to understand circuit evolution. To start with, the team will try to understand the time and spatial scales characteristic of different circuits, as well as which of a

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Living computation as a statistical physics problem

Scientists have sought new insights about plants, animals, and entire ecosystems by viewing them as living computers: they take in energy from the sun to process information and solve complex problems – where to find food, how to avoid predators, or even (in the case of human animals) how to build computers.

During a mid-November workshop on statistical physics, information processing, and biology, SFI scientists plan to take the first steps toward turning this intriguing but semiformal notion into a quantitative science.

"People have been saying forever that living systems are computational systems," says workshop co-organizer and SFI Professor David Wolpert. But the idea hasn't gone beyond a few, high-level papers, in large part because until recently physics didn't have the tools to analyze living things as computers.

The problem is a subtle one. To study computation and information processing, researchers often turn to statistical mechanics, a theory originally built to understand the microscopic processes underlying, well, steam engines.

But traditional statistical mechanics doesn't really apply to biology – it's an equilibrium theory, and biology is anything but an equilibrium phenomenon, notes Wolpert. Indeed, the main thing plants and animals do is disturb Nature's equilibrium by taking in food and sunlight and turning it into ever more complex biological structures.

Fortunately, Wolpert says, there's been an explosion in the last two decades in non-equilibrium statistical physics – meaning researchers interested in biological computation might finally have the tools they need to develop their ideas quantitatively.

With that in mind, Wolpert and members of SFI's resident and external faculty will bring together a multidisciplinary group of experts to begin building what Wolpert describes as a

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BEYOND BORDERS

That great perplexing polymath Marshall McLuhan wrote: "Once you see the boundaries of your environment, they are no longer the boundaries of your environment." This cannot be entirely true. For example, we know from special relativity that the speed of light is an upper bound on the velocity of all objects with positive resting mass, and this in no way allows us to overcome it. As we approach light speed we require infinite energy, and this, no being shall ever have.

What about more modest boundaries like the number of memories we can store in our brains? Or the speed at which we can swim the 200-meter freestyle? Or the highest possible score in an NBA basketball game? Or, perhaps more relevant to our everyday lives, what is the upper bound on the number of years we might expect to live…in the 21st century…or the 31st century?

In answering questions like these we should like a theory, or several, perhaps not as simple as special relativity, that could help us to understand fundamental limits in complex systems.

The progress of science can, in a very deep way, be thought of as an exercise that seeks to determine fundamental limits to the structure of the universe. Starting with the subatomic domain we observe that the orbits of electrons about the atom are restricted by the exclusion principle to discrete shells and prescribed numbers. These atomic limits impose further limits: on the structure of the periodic table of the elements, and, in turn, on the properties of molecules. At the other end of the size scale, stars reach their limits at around 150 solar masses.

The question of limits is made vastly more challenging when we deal with systems possessing emergent properties. In these cases, we cannot in any obvious way derive the limits of a system from the limits of its parts. The memory or processing limits of the brain are not apparent from the limits measured in single neurons. The limits of organismal metabolism are not to be found in the metabolic limits of single mitochondria within cells. And the limits to the efficiency of global trade are not captured by the regulatory limits imposed on the economic behavior of individual consumers or even companies.

This year at SFI, we have initiated a new program on the study of limits in complex systems. In 2016, we started with the limits to human performance and the limits to prediction [see article on page 3]. We shall follow with more explorations of limits: in conflict, in financial markets, and in technological innovation, for example. We seek new models and theories to describe these limits.

At SFI, we have always liked to challenge the limits of knowledge. These explorations provide the platform and support the collaborations that bring this ambition closer to reality.

— David Krakauer
President, Santa Fe Institute

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Parallax is published quarterly by the Santa Fe Institute. Please send comments or questions to John German at jdg@santafe.edu.

www.santafe.edu

On the cover: "Drawing on Complexity: Experiment Two" (frame from time-lapse), by Briony Barr & Andrew Melatos (www.brionybarr.com), 2012

SFI IN THE NEWS

Writing in *Fortune* on October 4, SFI Professor Luis Bettencourt reviewed various cities' progress in adopting driverless cars and cautioned that they could prove to be a setback to our urban systems if their advantages simply result in more cars driving more miles.

SFI External Professor Simon DeDeo's nonpartisan statistical analysis of word choice in the September 26 presidential debate, which found surprisingly little rhetorical distinction between the two candidates, was covered by the *Pacific Standard* and HowStuffWorks.com.

SFI External Professor John Miller wrote of suicidal army ants and the flash crash in his September 20 article "What happens when the systems we rely on go haywire," the latest in SFI's essay series with the *CS Monitor*.

The *Washington Post* and the *Albuquerque Journal* on September 14 described an SFI meeting that helped harvest the idea that the evolved agricultural practices of insects and humans have much in common.

In *Nautilus* on September 6, SFI President David Krakauer took a critical look at artificial intelligence in light of humanity's long tradition of using tools to augment cognition – and our recent, darker tendency to let them do the thinking for us.

SFI Science Board member Simon Levin and MIT's Andrew Lo wrote in the *CS Monitor* about biology-inspired approaches to financial regulation. The essay, part of our *CS Monitor* series, summarized ideas from a May 2016 SFI Applied Complexity Network meeting in Washington, D.C.

SFI Professor David Wolpert's research was cited in a July 11 BBC article about time's directionality and memory.

New metric quickly reveals network structures

Researchers often want to know what hidden structures lie within data representing real-world networks, from power grids to the internet. But current methods are limited.

Approaches that identify microscopic features miss the big structural picture. Methods that reveal macroscopic organization don't reliably show how the network is constructed – and also tend to be computationally intensive.

"We don't have a good toolbox to get a quick understanding of the network structure," says Laurent Hébert-Dufresne, a James S. McDonnell Fellow at SFI.

His frustration inspired him and two collaborators – Antoine Allard (University of Barcelona) and SFI Omidyar Fellow Josh Grochow – to develop a new metric that reveals network structure at the microscopic, mesoscopic, and macroscopic levels at once.

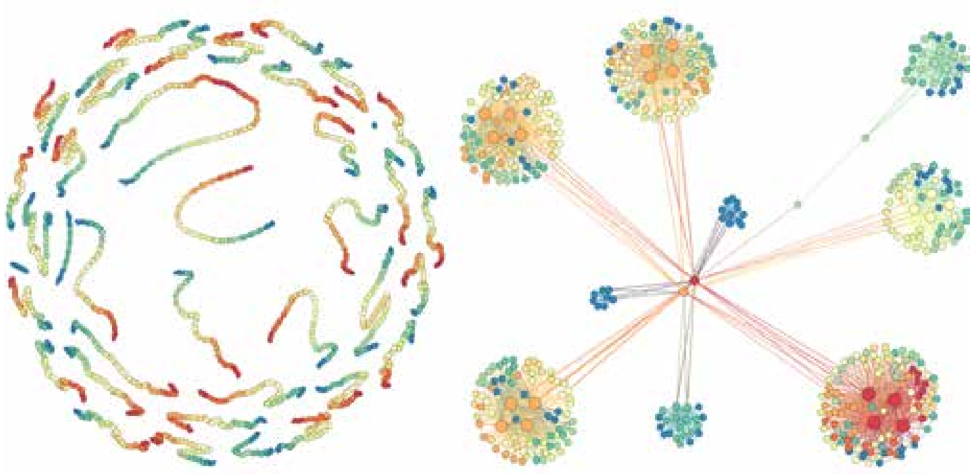
They introduced their approach, which they dubbed the "Onion Decomposition" as a metaphor for peeling back the layers of an onion, in a recent paper in *Scientific Reports*.

Their new tool analyzes a network by taking it apart – removing "layers" of nodes that have the same number of connections, usually starting with the layers having the fewest number of connections. That's not new, strictly speaking; the same approach is used by another powerful algorithm called "k-core decomposition."

But k-core decomposition loses valuable information about the layers it peels away, says Hébert-Dufresne. His group's goal was to build an algorithm that uses layer-level information to provide insights about the network at multiple scales.

In their paper, they report successful test drives of their method on a handful of real-world datasets, including the Northwestern U.S. power grid and the road system of Pennsylvania. In both cases, the Onion delivered accurate snapshots of the network structures at different scales, and the authors were able to draw interesting conclusions.

Hébert-Dufresne sees the new metric as a valuable first step for network analysis that "allows us to understand, at a glance, whether a network is tree-like or grid-like, how heterogeneous it is, and even identify surprising subgraphs."



Using the Onion Decomposition on the stanford.edu web domain, the authors discovered an unexpected subnetwork structure (left) — some 8,500 nodes with two connections joined in chain-like fashion, a deviation from the expected centralized tree-like structure. In the sixth layer (right) they found a more typical, highly centralized community structure.

In a race to the center, candidates split on pronouns

A statistical analysis of the words the candidates used during the first 2016 presidential debate on September 26 finds that the strongest distinction between Hilary Clinton and Donald Trump was not what, but who.

SFI External Professor Simon DeDeo, who performed the analysis, found that Clinton used the word "we" 50 percent more often than Trump, and Trump used the word "they" 70 percent more often than Clinton.

Perhaps more surprising was the strength of the differences (or, in this case, similarities) in word choice.

"In the modern history of presidential debates so far, we've almost never seen two candidates share so many of the same patterns and vocabularies," DeDeo says. "Candidates usually distinguish themselves from each other much more strongly. If you look at Obama-McCain and Obama-Romney, you find their use of language both richer and more distinct."

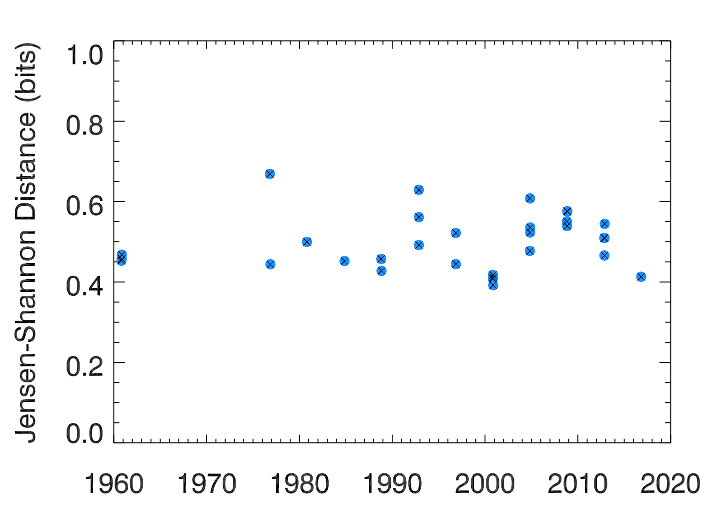
DeDeo performed his overnight statistical-textual analysis using transcripts from the first Clinton-Trump debate and those from previous presidential debates. He presented his results the following morning during a live online news conference with other scientists who analyzed the candidate's facial expressions, mannerisms, and other performance indicators. The event was a partnership between SFI and Newswise, a science news distribution service.

Rhetorically, DeDeo said, "to see something like what we saw last night, you have to go back to Bush-Gore in 2000."

Beyond their choice of pronouns, DeDeo says, one of the words that best distinguished Clinton from Trump was "think"; Trump, for his part, urged viewers to "look."

"The difference between telling someone what you think versus telling someone to look encodes a great deal – and along with the insider/outsider pronoun choices, it's one of the biggest splits between the candidate's choices of words we find," he says.

Still, he emphasizes, the truly surprising finding was how few such splits there were. "It's an utterly crucial moment in the country's history," DeDeo says. "Yet the candidates chose their words in ways at odds with the starkness of the choices they present. In terms of their rhetoric, the candidates were in a race to the center."



A filtered measure of how distinguishable each candidate's words are from his or her opponent for presidential debates since 1994. (Image: Simon DeDeo)

Laws OS

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complexity and the evolution of the law; a February 2016 paper co-authored by SFI External Professor Dan Rockmore (Dartmouth), Tom Ginsburg (University of Chicago Law School), and Krakauer on the evolution of national constitutions; and conversations with Rockmore, External Professor Jenna Bednar (University of Michigan), Ginsburg, and Michael Livermore (University of Virginia School of Law) about the complex systems implications of the legal system for technology, and vice versa.

"The internet really is one huge regulatory system," Krakauer says. "And with the emergence of whole new areas of technology for augmented reality, machine learning, genetic engineering, and optimization of all kinds, this program connects complexity science very directly with the future directions of our society."

Says Feldstein: "Laws form complex systems that have evolved over many centuries via complex processes; they regulate complex human networks and make large scale, interdependent society possible. Understanding the origins, the evolution, and the nature of law is to understand something important about civilization itself. There is no place better than SFI to undertake an interdisciplinary inquiry into this human innovation that structures and shapes our world."

How human settlements compare through time and space

Cities are "social reactors," concentrating people and accelerating interaction and social outputs – in essence, burning hotter and brighter as they get denser.

A recent working group at SFI, "Human Settlements and Networks in History," furthered a long-term exploration of urban scaling theory as it applies to human settlements through history and across cultures.

The team – including SFI External Professor Scott Ortman, now at the University of Colorado Boulder, and SFI Professor Luís Bettencourt – recently published an article in the *Journal of Archaeological Science* that involves a case study of the Inka expansion in Peru, which occurred around 1450. They found that changes in settlement size distribution seem to predict the level of economic growth that occurred in the subsequent century, suggesting it might be possible to learn more about the factors that encourage economic development by paying attention to the distribution of population in settlements across a society.

A more recent paper in *PLOS One* showed that medieval and modern European cities share remarkably similar population density characteristics.

What is emerging, says Ortman, is an awareness that the framework initially developed to make sense of contemporary urban data may be very broadly generalizable to societies of the past. "If it's true," he says, "the archaeological record then provides a rich data source for elaborating and testing the theory, and the things we learn about scaling phenomena by studying the archaeological record should be directly relevant to the way contemporary societies work."

Beyond this possible connection, Ortman thinks there is potential for archaeological research to contribute to a general theory of human societies as complex systems.

The SFI-inspired Social Reactors Project, now centered at Boulder, seeks the common properties of human settlements through time and space. More at www.colorado.edu/socialreactors/.

A way to secure future computers: Limit their capabilities

In the 1930s, British polymath Alan Turing described a "universal computing machine," a device capable of performing any computational chore. His idea underlies the versatility of virtually all modern computers – servers, laptops, tablets, phones, and other devices that can run almost any program – and our very conception of what a computer is.

But this far-reaching versatility brings vulnerability, says SFI External Professor Chris Wood. An attacker who gains access to a general-purpose machine can exploit its broad computational abilities to accomplish nefarious ends. As more devices go online – through cloud computing, connected cars, and the internet of things, for example – security becomes an increasing threat and challenge.

"The more general-purpose computers we put on the open internet, the more serious the threat becomes," says Wood.

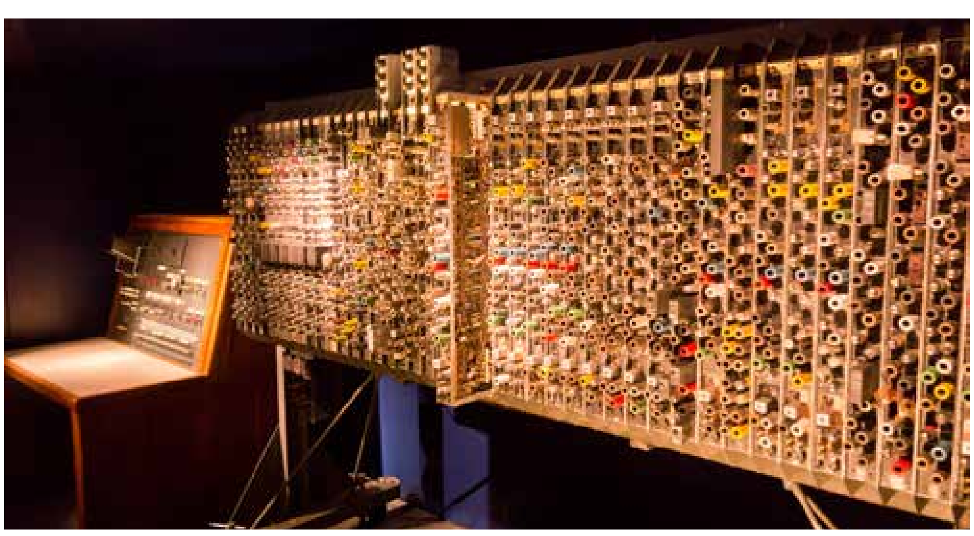
But what if we rewind the tape of history? Is there another sequence of events that would head off such security worries?

If computers had instead been developed as specialized devices, each programmed to do specific tasks, then perhaps they'd be less vulnerable to attacks. In such an alternate history, says Wood, the damage from a hacker who commandeers a single-purpose device would be limited. Contemplating this alternate history might help inspire better security measures.

"How can we create the security advantages of such an alternate history now without losing the advantages of our general-purpose devices?" he asks. To explore that question, Wood has invited representatives from tech companies, government agencies, and academic institutions to a mid-November working group at the Institute. The meeting, "Circumventing Turing's Achilles Heel," will focus on improving the security of computing systems having a specific range of functions that require continuous connection to the internet.

Wood's research interests have included the relationships between the structure and function of information processing devices, both natural (like brains) and artificial (like computers). This working group is an extension of those interests into computer security.

He hopes the meeting will provide leaders in the field with an opportunity to explore novel strategies for boosting security in an age of increasing risk.



Pilot ACE (Automatic Computing Engine), a simplified version of an early electronic stored-program computer design produced by Alan Turing. In a 1936 paper, Turing described his idea as a "universal computing machine." *(Image: Antoine Taveneaux, Wikimedia Commons)*

(Image: Eleanor Power)

Religious acts send others clear signal of pro-social intent

Religious expression has a central role in societies around the world, but exactly what role it plays isn't always clear. SFI Omidyar Fellow Eleanor Power has an answer: whether it's walking across hot coals or simply going to church on Sunday, people who participate in religious acts send a signal to others that they're ready and willing to contribute to their communities.

Power's study, recently published in the journal *Evolution and Human Behavior*, was designed to test whether signaling theory applies to religion. The theory's key prediction is that people will pay a price in time, money, or even physical pain to demonstrate something to others – in this case, people would engage in religious acts to demonstrate their generosity, devotion, and so on.

There's some evidence to suggest that regular churchgoers, for example, really are more generous than others. But to demonstrate that signaling theory is part of the answer, it's not enough to prove that people who engage in religious acts also engage in pro-social behavior – you also have to show that others in the community get the message.

Do religious acts get the message across? Power spent two years living in a pair of Tamil villages in southern India studying the question. Based on interviews, formal surveys, and other observations, Power's answer is "yes." She found that those who engaged in more religious action were perceived as more hardworking, more generous, and even stronger compared to others.

Interestingly, dramatic acts in the name of religion, such as being pierced by hooks and swung from a crane, didn't send the strongest messages. The message was strongest for the simple act of regular worship. "That has often a bigger effect on your reputational standing than big, extreme acts," Power says. She adds, "dramatic displays do quite a lot. It's just that the effect of regular worship is slightly larger."

Also surprising: just how much of an effect religious acts had on others. "These are people who know each other well and have many lines of evidence to draw on, of which religion is just one." Power says. "Given all those other opportunities for observing one another, the fact that there are such strong relationships – it's pretty telling."

Toward the limit: SFI research meets application

A September meeting of the Applied Complexity Network (ACtioN) in London tested the link between SFI's scientific research and its practical application.

The ACtioN Limits to Prediction meeting, which drew participants from business and government, followed a meeting of scientists that took place in August at SFI. Both meetings concerned factors that determine the precision and reliability with which a system's behavior can be predicted.

"Previously, a popular scientific topic at the Institute one year might be featured in a topical meeting a few years later," says Will Tracy, SFI's VP of Strategic Partnerships. "There was a tendency for the ACtioN topics to lag behind the scientific topics."

This time, attendees of the London meeting heard presentations on the topics the researchers at the Santa Fe science meeting had, just weeks before, deemed among the most interesting new insights. Other scientists from the UK and Europe also joined the ACtioN dialog.

"From the feedback we've gotten, it seems to have worked quite well," Tracy says.

Not only were ACtioN members provided access to scientific insights sooner and more directly than they would have been offered them in the past, visiting presenters from the research community garnered a new and richer understanding of the sorts of insights that stand to yield immediate practical benefit.

Formerly known as the Business Network, ACtioN acquired its new name and acronym earlier this year. Members are businesses, institutions, and agencies that draw on complex systems science to understand complex systems in their worlds: economies, markets, organizational structures, ecosystems, digital networks, political systems, and other kinds of adaptive interactive networks.

Both meetings explored the idea that increasing a system's heterogeneity or the number of rules governing it sometimes makes it more predictable, not less. Another common theme was the difficulty of accurately modeling and predicting a system's behavior if not all its possible states are known.

Tracy sees the intertwining of SFI research and application as forming a virtuous circle, and he plans to incorporate the same format next year.

"It's about creating a conversation between science and application in real time," he says.

Living computation

(cont. from page 1)

"completely new science" that draws heavily from physics, biology, and computer science.

To narrow down their challenge some, the group will focus on three questions: how much energy does biological computation require, how much energy does the evolution of biological computers require, and how has the fraction of the energy in sunlight that the entire biosphere actually uses changed over time.

Although still a nascent exploration, Wolpert says, a "thermodynamics of biological computation" could have wide-ranging implications across other sciences. It could, for example, aid computer scientists hoping to develop more efficient supercomputers, or help biologists understand how the human brain – a computer with enormous energy requirements – could have evolved.

Hacking geometry to crack math's toughest unsolved problem

For more than five decades, mathematicians and computer scientists have been chasing an answer to a problem that, to the uninitiated, looks suspiciously simple: Does P = NP?

Loosely translated, it asks whether NP problems – those with solutions that are hard to compute but easy to verify – are equivalent to P problems – those that can be solved quickly by a computer program. For a computer scientist, the question boils down to whether or not brute-force algorithms can be replaced by smarter, more efficient strategies.

NP problems show up in many fields, including science, business, mathematics, medicine, and engineering. If researchers can prove that P = NP, they can begin to pursue efficient algorithms to solve NP problems. But equivalency isn't likely; most experts in the field expect that P and NP are not the same. The Clay Mathematics Institute, in Boston, has deemed this proof so important that it has offered a $1 million reward to its "prover."

One research area focused on proving that P is not equal to NP is called Geometric Complexity Theory, or GCT. This approach recasts P versus NP as a geometric question, explains Josh Grochow, an Omidyar Fellow at SFI.

Imagine that all possible algorithmic problems take up some space; NP forms a blob within that space, and so does P. Given that setup, says Grochow, "we want to understand if one is contained in the other by understanding their geometry."

Together with J. M. Landsberg from Texas A&M University and Jerzy Weyman from the University of Connecticut, Grochow has planned a December working group on GCT. His goal is to explore some of the stepping stones needed to understand the geometry of the big question.

"We have a good idea of the immediate questions we want to tackle," he says. "We're bringing in a lot of advanced math and techniques that haven't been used much in computational complexity before."

Gunn named new HR director

SFI welcomes Janet Gunn as its new Director of Human Resources. Gunn comes to SFI from the Akal Group (formerly Akal Security), where she most recently served as Chief Administrative Officer. She joined Akal in 2002 from the BiosGroup, a Santa Fe software company founded in 1997 specializing in applied complexity science.

Gunn enjoys the challenges of finding paths to solutions through the competing and sometimes confusing framework of policies and regulations.

SFI's former HR director, Ronda Butler-Villa, retired in September after 29 years at the Institute.

Nature's circuits

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circuit's features have the most impact on outcomes – those features, Flack says, "will give us a starting point for thinking about what properties of the circuits could be targets for natural selection to act on."

In addition to biological perspectives, the working group will look to statistical physics and information theory to work it all out, Flack says. Once they make progress, the group's members hope to produce a special issue of *Philosophical Transactions of the Royal Society.*

How cheating arises, evolves

For those of us with smartphones, it's an unusual week when we're not notified of a handful of updates to our apps. While some add features, many address vulnerabilities that threaten the security of our data. In the world of online data, malice seems ubiquitous.

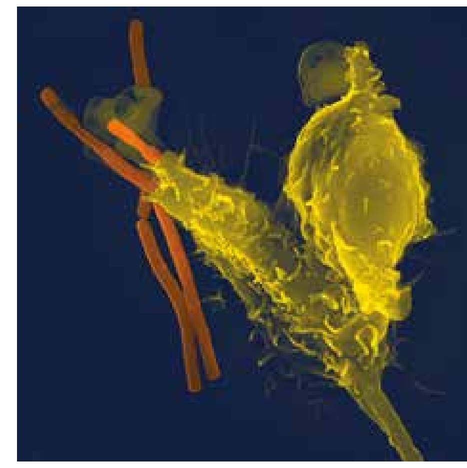
Malicious behavior is similarly common in the natural world, where agents find a means to enter a system and subvert its rules in their favor. This "cheating," as most of the world calls it, can damage, disrupt, and destroy other agents or the system itself.

"Malicious behavior tends to arise in almost every complex system that is comprised of self-optimizing agents – if they also have the ability to learn or evolve," says SFI External Professor Stephanie Forrest. She and fellow University of New Mexico professor Melanie Moses, also an SFI external professor, have been considering this theme over the past few years, in connection with Forrest's work on cybersecurity and software evolution and Moses's work on robotic swarms and ants.

As part of their early December working group, "Evolution and Restraint of Malicious Behavior in Complex Systems," they hope to explore and generalize how cheating evolves and how a system identifies and handles it.

Simple but adaptable robots and cyber-physical systems are also of interest, as "they may find ways to subvert rules or produce unintended consequences if cheating lets them meet their specified goal," Moses says.

Conversations with SFI President David Krakauer and VP for Science Jennifer Dunne sparked the idea of bringing together experts in the evolution of cheating and its restraints in natural systems together with experts knowledgeable and open-minded about malicious behavior in software and robotics.



Bacteria and viruses evolve multiple stages of ploy and counterploy to evade and overcome the defenses of immune systems. Here, a scanning electron micrograph shows a neutrophil (yellow), the most abundant white blood cell and the first line of defense against invading microbes, engulfing rods of Bacillus anthracis *(orange), or anthrax. (Image: Volker Brinkman,* PLoS Pathogens 1 [3], *Wikimedia Commons)*

Among the topics germane to the project are the dynamics of individual and collective behavior, conflict management in social primates, immunity and other biological defenses, stable ecologies that inhibit harmful behavior, cognitive robotics, robot ethics, swarm intelligence, and trends in data-mining for fraud and abuse.

Mind-numbing or crowd-wise? Optimizing problem solving

It's a contradiction we have grown accustomed to: When big problems arise, we insist on the power of many brains. At the same time, everyday work meetings are notoriously dull and fruitless. Can certain conditions nudge collaborative problem solving in a more reliably productive direction?

First, a definition: collective problem solving here refers to a group of heterogeneous agents with divergent interests who congregate to identify, solve, and act on problems of common concern, typically with better results than any individual agent could achieve.

Straightforward enough. But attempting to make progress on improved problem solving quickly gets complicated and many-disciplinary, leading to a variety of new questions from the philosophical to the pragmatic.

What, for example, is the social psychology behind argument and reasoning? How does diversity influence social problem solving? How might ensemble methods in machine learning inform communication in iterative work?

An upcoming working group at SFI aims to connect some of these elements. Co-host Cosma Shalizi, an SFI external professor and associate professor of statistics at Carnegie Mellon, has a background in the statistical physics of complex systems; his current research involves devising algorithms to identify optimal predictors from finite data and applying them to concrete problems.

He and co-host Henry Farrell, an associate professor of political science and international affairs at George Washington University, recently published a paper outlining how democracies can work better than markets and hierarchies at solving complex problems. The pair is working on a second paper exploring evolutionary models to re-think institutional change.

Their early November working group, "Collective Problem Solving," is the final in a series of small meetings. The sessions have themselves used elements conducive to collective problem solving: the small group has met regularly to maximize engagement and dialogue, new versions of papers have been presented each time, and each paper is presented by someone from another field.

This last exercise, in which a scientist considers an unfamiliar subject using their own discipline's frameworks and tools, offers a refreshing opportunity to generate unexpected perspectives on a problem – which is often exactly what's needed to get to the next step, Shalizi says.

MOOC update: 27,000 and counting

Class Central, a site that collects information and reviews on thousands of online courses from around the world, recently ranked SFI's "Introduction to Complexity" online course highest among 614 other online science courses.

Since it was first offered in early 2013, the 16-week massive open online course (MOOC) has been offered five times, with another session under way as of October 3. All told, some 27,000 people have enrolled in the course, taught by SFI External Professor Melanie Mitchell, with an average 13.1 percent completion rate – significantly higher than the world MOOC average.

Mitchell has updated the course with new interviews with SFI External Professors Doyne Farmer and Simon DeDeo and SFI Professors Jennifer Dunne and Sam Bowles.

Participants in the introductory course learn about dynamics, chaos, fractals, information theory, self-organization, agent-based modeling, and networks. There are no prerequisites and you don't need a science or math background.

Hence, participants have included graduate students in the sciences and social sciences to retirees and high school students from 100 nations.

To join the current sessions, visit intro.complexityexplorer.org.

Two other SFI MOOCs – Introduction to Dynamical Systems and Chaos, and Fractals and Scaling, both taught by College of the Atlantic Professor David Feldman – are first and second in Class Central's math category of 225 courses listed.

Fall 2016
Parallax
THE NEWSLETTER OF THE SANTA FE INSTITUTE
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