Summer 2018

Parallax

THE NEWSLETTER OF THE SANTA FE INSTITUTE

Pages from the Dresden Codex show Maya hieroglyphics that track the planet Venus.

On time and being Maya

Ancient Mayas developed astonishingly accurate calendars by studying the sky. They interpreted the movements of the sun, moon, and stars as glimpses of the mystery of creation. They used enclosed cave-like spaces to contemplate big questions about time, creation, mathematics, and the cosmos.

"Their interior spaces were designed for divination, vision questing, and for mathematical calculations," says anthropologist David Freidel, a Maya iconographer and professor at Washington University in St. Louis.

For the last two years, scientists with the Maya Working Group at the Santa Fe Institute, organized by Freidel and supported by SFI Trustee Jerry Murdoch, have been studying archaeological data pertaining to how the Mayas considered time. The group focuses on how those ancient ideas influenced other parts of their culture, including architecture. In late August, the members will convene in Santa Fe to brainstorm ways to integrate the interdisciplinary analyses into a finalized, unified anthology scheduled to be published next year.

In addition to discussions of ancient calendars, topics addressed in the book include how the Mayas organized ceremonial spaces and temples to reflect ideas about the past, present, and future; how they calculated time; how interior spaces were used for divination and prophecy; and how they considered creation and the cosmos.

The book on Maya time will be the second from the SFI Maya Working Group, which has been meeting since 2012. The first, published in the summer of 2017, collected studies of E Groups — the ancient Maya buildings that served as ceremonial centers.

Freidel says discussions about the book will occupy most of the first part of the working group. For the rest of the time, they will launch into a new theme, "Being Maya," which will focus on the cultural identity of the lowland Maya civilization and what sets it apart from other Mesoamerican peoples of the same time period. Scientists have long debated what's culturally Maya and what's not, says Freidel. The August meeting will include presentations of new archaeological data that can help inform the field.

The new theme will elucidate what makes the lowland Maya distinct, he says, as well as how their identity and interactions with other societies set the foundation for modern nations with Maya roots.

"In the spirit of the SFI, we are working with complexity in terms of the Maya civilization," says Freidel, "but we're also looking at how that complexity unfolds over time, over millennia."

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Broken brains and network structures

Sometimes a disease is the handiwork of a clear culprit: the invasion of a bacterium, or the mutation of a gene. Conventionally, scientists have assumed the same for neurological disorders, such as Alzheimer's disease, and zoom in on the brain to look for potential localized causes, such as particular molecules or genes. For example, they've found that the brains of Alzheimer's patients contain proteins that have folded in the wrong way.

However, it's difficult to assign blame to one specific part in the brain for causing a neurological disease. "It would be like saying that a building fell down because there was something wrong with a single brick, instead of some kind of structural problem," says SFI President David Krakauer. The brain functions as an integrated network of parts rather than a discrete machine with one specific task like the kidney. It's limiting to study parts of a diseased brain in isolation.

That's why researchers are trying a different strategy: to zoom out and investigate the connections in the brain as a whole. Emphasizing the whole over the parts is a hallmark approach of complexity science, which has also been used to study networks such as electricity grids and ecosystems. This July, Krakauer and neuroscientist Steven Petersen of Washington University in St. Louis have organized a workshop for neuroscientists and complexity scientists to develop new tools for studying the brain as a complex network. The workshop, titled "Cognitive Regime Shift: When the Brain Breaks," is part of SFI's Aging, Adaptation, and the Arrow of Time research theme, funded by the James S. McDonnell Foundation.

"I hope that we foster strong collaborations between the two groups," says Petersen. Specifically, he and Krakauer would like neuroscientists to learn how to apply mathematical

Workshop asks: Will AI ever crash the barrier of meaning?

In his 1950 paper "Computing Machinery and Intelligence," Alan Turing posed his famous test: If a computer can engage in conversation in such a way that a human judge cannot distinguish the computer from a human being, it passes the test, and we say it can think. While Turing's test met with no end of objections, it became a catalyst for many of the advances in artificial intelligence and machine learning that we see today. To a striking degree, computers can do many of the things we previously thought only intelligent minds could do — they can translate between languages, recognize faces, beat human champions at complex games, and drive cars in traffic-filled cities.

Yet one area of human intelligence is notably unyielding to machines: the meaning of things. While humans are able to understand situations they encounter, artificially intelligent systems do not possess the same understanding. When Google translates for us, it does not grasp the meaning of what it displays. The outputs that machines can learn to display do not contain the rich meanings that humans see in them.

In 1986 mathematician Gian-Carlo Rota wondered "whether or when artificial intelligence will ever crash the barrier of meaning." Rota's reflection continues to challenge scientists today, and it inspires SFI's upcoming workshop, "Artificial Intelligence and the 'Barrier of Meaning'," which is set to take place in Santa Fe from October 9-11, 2018. The workshop will examine what the key impediments are to building machines that understand meaning. It will ask what meaning would look like for artificial intelligence, and how far understanding is necessary for artificially intelligent machines to approach human-level abilities in language, perception, and reasoning.

The rise of big data in the past decade has meant that computers are increasingly successful at performing tasks that we usually assume require intelligence, according to SFI Science Board Member Melanie Mitchell (Portland State University), who is co-organizing the workshop with Science Board Member

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"Cyborg Meld" by Randy Adams

BEYOND BORDERS

SYNERGIES OF THE SOLSTICE

". . .to be irreversible is a grave responsibility of divine proportions. . ."

— Cloudless, *Tim Ramick*

The obliquity of the ecliptic (Earth's 23.44 degree tilted axis of rotation) and the geometric origin of our seasons creates the summer and winter solstices. Twin events corresponding to the most northerly and southerly points of the sun on the celestial equator. Through collective efforts spanning generations of observation, subtle regularities of time and space find a place in the myths and models of societies. In this way adaptive systems evolve to encode features of the environments they inhabit.

Here at home in the Southwest the solstices have been cosmic guides scheduling the activities of the Pueblo peoples. Those who lived by corn ritualized the long days of maximum growth and the short days of harvest. Dorothy Washburn and Donald Crowe have observed that the scalloped sandals of the Southwest Pueblo people encode the movement of the sun across the horizon in the two-color symmetry dyes of sandal insteps. In this way celestial time weaves its way through nature into the patterns of culture.

At SFI throughout June we have been celebrating the collective, temporal, and ritual forms of the solstice in our own complex fashion, weaving space and time into our InterPlanetary Festival, and workshops on The Origin and Implications of the Arrow of Time and The Limits to Human Performance.

The InterPlanetary Festival (v1.0, codename: Gemini), supported by the Miller Omega Fund and generous donors, organized by Caitlin McShea and team, was an effort to create large-scale terrestrial awareness by focusing on planetary life-support systems: the connected mechanisms that sustain life from ecosystems to economies and from transport networks to artistic work. Over two days several thousand of the curious, the engaged, and the mystified, listened to panels discuss game design for cell biology, autonomous ecosystems, the future of social and economic life, the prospects of discovering life on exoplanets, all while admiring the retro-futurism of the gesture-driven Theremin analog synthesizer and attending concerts and films celebrating the imagination and the impossible.

The Origin and Implications of the Arrow of Time workshop was the inaugural conference of the James S. MacDonald program on Complex Time, organized by James Hartle, Sean Carroll, and Jessica Flack. Participants from theoretical physics, complexity science, and cognitive science, struggled to grasp the directionality and irreversibility of time, the origins of order and disorder in the universe and through earth history, and debated new theories required to connect the second law of thermodynamics to the emergence of life and intelligence in our solar system.

The Limits to Human Performance, sponsored by the Miller Omega Fund and organized by Jessica Flack and John Krakauer (my sibling, not the mountain climber) brought together sports analysts, complexity scientists, the special forces, climbers, and athletes to inquire into the nature of team performance. We know a great deal about measuring and training individuals, but how best to define, measure and improve collective performance? The meeting considered new methods from statistical mechanics and information theory that might break through the current limits of team performance.

For SFI the synergies of the solstice demonstrate the far-reaching value of complexity science in addressing some of the most challenging and exciting activities for life on Earth.

— David Krakauer
President, Santa Fe Institute

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SFI IN THE NEWS

InterPlanetary news abounds! *The Santa Fe New Mexican's Pasatiempo*, KSFR, and *The Santa Fe Reporter* offered pre-festival coverage, as did Boing Boing, *Popular Mechanics*, and the Future Fossils podcast.

On June 1, *The Washington Post* quoted External Professor **Jessika Trancik** (MIT) on the impact of the US intention to withdraw from the Paris Climate Agreement.

Former Omidyar Fellow **Caroline Buckee** (Harvard School of Public Health) spoke with *The New York Times, Nature*, and other publications in May about her analysis of the death toll in Puerto Rico from Hurricane Maria. Her analysis: ~4,600 casualties. The government's: 64.

External Professor **Andrew Lo** (MIT) was featured in *Bloomberg* on May 24 in an opinion about "right to try" legislation and in *US News & World Report* on May 14 in a story about how investors use Twitter to spot nascent trends.

On May 29, External Professor **Brian Arthur** (Palo Alto Research Center) told *Forbes* that infrastructure is the most fundamental of all human technologies, in an article titled "The Future Is Physical."

The 'Facts So Romantic' blog in *Nautilus* quoted SFI President **David Krakauer** in a May 23 article that questions "genius" as a capability.

The Christian Science Monitor featured a recent study by External Professor **Simon DeDeo** (Carnegie Mellon University) and coauthors in an article about quantitative approaches to studying the humanities on May 16.

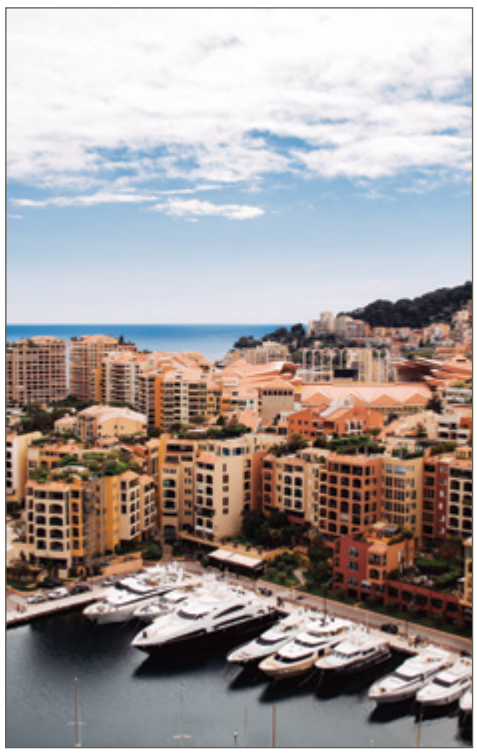
Work by SFI Trustee **Michael Mauboussin** was highlighted in "Invest Like the Best," the podcast of the Investor's Field Guide during an interview with Microsoft's Tren Griffin.

On May 9, *Quartz* featured Professor **Mirta Galesic's** research in an article about team decision-making and group diversity.

May's most-read article on *VoxEU* was Professor **Sam Bowles'** op-ed on how Marx influenced modern microeconomics.

Daimler Next interviewed Distinguished Professor **Geoffrey West** about scaling laws, and "escaping the treadmill of superlinear growth" for an April 27 article.

SFI co-founder **David Pines**, who died on May 3, was remembered by *The New York Times* as an "insightful and influential physicist."



Monte Carlo, Monaco-Ville, Monaco (Photo: Simon Moore)

Working group to discuss climate change and the human niche

Over the course of our species' existence, humans have migrated to inhabit most ecosystems on earth. We've adapted to hot and humid climates, found ways to survive cold deserts, and made homes in coastal, arid, and intermountain landscapes. Our human niche — the environments we call home — has changed over the past six thousand years as we have found new ways to adapt to novel conditions. But despite our movements and expansion, our basic preferences for certain combinations of temperature and precipitation have remained remarkably stable.

In the next 50 years, though, Earth's changing climate will likely force dramatic human migrations as places that are now in this preferred niche become less hospitable.

SFI External Professor Tim Kohler (Washington State University), Marten Scheffer of Wageningen University in the Netherlands, and Chi Xu of Nanjing University in China, will co-lead a working group at SFI on July 10-13, 2018 to discuss climate projections for the next 50 years, and what those projections may mean for the future human niche.

"We'll be looking at climate projections under three basic scenarios," says Kohler. "These range from 'business as usual' to a scenario where the world moves aggressively to limit additions to greenhouse gases."

The projections the group has examined so far are sobering. "A key problem humanity will face is that those places in the world that the UN projects as gaining the most population in the next several decades are those least likely to remain in the preferred climate niche."

During the July meeting, the working group's members will take a close look at their models and analyses to identify any pitfalls and to consider the ramifications of their results as they work toward publication.

Toward a new understanding of aging and infectious disease

The 21st century is an excellent time to be an infectious disease. Eight billion people now live on Earth, providing countless new hosts; international travel allows for rapid transmission; and climate change is helping some pathogens expand into new areas. As the spread of infectious diseases becomes an ever more challenging threat, it's crucial to understand the interplay between age — both of hosts and pathogens — and infectious disease.

In July, an interdisciplinary group of researchers will gather at SFI in hopes of deepening that understanding at a three-day working group to be held July 26-28. Infectious disease expert and theoretical ecologist Mercedes Pascual (University of Chicago), Co-chair of SFI's Science Board, says scientists still have a lot to learn about the relationship between aging and infectious disease. Pascual is co-organizing the working group with physicist and modeling specialist Jean Carlson of UC Santa Barbara.

"The question of human health is central of course, since we are talking about questions of resilience in the face of aging, and infectious diseases are a major component of human health and what happens with our susceptibility to disease," Pascual says. "It's important to our quality of life and the length of our life."

And just as important as understanding how people respond to infectious diseases at various ages is how those diseases are evolving to outsmart the defenses of their human hosts, she adds. "Pathogens are evolving to escape the immune system," Pascual says. "The immune system is also adapting to [the pathogen]." HIV and malaria are two examples of this, she notes. "I think we need to better understand how to put those two feedbacks together, and use that understanding to better intervene or control."

One key topic of discussion will be how the age a person is when she or he is exposed to an infectious disease can affect susceptibility to that disease later in life — especially if the disease has evolved and changed itself.

"I'm talking about pathogens that are escaping our immune system and don't respond well to vaccines," Pascual says. "In some sense, two people who are 20 at two different times may have seen something very different in their past. As the virus changes, they may therefore have very different susceptibility."

The flu is a good example, she adds. "Some ongoing research on the influenza virus would indicate that the types of exposure, the variants of the viruses that we see early in life, determine our responses later on in life. So our immune responses are influenced by the first exposures, the first variants we encounter. It's the conditions one encounters when young that would then determine later susceptibility. So what matters is what age cohort you are, and not your real age. It's very interesting and an example of complex time."

Pascual credits the James S. McDonnell Foundation for supporting research in this area as part of SFI's Aging, Adaptation, and the Arrow of Time research theme. She says she is hopeful that bringing together experts from fields as varied as immunology, ecology, evolution, and computational science will lead to new insights and further discussion about the nexus between aging and disease. "A major goal of having this meeting is to bring together people working on different aspects of infectious diseases," she says. "We have different types of scientists, including let's say complex systems types that do not work with infectious diseases. The idea is to formulate new questions that are important in this area, and develop new ideas and new models, as well as new ways to look at data."

Understanding the complex relationships between infectious diseases and aging is crucial in determining how to effectively combat them, adds Carlson. "I believe that the importance of taking a systems level approach is increasingly appreciated, especially as it relates to aging and variability of response to disease and therapies," she says. "Questions that arise generally in complex systems — adaptation, co-adaptation (of the host and the pathogen), complex and time-varying environments, diversity, dynamics, tradeoffs, information, and entropy — are central to understanding infectious diseases and developing robust therapies."

A man covers his mouth with a handkerchief while walking, ca. 1862

ACHIEVEMENTS

SFI External Professor **Melanie Moses** (University of New Mexico) has won a 2018 Women in STEM Award to support her research in multiscale modeling of swarm dynamics. The awards, ranging from $3,000 to $15,000, are supported by an anonymous gift to the University of New Mexico.

SFI Science Board member **Richard Lenski** has been elected as a member of the American Philosophical Society. The APS, founded by Benjamin Franklin in 1743, promotes "useful knowledge" by engaging top scholars from a variety of academic disciplines. Lenski is a Hannah Distinguished Professor at Michigan State University where he has been running the longest-running evolution experiment in history, breeding strains of *Escherichia coli* since 1998.

SFI External Professor **Mahzarin Banaji** has been elected as a member of the National Academy of Sciences. Banaji is the Richard Clarke Cabot Professor of Social Ethics at Harvard University. SFI External Professor **Pablo Marquet** has also been elected to the NAS as a foreign associate. Marquet is Full Professor of Ecology at Pontifica Universidad Católica de Chile in Santiago, Chile. Election to the NAS is a recognition of distinguished and continuing achievements in original research.

A canonical paper by External Professor **Mark Newman** (University of Michigan), Duncan Watts (Microsoft), and Steven Strogatz (Cornell University) was included in the American Physical Society's timeline of significant papers and events of the past 125 years. Their 2001 paper provides a framework for analyzing random graphs, which, "are good models for many real-world networks, such as epidemic spreading or social interactions," according to the APS summary.

SFI Distinguished Fellow **Murray Gell-Mann** also made the APS list for his "eightfold way" classification of elementary particles, published in 1962.

SFI External Professor **Constantino Tsallis** (Centro Brasileiro de Pesquisas Fisicas) has been elected as a member of the *Academia de Ciencias de America Latina*, which promotes development and applications for math and science research in Latin America and the Caribbean.

SFI Professor **David Wolpert** has been included in a NASA Group Achievement Award for his work on the Machine Learning and Data Sciences Team. Over 15 years, the team organized workshops on machine learning when the field was still nascent, published more than 100 journal and conference papers, and identified machine learning solutions that and influenced fields from aeronautics and space exploration to earth and space sciences.

SFI Trustee and writer **Cormac McCarthy** has been awarded the Humanities Prize by the School of Humanities and Education at Tecnológico de Monterrey in Mexico. The prize recognizes McCarthy's "deep and important contribution in the understanding of Mexico-USA relations through" his books like *Blood Meridian* and his Border Trilogy.

SFI Miller Scholar **Laurence Gonzales** won the Eric Hoffer Book Award and Montaigne Medal for his 2003 bestseller *Deep Survival: Who Lives, Who Dies, and Why* (W.W. Norton, 2003). The Eric Hoffer Book Award is given in honor of the American philosopher Eric Hoffer, who reflected on the human condition. The Montaigne Medal is a special distinction under the Eric Hoffer award umbrella that recognizes "the most thought-provoking books . . . that either illuminate, progress, or redirect thought."

The growing gap between physical and social technologies

The word "technology," from the Greek *techne*, usually evokes physical technologies like artificial intelligence, swarm robots, and the like. But there's an older meaning. By Jacob Bigelow's 1829 definition, technology can describe a process that benefits society. In that sense, social institutions, like governments and healthcare systems, can be seen, and studied, as technologies.

This summer at the Santa Fe Institute, a small cadre of scientists and entrepreneurs will convene a two-week long working group to address "the growing gap between our physical and social technologies." By bringing together an eclectic forum of engineers, writers, scientists, historians, lawyers, futurists, economists, philosophers, founders, philanthropists, and policymakers, the organizers aim to confront the apparent lag between our collective social technologies (e.g., political, economic, and cultural systems) and the nascent realities being synthesized by our physical technologies.

Labor efficiency, speed of transportation, and human communication have advanced in step with physical techonologies. These advancements have simultaneously exposed an unmet need for social technologies whose creation is outside the scope of the physical-technological toolkit. Thus, the working group, which will run July 30–Aug. 10, will examine the two technological domains from a multidisciplinary, non-dogmatic framework in pursuit of novel solutions to these complex problems.

"I have had my eyes on the approaching tsunami of change for a long time," says the working group's lead organizer, External Professor Steen Rasmussen (University of Southern Denmark). "It is difficult to assemble the needed diverse teams so we together can understand the complex issues as well as develop and explore potential solutions."

Those solutions could include blockchain-style, citizen-centric ownership of private data, for example, to address the privacy concerns that have been exacerbated by digital technology. Developing a new school of economic thought that looks beyond the capital/labor dichotomy might be another social technology that could ameliorate the effects of technological automation on economic inequality.

Rasmussen says the transformations that could result from such solutions would change "our economy, our institutions and what it means to be human."

Rasmussen's co-organizers include External Professors Eric Beinhocker and Doyne Farmer, both based at Oxford University, and physicist Fotini Markopoulou, CEO of the wearable technology company, doppel.

In conjunction with the working group, SFI's Applied Complexity Network (ACtioN) will be holding a pair of topical meetings on Aug. 1 and 8 in which participants from ACtioN's corporate, non-profit, and government member organizations will have the opportunity to participate in the group's proceedings. Interested ACtioN members should contact ACtioN@santafe.edu for more details.

Image: Feferefe via Pixabay

Incoming Postdoctoral Fellows

TAMARA VAN DER DOES

Beliefs about science

The people who surround us — our families, friends, and people in our broader communities — hold tremendous influence over how we understand the world. They impact our beliefs about religion, politics, and even science.

Starting in July, sociologist Tamara van der Does joins SFI as a Program Postdoctoral Fellow working with Professor Mirta Galesic to study how people's beliefs change over time. Through a grant from the US Department of Agriculture, she will investigate how people form beliefs about scientific issues like genetically modified organisms. She expects the results will be relevant for other hot-button issues like climate change and vaccines.

Van der Does explored how a specific demographic — children of immigrant parents in the US and western Europe — formed religious beliefs, and how that impacted their sense of identity, during her Ph.D. in sociology at Indiana University in Bloomington.

"I believe that religiosity and social identity shape individuals' core moral values and can explain resistance to changing beliefs about scientific issues," says van der Does, who plans to draw from sociology, psychology, and statistical physics to build mechanistic models of belief change.

MEYSAM ALIZADEH

Extremism and social networks

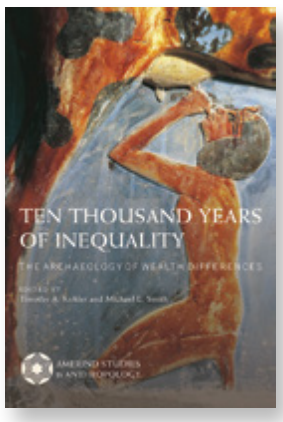
Computational social scientist Mesysam Alizadeh has been harnessing the wealth of network and human social data available through Twitter to understand the roots and spread of extremist ideology.

In recent projects during his Ph.D. at George Mason University and a postdoctoral fellowship at Indiana University Bloomington, Alizadeh has explored the moral and emotional factors underlying political extremism, and the personality factors that contribute to militancy.

He is also studying how extremism spreads on social media, and whether a person who holds an extreme opinion on one issue is likely to have similar extreme views of other issues as well.

Alizadeh will join SFI as a Program Postdoctoral Fellow in August 2018. He will be working with SFI Professor Mirta Galesic on a project that studies how communities make decisions about exploring new solutions to problems versus using known solutions in the face of a threat. The project, funded by the National Science Foundation — Decision, Risk and Management Sciences, addresses what is expected to be one of the most complex challenges in the near future.

New books by SFI authors



Ten Thousand Years of Inequality: The Archaeology of Wealth Differences (The University of Arizona Press, 2018) co-edited by SFI External Professor Tim Kohler and Michael Smith (Arizona State University) explores wealth inequality in historic human societies. Melding archeology, anthropology, and tools from modern economics, the book presents a set of quantitative measurements of ancient wealth disparities. Its chapters focus on societies ranging from hunter-gatherers to farmer villages to agrarian states and empires. Ancient Old World societies, the authors conclude, had higher levels of inequality than their New World counterparts.

The Emergence of Premodern States (SFI Press, 2018), edited by SFI External Professors Jeremy A. Sabloff and Paula L.W. Sabloff, tackles one of the most deceptively simple inquiries in archaeology: How did humans transition from hunter-gatherer societies into states — collective entities that are the movers and shakers of the modern world? In this volume, archaeologists, anthropologists, and evolutionary theorists investigate why, and how, this transition occurred independently in so many parts of the world, but not in others. The contributors leverage innovative methodologies — including agent-based modeling, network analysis, and theoretical applications of evolutionary biology — to push quantitative archaeology and anthropology in new directions.

Painting of deer hunt by unknown artist commissioned by Qing dynasty (Wikimedia Commons)

ArchaeoEcology Project studies ancient socio-ecological dynamics

The ArchaeoEcology Project — a group of ecologists, cultural anthropologists, geoscientists, and archaeologists studying the unique and myriad ways that humans interact with other species across space and time — meets for the third time at SFI October 15-19, 2018.

Most ecological studies don't include humans, but for thousands of years, our species has used other species more intensively and extensively than any other organism on the planet. We use plants and animals for food, clothing and shelter. We also recombine species in novel ways: we've used tree parts and animal hides to construct boats; mixed dairy, sugar, and coffee for a morning drink; constructed wardrobes of leather, silk, wool, and cotton. Sometimes our use has been sustainable, and sometimes we overexploit our resources.

"As an archaeologist, I'm interested in this because it tells us about a society's resilience," says Stefani Crabtree, a postdoc at Penn State who coordinates the ArchaeoEcology Project with SFI Vice President for Science Jennifer Dunne. The Ancestral Puebloans of the American southwest, for instance, had seven centuries of robustness, then experienced ecological collapse. "They dealt with the things we're facing today — things like hunger and climate change. They migrated away from their settlements, but their culture was resilient."

With a focus on deep time, the group has identified six cultures around the globe with good archaeological, anthropological, and ecological data for the project. The week-long October meeting will give participants a chance to meet in small breakout groups to analyze the data collected for each particular society. They will also meet as a larger working group to integrate the analyses into a comprehensive look at socio-ecological dynamics of the past.

"We are essentially trying to create a narrative of six cultures that had zero interaction with each other," says Crabtree. "They aren't even necessarily contemporaneous. But we're telling a story of resilience and robustness with the environment. We're interested in the historical data, but we're also trying to bring the lessons of the past cultures to modern day."

The working group is supported in part by a grant from the Coalition for Archaeological Synthesis (CfAS).

Postdocs to give flash talks, get writing tips in upcoming conference

The fourth Postdocs in Complexity Conference will be held at the Santa Fe Institute September 5-7, 2018. It will bring together many of the same participants who have attended prior conferences — two sets of prestigious interdisciplinary researchers including 13 postdoctoral fellows based at SFI and 27 James S. McDonnell Foundation fellows who hail from academic institutions around the globe.

The bi-annual meeting provides networking opportunities for early career researchers working on complex systems science, as well as special sessions from SFI faculty and other prominent speakers.

This three-day conference will build on the themes of the previous three Postdocs in Complexity meetings, refining the structure to allow additional time to build community and focus on collaborations.

Early on the first day, participants will reintroduce themselves to one another through 3-minute flash talks with a creative bent: they'll be allowed a single slide to convey their research. Later, participants will pitch ideas for the Research Jam sessions, a popular component of the conference where the postdocs work in small groups, to tackle challenging research issues.

A new component of this conference provides an opportunity to foster collaborations: participants are invited to submit proposals to SFI's science office for future small group meetings at SFI.

The agenda also includes a science writing session laying out principles for writing for scientific journals, and another session on writing op-ed columns. "Participants will learn how their area of expertise can be part of the wider public debate, helping to establish themselves as leaders in their field," says Hilary Skolnik, SFI's Postdoctoral Fellows Program Manager.

The Postdocs in Complexity conference is generously funded by the James S. McDonnell Foundation.

Working group seeks laws of synchrony in ecology

Complexity scientists search for deep similarities between physical and living systems — molecules and investors, coin flips and foraging animals, even magnets and pistachio trees, as described in a recent research paper by SFI External Professor Jon Machta (UMass Amherst) and colleagues.

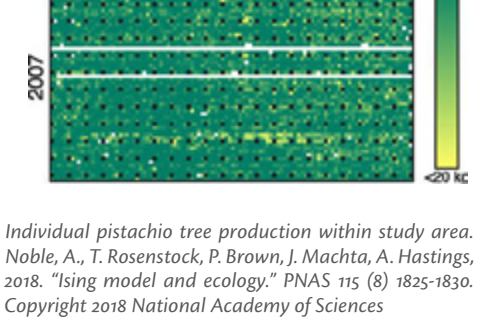
Though seemingly unrelated, magnetism and pistachios converge in the study of synchronization, where researchers seek to determine universal predictions about collective behavior. Synchrony drives the magnetism on the refrigerator as countless electrons, behaving like individual magnets, align themselves on a microscopic scale while also syncing up on a large scale to create a magnetic force. Similar patterns play out in the periodic behavior of organisms like pistachio trees and locusts, where local interactions coalesce into widespread patterns across both space and time.

Ernst Ising first developed a model for macroscopic magnetism, or ferromagnetism, in the 1920s, and Machta and his colleagues have recently started to apply the eponymous Ising model and other tools from statistical physics to ecological problems.

"It's an extraordinary fact that a theory developed for magnetism works for a much more complicated system," says Machta. "If you're thinking ecologically, let's say in the case of a pistachio orchard, the electrons are like trees and they interact somehow so that many nut-bearing trees will be synchronized in having a heavy crop followed by a light crop."

Machta and his colleagues Alan Hastings of UC Davis, Karen Abbott of Case Western Reserve University, and Julie Blackwood of Williams College are convening an SFI working group in August to further explore how ideas and approaches from statistical physics can offer additional insights into ecological and biological phenomena. "The very generic question of the working group is how do simple, locally interacting systems develop synchrony?" says Machta.

The working group will explore datasets, both old and new, but will also tackle some purely theoretical ideas, such as whether the physics concept of self-organized criticality can apply to biology as well. Machta hopes the group might eventually write up a review on the implications of statistical physics ideas for ecology and clarify some of the mechanisms behind previous insights. For now, however, the more immediate goals are to foster collaboration and interdisciplinary research.



Individual pistachio tree production within study area. Noble, A., T. Rosenstock, P. Brown, J. Machta, A. Hastings, 2018. "Ising model and ecology." PNAS 115 (8) 1825-1830. Copyright 2018 National Academy of Sciences

Barrier of meaning *(cont. from page 1)*

Barbara Grosz (Harvard University). But in some cases, Mitchell remarks, modern computers are quite vulnerable. One clear sign that computers do not function like intelligent beings — even in cases where they perform tasks that appear intelligent — is that they can be tricked by what are called "adversarial examples" into making mistakes that humans would not make. Researchers at Carnegie Mellon, for example, developed glasses that would make facial recognition systems misidentify the person wearing them.

Mitchell asks, "Does the lack of understanding inevitably render these systems fragile, unreliable, and vulnerable to attacks?"

The workshop will bring together a diverse group of researchers across multiple disciplines including psychology, biology, social science, information theory and artificial intelligence. Mitchell hopes that it will be the first of many conferences. Computers have made impressive advances, Mitchell remarks, but the challenge to get computers to, say, make sense of a text is still really hard. Workshop participants will ask questions about new developments and revisit questions that often leave them divided, like the old cognitive science question that persists: How much is intelligence innate to humans?

Broken brains *(cont. from page 1)*

concepts borrowed from network theory, nonlinear dynamics, and collective computation to the brain, and for the theorists to understand the kinds of brain data-gathering techniques that neuroscientists currently use, such as specific types of magnetic resonance imaging.

Broadly, they also hope to discuss what it means for a brain to "break." It's easy to tell if someone has dementia from interacting with them — but it's difficult to connect those behaviors with observable physical signals in a brain. The big idea is, "If someone has a stroke or dementia, what does that brain look like?" Petersen says. These new mathematical tools could help spot recurring patterns in how different parts of a diseased brain signal to each other.

Working group to parse words, meaning

When a student of German offers you *ein Gift*, it's fairly safe to say that he didn't mean to threaten you with poison. A newcomer to Italian might wonder why lamb's wool is considered *morbido*, while in Spanish, the beginner who has misspoken now confesses to be *embarazada* — pregnant.

These false cognates — *falsche Freunde*, *faux amis*, or "false friends" — abound in any two languages, particularly those that are closely related. The bane of the language-learner, however, is a gold mine for linguists, cultural evolutionists, and computer scientists, a group of whom will meet at SFI Aug. 27–28, 2018. Given the messy state of linguistic affairs, they ask, is it possible to quantitatively encode "meaning" independent of any particular language?

"If I tell you all of the contexts in which a given word fits, you probably have a pretty good sense of what its 'meaning' is," explains SFI External Professor Tanmoy Bhattacharya (Los Alamos National Laboratory), a co-organizer of the working group. But it is a far cry from that to quantifying the linguistically salient measures of distance between meanings. Nevertheless, "It seems that all over the world, people have similar notions of [linguistic] distance. For example, if you didn't have a word for 'salt' and wanted to use a word, you say 'salt' is made by 'drying seawater.' And it turns out that no matter which language you take, *salt* is close to *seawater*. What can that tell us about how we divide the world into pieces?"

Translation may be one place to start. Rather than going the language-class route, scientists are interested in removing any kind of cultural bias: simply feeding large linguistic datasets to a computer, telling it only what translates, and testing what the machine learns. The computer takes, say, a German sentence, changes it into an intermediate representation as zeroes and ones, and takes that to another language, such as English.

What happens, then, when the German-to-English translation is halted halfway and redirected to French?

"It may turn out this is a pretty good translation from German to French," Bhattacharya notes. "The zeroes and ones could be powerful enough to go from *any* language to *any* other language." In fact, recent work by Google scientists found evidence for such an interlinguum.

Among the organizers of the working group is External Professor George Starostin (Higher School of Economics, Moscow), a curator of the Evolution of Human Languages (EHL) Project, SFI's long-standing project for investigating deep-level historical connections between the many linguistic families of the world. "The study of semantic shifts — subtle, gradual changes in word meanings that accumulate over time — is just as important for unraveling language history as is the study of sound change, which has traditionally dominated historical linguistics," says Starostin. "In addition, historical databanks on semantic shifts, built up in the process of our investigation into the distant past of modern languages, may help shed valuable light on certain universal or culturally conditioned properties of the human mind — letting us understand which types of meanings are more commonly connected in the brain, bringing us even closer to the construction of a universal semantic meta-language." In between elements of historical and synchronic research, the working group will be using semantic networks and aspects of cultural evolution to, among other things, predict true cognates and break down how meanings shift over time.

Is the goal to perfect Google Translate? Not exactly: the aim reaches far beyond. "This internal set of zeroes and ones is probably a representation of *meaning*," says Bhattacharya. "*This* is an idea that we want to follow."

External Professors Eric Smith (Tokyo Earth-Life Science Institute) and Peter Stadler (Leipzig University) are also organizing the working group.

"... no matter which language you take, salt is close to seawater." Above: salt farmers harvesting salt, Pak Thale, Ban Laem, Phetchaburi, Thailand. Photo: J. J. Harrison

Not to scale? Maya civilizations show strange correlation

Researchers who study urban areas have long observed a connection between size and proximity — namely, that cities become more dense as they gain in population. The more people live in a place, the closer together they live and work. This closeness is important: It likely accelerates learning and facilitates the sharing of ideas. It's readily demonstrated by data on civilizations separated by time and space, from pre-conquest Central Mexico to Medieval European cities to present-day metropolises.

But some societies buck the trend. Archaeologists have found evidence of "low-density urbanism" around the globe, including Maya sites in Mesoamerica. These populous areas didn't undergo a density increase as their numbers swelled; in some cases, they followed an inverse correlation.

"The existing data we have for Maya society shows the opposite pattern," says anthropologist and SFI External Professor Scott Ortman (University of Colorado-Boulder). As the Maya population rose, the city spread out, and the density fell. People didn't live closer together; they spread out.

Together with External Professor José Lobo at Arizona State University, Ortman leads the Social Reactors Project. At a working group at SFI this August, Lobo and Ortman will bring together a group of early career scholars to examine the challenge posed by low-density Maya settlements to the idea that density increases with population.

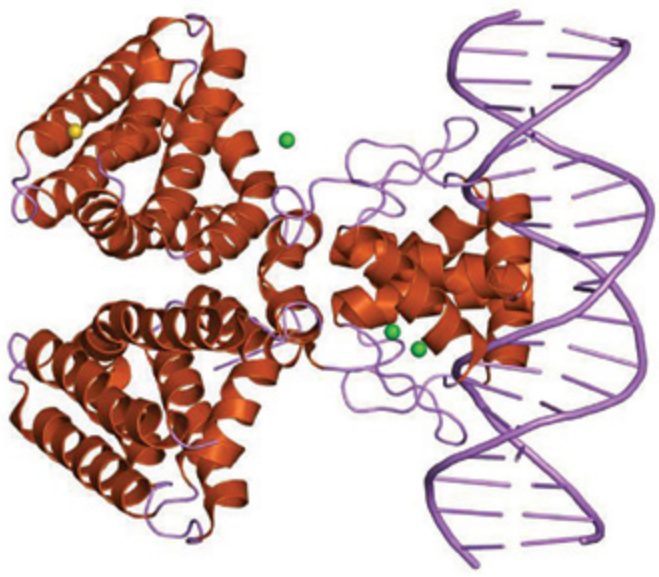
In recent years, scholars' abilities to probe Maya history and culture have increased thanks to LiDAR surveying technology. *LiDAR*, a remote-sensing tool, is particularly useful in mapping rugged terrain. It works by firing laser pulses over an area from above, then measuring the return time of the pulses to produce a three-dimensional map of landforms and buildings, including those that might be hidden by jungle. Many scholars who will attend the August working group have expertise in using LiDAR on Maya sites.

Ortman says that by revealing the hidden boundaries of settlements, LiDAR might help scholars understand how low-density societies align with the general scaling framework observed in other civilizations, old and new. The data from Maya studies challenge not only the correlation between population and density, but also the very idea of what it means to be a city.

"What we're not sure about is whether the difference we see implies that Maya society worked in a different way," says Ortman, "or if it's just a function of the way Maya archaeology has been done."

"Mayan Ruins, Yucatan" by Robert S. Duncanson, 1848

RESEARCH NEWS BRIEFS



Culaea inconstans by Stephen Alfred Forbes

HOW LIFE GENERATES NEW FORMS

When organisms change during the course of evolution, often what drives new forms is not genes themselves, but gene regulation — what turns genes on and off. A new study co-authored by SFI External Professor Andreas Wagner (University of Zürich) and Joshua Payne (ETH Zürich, Swiss Institute of Bioinformatics) identifies the kind of gene regulation most likely to generate evolutionary change. According to the paper, published in March in *PNAS*, it's the gene regulation by protein transcription factors that more readily powers evolutionary change than another kind of regulation that works at the RNA level. The evolvability of transcriptional regulation may help explain why organisms switched from using RNA to store information some 4 billion years ago, to using DNA and proteins, says Wagner.

PITFALLS IN THE LANGUAGE OF ECOLOGY

When science relies on language to describe and categorize phenomena, it's easy to stumble across the shortcomings of words. In ecology, concepts and acronyms can oversimplify complex realities, write Andrew Johnson of the Scripps Institute of Oceanography, a participant in the 2017 SFI Complex Systems Summer School, and co-author Susanna Lidström in a *Nature Ecology & Evolution* Comment. Popular terms like "ecosystem-based management," "Anthropocene," and "resilience" lack clear definitions and specificity. In some cases, there may not actually be the scientific consensus around the idea that a term's popularity implies. Others, like "ecological niche" have changed in meaning throughout the history of the field. But highly specific language and jargon can also pose problems when policy makers and scientists from other fields need to apply ecological research to management decisions. "Rather than hiding uncertainty and complexity behind apparently robust concepts, we believe that maintaining intricacies and details through plain descriptions can increase the explanatory power of ecological science," write the authors.

PATRILINEAL WARFARE BEHIND THE "Y CHROMOSOME BOTTLENECK"

Since 2015, researchers have known that something dramatic happened 5,000 to 7,000 years ago to the world's male population. Genes of modern men suggest that most male humans died, leaving one male for every 17 females. Theories explaining this hypothesis have ranged from environmental to political, but a study published in *Nature Communications* by SFI Science Board Member Marcus Feldman (Stanford University) offers another explanation: patrilineal clans fighting one another reduced not the total male population, but rather genetic diversity among males. In patrilineal societies, where males share a common ancestor, there is little diversity in the population's Y chromosome. Warfare between these clans could have led to the "Y chromosome bottleneck" identified in 2015.

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SNAPSHOTS FROM THE INAUGURAL INTERPLANETARY FESTIVAL *(clockwise and spiraling inward from top left): Festival Director Caitlin McShea; author Cory Doctorow signs books; Ozomatli performs; Shay Youngblood keeps the audience enrapt; a Currents New Media exhibit, SFI Professor Michael Lachmann and his daughter, Ella; a very InterPlanetary crowd, panelist Annalee Newitz; an InterPlanetary fist bump; Amy Lindquist of The Sticky; panelists Graham Spencer, Jonah Nolan, and Kurt Squire, along with emcee D.A. Wallach; Bob Davis's rocket in the Railyard. (Photos by Kimberly Corante, Aaron Leventman, Katherine Mast, and Scott Wagner)*

InterPlanetary Festival 2018

June 7–8 of 2018, the first annual InterPlanetary Festival drew space enthusiasts from around the world for a celebration of human ingenuity. Each day, approximately 4,800 people attended festival events in the Railyard District in downtown Santa Fe. In addition to live music, immersive art, games, and an innovation expo, festival-goers enjoyed panel discussions with leading thinkers on topics central to the future of our species.

The annual festival is part of the Santa Fe Institute's larger InterPlanetary Project that seeks to "Change the world one planet at a time." By embracing the challenge of sustaining complex life on other planets, the project hopes to foster a shared understanding of life's place in the universe. The organizers believe this shared understanding could ultimately benefit our first planet, Earth.

Video recordings of the panel discussions are available through the Santa Fe Institute's YouTube channel: youtube.com/user/santafeinst. Additional information about the annual festival can be found on the InterPlanetary Festival website: www.interplanetaryfest.org

RESEARCH NEWS BRIEFS

(cont. from page 5)

INSTITUTION SHOCKS

On September 4, 1970, socialist Salvador Allende won the Chilean presidential election. His victory triggered an unanticipated "institutional shock" with a dramatic drop in the Santiago Stock Market. Three years later, when the Chilean armed forces overthrew the constitutional government and replaced Allende with autocrat Augusto Pinochet, the stock market skyrocketed. In a paper published online in April in the *Journal of Development Economics*, SFI Professor Sam Bowles and co-author Daniele Girardi of UMass Amherst examine new data from these events in Chile, which offer a rare natural experiment to study the impact of institutions on economies. "The most parsimonious interpretation of these share price changes is that they reflected, respectively, the perceived threat to private ownership of the means of production under a socialist government, and its subsequent reversal," write the authors.

HOW WE SEE THE WORLD DEPENDS ON WHO SURROUNDS US

Humans make judgments about ourselves and others, assessing our thoughts and status against what we perceive around us. Social judgments like "I'm doing better (or worse) than everyone else" or "My ideas are totally unique (or everyone thinks like me)" can appear contradictory. But a new Social Sampling Model, published in *Psychological Review* in April by SFI Professor Mirta Galesic, External Professor Henrik Olsson (University of Warwick), and Jörg Rieskamp of the University of Basel, suggests they can be explained by a single quantitative theory. Social judgments, find the authors, depend largely on the composition of people's social circles.

COOLER COMPUTING THROUGH STATISTICAL PHYSICS

Recent breakthroughs in the field of nonequilibrium statistical physics have revealed vast areas of research lying hidden within the "thermodynamics of computation." Advances in this field, which involves elements of statistical physics, computer science, cellular biology, and possibly even neurobiology, could have far-reaching consequences for how we understand, and engineer, our computers. To kick-start this line of research, Santa Fe Institute scientists and their collaborators have launched an online wiki for collaboration. In June, SFI External Professor Joshua Grochow (CU Boulder) and Professor David Wolpert also published a paper in *SIGACT News* that neatly summarizes insights and open questions in the field Ultimately, they hope their research will inspire more energy-efficient designs for technology.

Parallax
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