Science Club explores puzzles of politics and voting

Over the last few decades, the divide between the two major political parties in the United States has deepened. Studies of Congressional voting patterns show that politicians take increasingly polarized positions, and that those positions drift farther and farther apart over time. Not voters, though. Since the 1960s, voters have stayed in the middle, usually preferring centrist or moderate policy positions over extremes.

This contrast gives rise to a paradox: If voters gravitate toward the center of the political spectrum, why are the parties drifting farther apart?

At the latest meeting of SFI's Virtual Science Club on Sept. 16, Vicky Chuqiao Yang, an SFI Omidyar Fellow and Peters Hurst Scholar, showed 40 attendees how dynamic mathematical models can help us make sense of this and other puzzles of politics and voting.

"As part of a growing body of SFI work related to belief dynamics, Vicky uses mathematics to model the impact of different learning, decision-making, and group formation rules on emergent, political outcomes" says Will Tracy, SFI's Vice President for Applied Complexity. "She also explores predictive models that connect polarization at different levels of political granularity; a topic that is particularly relevant on the eve of the U.S. presidential election."

Following the presentation, SFI External Professor Sean Carroll (Caltech) asked about an interesting intersection between Yang's current projects on group formation and learning rules. Other participants posed questions and conversed on topics related to Yang's unpublished research on how "us vs. them" dynamics impact moderate voters, and what happens when the majority of voters "follow the crowd."

Membership in the Science Club is one of several benefits extended to SFI's financial supporters at the Emergence Circle level ($1,000) and up. In 2020, meetings moved to a virtual platform, which organizer Alanna Faust, SFI Applied Complexity Associate, says has increased engagement well beyond the immediate Santa Fe community.

Politics is just one of many topics Science Club members grapple with in direct conversation with leading complexity researchers. Past meetings have delved into climate records, quantum computing, the science of cities, maladaptive medical beliefs, and other captivating regions where science meets society.

To be part of the conversation and the next scientific advances, go to www.santafe.edu/support. 🐦

Have you no humanities?

The sciences and humanities are often characterized as disparate cultures. Scientists quantify the natural world, studying patterns produced by the forces of nature. Humanities scholars dissect texts, stories, and human-made artifacts, studying patterns produced by the forces of culture.

As archives of digital texts expand and become widely available, though, digital tools are becoming not only useful but also necessary to advance fields that don't fall under the STEM umbrella. Experts at SFI say the computational and quantitative tools used by scientists have a potentially transformative role to play in advancing the humanities.

Later this year, supported by a grant from the National Endowment for the Humanities, SFI will launch a new NEH institute called "Foundations and Applications of Humanities Analytics," to introduce early-career humanities scholars to new ways of studying culture using a wide range of computational tools. Leading researchers in the humanities and sciences will draw on models and ideas in information theory, statistics, and computer science for new insights into the dynamics of literature, history, and the arts.

In its first year, the institute will be offered online to a wide audience through SFI's Complexity Explorer platform; in years two and three, a smaller group of students will be invited to SFI for an in-person intensive school.

"This institute puts SFI in a position to bridge cultural gaps that don't need to be there," says philosopher David Kinney, an Omidyar Fellow at SFI who is leading the new institute.

"We want to introduce people who study the humanities to new ways of seeing everything from the experience of reading a poem to the arc of global history," says SFI External Professor Simon DeDeo, a cognitive scientist at Carnegie Mellon University who is co-leading the institute with Kinney and Carrie Cowan, SFI's Director for Education.

Recognizing the opportunity to introduce complexity science to a new audience, Cowan enlisted

SFI @SciWri: *Researchers unveil massive analysis of online hate & counter-speech*

In a special presentation for the online Science-Writers2020 conference in October, SFI's Joshua Garland and Mirta Galesic will present the first large-scale analysis of tens of millions of instances of hate and counter-hate speech on Twitter.

Their preliminary findings, which have not yet been peer-reviewed, suggest that organized movements to counteract hate speech on social media are more effective than striking out on one's own.

"I've seen this big shift in civil discourse in the last two or three years towards being much more hateful and much more polarized," says Garland, a mathematician and Applied Complexity Fellow at SFI. "So, for me, an interesting question was: what's an appropriate response

when you're being cyber-bullied or when you're receiving hate speech online? Do you respond? Do you try to get your friends to help protect you? Do you just block the person?"

To study such questions scientifically, researchers must first have access to a wealth of real-world data on both hate speech and counter-speech, and the ability to distinguish between the two. That data existed, and Garland and collaborator Keyan Ghazi-Zahedi at the Max Planck Institute in Germany found it in a three-year interaction that played out over German Twitter: As an alt-right group took to the platform with hate speech, an organized movement rose up to counter it.

"The beauty of these two groups is they were self-labeling," explains Mirta Galesic, the team's

social scientist and a resident professor at SFI. She says researchers who study counter-speech usually have to employ hundreds of students to hand-code thousands of posts. But Garland and Ghazi-Zahedi were able to input the self-labeled posts into a machine-learning algorithm to automate large swaths of the classification. The team also relied on 20-30 human coders to check that the machine classifications matched up with intuition about what registers as hate and counter-speech.

The result was a dataset of unprecedented size that allows the researchers to analyze not just isolated instances of hate and counter-speech, but also compare long-running interactions
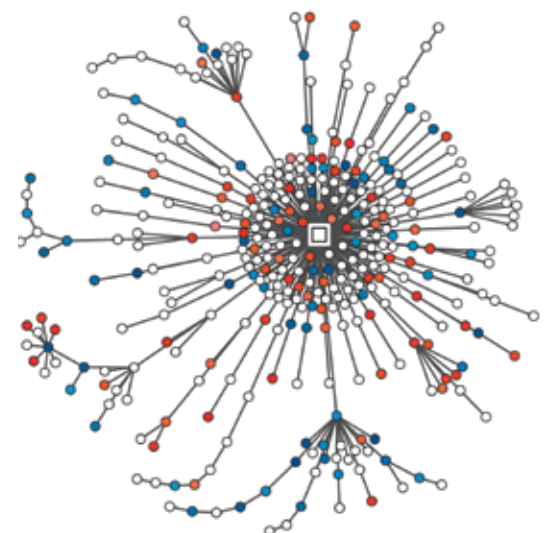
Examples of Twitter conversations (reply trees) with labeled hate (red), counter (blue), and neutral speech (white). (Figure: Garland et al.)

BEYOND BORDERS

THE INEQUALITIES THAT DEATH COMPLETES

In what is widely considered the preeminent biography, *The Life of Samuel Johnson*, James Boswell declares, "It matters not how a man dies, but how he lives." Johnson, of course, had more to say on the topic, making his equalizing point: "Disease generally begins that equality which death completes; the distinctions which set one man so much above another are very little perceived in the gloom of a sick chamber…"
Johnson: Rambler #48 (September 1, 1750)

If there is one thing we have learned during these months of pandemic, it is that far from being indiscriminate in its actions, COVID-19 has attached itself to the lopsided superstructures of society in such a way as to brutalize some groups and only challenge others. The complex nature of this infection has revealed, through differential stresses, the inadequacy of both our understanding and control of cascading perturbations. And the great diversity of areas affected by the infection are only now being fully revealed.

In a recent analysis of 5,800 small businesses, published in *Proceedings of the National Academy of Sciences*, Alexander Bartik at the University of Illinois at Urbana-Champaign (with colleagues at Harvard and Chicago), reported that 43% of all businesses in their sample had temporarily closed as a result of COVID-19 and reduced their active employment by 39%. The average firm with monthly expenses over $10,000 had barely enough cash to survive for up to two weeks. In the U.S. alone more than 20 million people have been removed from the workforce.

The impact of the pandemic has been highly uneven sector-by-sector and state-by-state. In Pennsylvania, the Accommodation and Food Services industry lost 29.2% of jobs, Manufacturing 7.0%, and Health Care and Social Assistance employment 5.4%. Idaho experienced the smallest drop in employment at 1.8% of its payroll jobs, followed by Mississippi at 3.0%.

Leisure and Hospitality experienced the largest reduction in employment with the Accommodation and Food Services industry down 22.7% (3.3 million jobs), and the Arts, Entertainment and Recreation industry 35.2% (870,000) jobs as of August. Hawaii — the most remote state from the mass of infections — is down 54.3% (with a loss of 61,600 jobs).

The economic effects of the pandemic have been compounded by challenges to both physical and mental health. In a recent brief on "The Implications of COVID-19 for Mental Health and Substance Use" Nirmita Panchal (a policy analyst for the Health Care Marketplace Project at the Kaiser Family Foundation) and her colleagues found that "More than one in three adults in the U.S. have reported symptoms of anxiety or depressive disorder during the pandemic (weekly average for May: 34.5%; weekly average for June: 36.5%; weekly average for July: 40.1%)." They describe a related study in which 13.3% of adults resort to substance use as a means to manage stress related to the coronavirus.

Health-related concerns are concentrated along ethnic lines. In a recent paper published in *Clinical Infectious Diseases*, Don Bambino Geno Tai and colleagues at the Mayo Clinic report on "The Disproportionate Impact of COVID-19 on Racial and Ethnic Minorities in the United States." They describe recent CDC data in which "21.8% of COVID-19 cases in the United States were African Americans and 33.8% were Latino,

> MORE ON PAGE 3

www.santafe.edu

SFI Professor **Jessica Flack** and Davis Professor **Melanie Mitchell**'s momentous essay on COVID-19, and how complex systems can show us new paths forward, was published in *Aeon*. It was the magazine's most-read article for September.

Mitchell was also quoted in *WIRED* and in *The Economist* for her perspective on GPT3, a remarkable and imperfect text-generating AI program.

New Scientist, *Smithsonian*, *Cosmos*, and other outlets featured new research into the function of sleep by SFI External Professor **Van Savage**, Distinguished Shannan Professor **Geoffrey West**, and their colleagues. (See also "Size and sleep," below)

A sweeping *Aeon* essay told the origin story of origins-of-life research, with perspectives from SFI Professor **Chris Kempes**, External Professor **Eric Smith**, External Professor **Sara Walker**, and President **David Krakauer**.

For *Smithsonian*, SFI Postdoctoral Fellow **Natalie Grefenstette** commented on the requirements for massapanspermia, in an article about the implications of recent findings that bacterial clumps survived for three years on the outer surface of the International Space Station.

In a two-part interview for *KSFR FM* (Santa Fe's public radio station), SFI Professor **Cris Moore** and University of New Mexico's **Kathy Powers** discussed algorithms, big data, and criminal justice, following their presentation to the NM legislature's subcommittee on criminal justice reform.

SFI External Professor **Danielle Bassett** was quoted in *WIRED* in a feature about network neuroscience.

WIRED also quoted External Professor **Sam Scarpino** in an article about the lack of accurate COVID-19 data for low-income and minority communities.

In a Q&A for *Physics World*, External Professor **Doyne Farmer** shared his perspective on the economic impacts of COVID-19.

In a data visualization titled: "The Risk That Students Could Arrive at School With the Coronavirus," *The New York Times* featured work by SFI Professor **Michael Lachmann**, and by **Spencer Fox** and External Professor **Lauren Ancel Meyers** at the University of Texas Austin. It built on Lachmann and Fox's essay for SFI's "Transmission" series, adding a heat-map and county-level calculator for estimating how many infected students & personnel would arrive in schools of different sizes. 📄

Size and sleep: Why little things sleep longer

Sleep, in spite of its ubiquity, holds mysteries that have perplexed scientists for decades.

Now, using data from humans and other mammals, a team of scientists including researchers from SFI has developed one of the first quantitative models that explains why sleep times across species and during development decrease as brains get bigger. Crucially, the model identifies a sharp transition at around 2.4 years of age, where sleep patterns change in humans as the primary purpose of sleep shifts from reorganization to repair.

"By looking at sleep, and looking how it changes, you get insight into something truly fundamental about brain development," says Geoffrey West, a theoretical physicist who is Distinguished Shannan Professor and a past president of SFI.

Previous work done by West and Van Savage, a physicist and biologist who is a professor at UCLA and an SFI external professor, looked at differences in sleep times among mammals. The new research in *Science Advances* ties phylogeny — the evolutionary relationships between species — and ontogeny — the development of an organism as it ages — into a unified framework.

Although experts have proposed many possible reasons for sleep, the two most prominent are neural reorganization, which is essentially learning, and repair. During waking hours, the brain experiences wear and tear from blood flow and the everyday production of harmful chemicals; sleep cleans this up. The brain reorganizes and repairs mainly when asleep — West likens it to subway repairs that take place at night to avoid disrupting normal traffic.

Time asleep can roughly be divided into REM (random eye movement) and NREM (non-REM). Colloquially, REM sleep is often known as "deep sleep," but its purpose has remained an open question.

A sleeping child of about 3 years old (Photo: iStock)

To answer questions about REM and NREM, the new model reduces the brain to a series of simple equations that capture how the brain uses energy to process information (which it must then reorganize). Then the authors input data from a variety of studies that looked at sleep time, metabolic rate, and brain size for dozens of participants who ranged from infants to adolescents.

By determining the ratios of REM and NREM to total sleeping time — among other factors like brain size — the researchers were able to use the model to predict their respective purposes. It turns out REM sleep is primarily responsible for reorganization/learning that dominates early development, while NREM handles the everyday repair that occurs throughout life.

Around 2.4 years old, the researchers observed a sudden change, where the majority of sleep shifts from REM to NREM — a phase shift from sleeping to reorganize to sleeping to repair. In other words, humans sleep less in part because they no longer need to form as many new neural connections. This transition point has not been pinpointed before, but it could have important implications for development, according to Savage.

"The brain is doing something really amazing and very different during that period," he says. "What are the consequences of that, in terms of our ability to learn languages or adapt our brains to different situations?"

Preliminary measurements of other animals in development (rabbits, rats, and guinea pigs) show similarities to human sleep, but it's too soon to say if all mammal babies follow the same sharp transition.

"I'm very interested to see if our framework also can be extended to other mammals," says Junyu Cao, a researcher at the University of Texas at Austin and the paper's lead author.

The research was initiated at SFI in 2007 when Savage was a postdoctoral fellow working with West. It has since evolved through a series of workshops and working groups as part of the Institute's ongoing research on biological scaling laws and time. 📄

How early 'infotech' fueled collective computation & growth

In the last 10,000 years, the human species has gone from a population of perhaps one million people — almost all living as mobile hunter-gatherers — to close to 8 billion.

The ancient civilizations at the beginning of this rapid expansion across the globe differed in many ways. Each had its own culture, religion and system of government.

But one characteristic they all tended to share was a reliance on innovations in collective information processing to grow beyond a certain size and scale, according to research published in *Nature Communications* earlier this year by Santa Fe Institute Professor David Wolpert, External Professor Tim Kohler (Washington State University), and other SFI collaborators.

Pixelated pyramid (Image: TheDigitalArtist/Pixabay)

"We performed a new kind of statistical analysis of the time series of the development of different societies in the ancient world" said Wolpert. "We were quite surprised when the data told us that there was a very tight relationship between the dynamics of a society's collective computational capabilities and the dynamics of its size."

"Without innovations like writing or a system of currency, expansion beyond a certain point was rare," said Kohler. "However, once these and related advances in information processing and storage were achieved, you start to see the big empires of history emerge."

To delve further into this intriguing pattern in history, Wolpert and Kohler are convening a panel of experts Nov. 2-4 for a virtual workshop. Bringing archaeologists, computational historians, data scientists and a wide variety of other experts together is "unusual," says Wolpert, and provides an opportunity to also discuss advances in how the time series data generated by archaeologists and other historical scientists may be most fruitfully analyzed.

As they did for the *Nature Communications* paper, the experts will draw on insights from the Seshat Global History Databank. It is a massive assembly of historical and archaeological information spanning 10,000 years of human history, including various aspects of how information technologies such as roads and money have influenced the growth of human societies both from the ancient and more recent past.

They also plan on discussing some of the more interesting implications the research could have for the study of contemporary society.

"You have enormous new capabilities for storing and processing data that are just well beyond the scope of anything anybody could imagine," Kohler says. "Does that imply that we're going to have another growth in scale for polities? And if so, what would that look like?" 📄

SFI's Vice President for Science **Jennifer Dunne** was elected a Fellow of the Network Science Society (NetSci) for her "pioneering work elucidating the network structure of ecology, particularly food webs, highlighting the interplay of dynamics and structure of networks." Her award was presented during an online ceremony Sept. 24, as part of the virtual NetSci 2020 conference.

NetSci also awarded SFI External Professor **Sonia Kéfi** (University of Montpelier) the Erdős-Renyi Prize, an annual award for a scientist under 40, for Kéfi's "foundational and empirically grounded theoretical research that has advanced network science and its applications in ecology, with a focus on multiple types of interactions among species and the implications for global change, opening the path to new ways to study ecosystems."

"For her prolific contributions to complex systems science and artificial intelligence," SFI Davis Professor **Melanie Mitchell** received the New England Complex Systems Institute's 2020 Herbert Simon award. The award is presented annually at the Interna-

tional Conference on Complex Systems, in recognition of a researcher's lifetime contribution to complex systems science.

SFI's **Susan Carter**, Director for Sponsored Research, was named a Charter Fellow by the National Organization of Research Development Professionals (NORDP). "Considered the highest professional honor" the organization bestows, the fellowship recognizes members who have "worked tirelessly to advance research development." Research development, according to the NORDP website, "encompasses a set of strategic, catalytic, and capacity-building activities that advance research, especially in higher education. Research Development professionals help researchers become more successful communicators, grant writers, and advocates for their research. Research Development professionals also serve their institutions. They create services and resources that transcend disciplinary and administrative barriers." (See also "humanities" on p.1)

The high-profile journal *Physical Review Letters* picked a paper co-authored by SFI Professor **Sidney Redner** as an Editor's Suggestion. "Optimization in First-Passage Resetting" was selected for being "particularly important, interesting, and well written."

SFI Professor **David Wolpert** and Omidyar Fellow **David Kinney** won second place in an essay contest run by the Foundational Questions Institute (FQXi). The panel of judges cited "the discussion of the role of mathematicians as imperfect reasoners as novel and interesting." Their essay, titled "Noisy Deductive Reasoning: How Humans Construct Math, and How Math Constructs Humans," is published online at fqxi.org.

SFI's signature **Community Lecture** series was voted #2 Best Lecture Series in the Santa Fe Reporter's annual Best of Santa Fe contest. Normally held in The Lensic theater and streamed online, the 34-year series brings leading thinkers to Santa Fe to explore the most alluring questions in science. 2020's programming has been postponed due to the COVID-19 pandemic.

Network scientist **Raissa D'Souza**, an SFI external professor based at UC Davis, was appointed to the board of reviewing editors at *Science* magazine— one the world's top peer-reviewed journals. She will assist the editors in "identifying those manuscripts to be sent for

in-depth review in the fields of network science, applied mathematics, and machine learning" and "also play an active role in shaping the research that is highlighted in *Science*, in particular concerning new developments deserving of a perspective or a review, and exciting research reported at meetings."

An interdisciplinary research team including SFI External Professor **Mercedes Pascual** was awarded a $12.5 million grant from the National Science Foundation to start a new biology institute — Genomics and Eco-evolution of Multi-scale Symbioses (GEMS). The institute will bring together "molecular, organismal, computational, and theoretical approaches" to biology.

The European Social Simulation Association (ESSA) honored SFI External Faculty Fellow **Joshua Epstein** (New York University) with its most prestigious award — The Rosaria Conte Award for Outstanding Social Simulation. A pioneer and world leader in agent-based modeling, Epstein was among the first scientists to use bottom-up simulation to replicate the statistical macrostructures seen in complex social systems.

"Follow the leader" (Photo: Kathryn Cooper Wildlife kathryncooperwildlife.com)

A new journal for collective intelligence

Since the 1980s, the Santa Fe Institute has championed the investigation of collective behavior and intelligence in diverse systems, from cell tissues to animal societies to human organizations and robot swarms. This fall, two of SFI's faculty will help launch *Collective Intelligence*, a new transdisciplinary open journal entirely devoted to this fruitful area of research.

Collective Intelligence will welcome contributions from computer science, physics, biology, mathematics, economics, psychology, sociology, philos-

ophy, anthropology, and political science, as well as from non-academic practitioners.

SFI Professor Jessica Flack is one of the journal's four Founding Editors, along with SFI External Professor Scott Page at the University of Michigan, Panos Ipeirotis at New York University and Geoff Mulgan at University College London.

The online-only journal will be co-owned by the Association for Computing Machinery (ACM) and SAGE Publishing with support from and in collaboration with the innovation foundation Nesta.

between the two.

"Now we can resolve this massive data set from 2016 to 2018 to see how the proportion of hate and counter-speech changed over time, who gets more likes, who is retweeted, and how they replied to each other" Galesic says.

The quantity of data, a tremendous boon, also makes it "incredibly complex," Garland notes. The researchers are in the process of compar-

ing tactics for both groups, and pursuing broader questions such as whether certain counter-speech strategies are more effective than others.

"What I'm hoping is that we can come up with a rigorous social theory that tells people how to counter hate in a productive way that's non-polarizing," Garland says, "And bring the Internet back to civil discourse."

'Pandemic Pod' recreates SFI experience

For much of the past decade, the SFI postdoc "retreat" has been more of an offensive: a madcap race to speed-write a paper on a brand-new scientific question in 72 adrenaline-soaked hours. But this year, the postdocs' gathering was a retreat not from SFI's day-to-day calm, but to a recreation of it.

And — sheltered by strict safety protocols — it took place in person.

From Sept. 27-Oct. 2, the "Postdoc Pandemic Pod" convened at a spacious but secluded Airbnb near Taos, NM. With high-ceilinged workspaces and nearby trails, the location bore a striking resemblance to SFI's Cowan Campus — which was exactly the idea, said ASU–SFI Center Postdoctoral Fellow Anjali Bhatt, one of the retreat's main organizers. The schedule, too, approximated "a day in the life" on campus, with presentations balanced by unstructured time to bond and bounce ideas around.

"We tend to assume that in the world of scientific research that we develop these collaborations around research topics first and then we get to know each other," says Bhatt, who is one of the six postdocs whose fellowships

have started since January.

Despite the plethora of virtual offerings, Bhatt recognized her community's hunger for more of what sociologists term "collective effervescence": the energy generated when a group of people reaches a state of flow together.

"That's a lot harder remotely," says Bhatt.

Bhatt worked with Hilary Skolnik, Program Manager for the Postdoctoral Fellows, to tailor the safety protocol so that as many postdocs as possible could participate and feel safe. The system that was developed — a combination of quarantine prior to the retreat and, when necessary, a negative COVID-19 test — is flexible enough to fit various travel and caring needs while also assuring everyone involved that the retreat would be COVID-safe.

Ultimately, SFI understands that "time to sit together in a beautiful place is an exceptionally valuable thing as a scientist," says Tyler Marghetis, an Omidyar Fellow and Assistant Professor at UC Merced, who attended the retreat. "You spend a lot of that time in silence, but every once in awhile someone will say, 'I've been thinking about this' — and there you go. That sparks years of research."

DeDeo and Kinney to design the course, and Susan Carter, SFI's Director of Research Development, to help secure the NEH grant. U.S. Congressman Ben Ray Luján, who represents New Mexico's Third District, called to congratulate the team.

Cowan says that the program offers a new way to look at humanities research through the lens of complexity.

"The humanities offer a natural place to think about complex systems," she says. "History, for example, is all about the complex intersection of culture, environments, wars, and everything else. Why not represent that at SFI?"

The organizers say the course has three primary

goals: To introduce these tools to humanities scholars; to drive the innovation of new scholarship; and to build a community of scholars who can continue to collaborate in the future.

"We want to teach people the different ways that scientists think," says DeDeo. "There are a lot of humanities scholars who don't think of themselves as particularly technical types but who are interested in engaging with this material."

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despite the fact that these groups comprise only 13% and 18% of the U.S. population, respectively."

And complex variations in susceptibility and vulnerability are embedded within larger national variations such as those described in a recent *Lancet* paper by Rabail Chaudry et al. from the University of Toronto in which elevated COVID-19 caseloads were associated with countries with higher obesity, longer

delays to lockdown, higher prevalences of smoking, and higher income dispersion.

I describe all of this, however obvious it might seem in retrospect from our improbable quarantine, to make clear the tangible properties and vulnerabilities of networks of adaptive agents that we call complex systems, and the impossibility of treating complex problems as if they were simple and easily modulated by intervening on a single

dominant variable — be that mobility, social behavior, or even a vaccine. Few of the vulnerabilities that I have listed above are treated by the vaccine; they are merely obscured for a short period before the next perturbation arrives. The most vital thing we might learn during this period it is that complex crises require thoughtful, factual, ongoing and multiple, corrections. And that these should weighted appropriately — non uni-

formly — across the heterogeneous domains that have been hit. Despite our hero-worshiping tendencies, future safety does not lie in the hands of another Edward Jenner or Jonas Salk, but in the concerted effort by society to accept complex connectivity and adopt new pluralistic methods that respect the density and diversity of global life.

— David Krakauer
President, Santa Fe Institute

New books by SFI authors

Calling Bullshit: The Art of Skepticism in a Data-Driven World (Random House, 2020) by former SFI External Professor Carl T. Bergstrom (University of Washington) and Jevin D. West (University of Washington) explores how misinformation has leached into every corner of society, from misleading statistics and gaslighting politicians to press release-driven science. In a world where unmanaged bullshit abounds, the authors call for a healthy dose of skepticism in science, media, and everyday life.

Bergstrom, who is fascinated by network phenomena and has studied how diseases spread over networks, takes a similar approach to studying the spread of bullshit over social media.
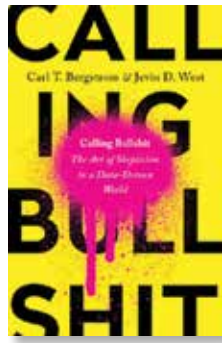
Unfettered Journey (Chiliagon Press, 2020) by SFI Trustee Gary F. Bengier is "an adventure for the mind on many levels," according to SFI External Professor and Science Board member Raissa D'Souza (UC Davis). The speculative fiction novel follows protagonist Joe Denkensmith through a journey in a realistic near-future world, one that seems a natural extension of today. With a computer chip embedded directly into their brains — an evolution of our cell phones — people struggle to keep up with Moore's law as their biological "wetware" lags behind at the pace of just sixty bits per second. The hard-science novel eschews a "cyborg" vision, but instead is populated by strong characters dealing with issues we face today – privacy, an economic system lacking jobs due to automation, and social injustice.

Bengier writes as a philosopher and technologist who has spent 20 years studying astrophysics and philosophy and writing speculative fiction, following a career in Silicon Valley.

Unsolved Problems in Ecology (Princeton University Press, 2020) is an essay collection curated by External Professor Andrew Dobson (Princeton University) Robert D. Holt (University of Florida), and David Tilman (University of Minnesota). From the social systems of songbirds to the ecosystems of disease, the topics that inspire some of today's top ecologists reflect a surprisingly diverse array of scientific questions. The essays in this collection consider unanswered questions about scaling, population biology, ecosystems and communities, collective behavior, and conservation, among other themes. From graduate students seeking new areas of study to established researchers inspired by fresh ideas, this book is ideal for ecologists of all stripes.

"If you go back to Aristotle, he was interested in things still studied at the Santa Fe Institute and still mentioned in this book," Dobson says. "But now we have a more formal scientific framework in which to think about them."

"Crown Shyness" (Photo: Tom Cowey)

ECOLOGY FOR PANDEMIC PREVENTION

What would it cost to prevent the pandemic from happening again? In a policy forum article for the journal *Science*, ecologist and SFI External Professor Andrew Dobson (Princeton University) and co-authors estimate that $260 billion over ten years — about 2% of Covid-19 economic damage — could substantially decrease humanity's risk of contracting and spreading a pandemic viral pathogen from wildlife. The researchers' suggestions for mitigating pandemic risk include activities such as stepping up the monitoring and regulation of the wildlife trade, and preventing the deforestation and fragmenting of tropical forests.

"There is substantial evidence that the rate of emergence of novel diseases is increasing and that their economic impacts are also increasing," the researchers write. "Postponing a global strategy to reduce pandemic risk would lead to continued soaring costs."

Read the paper at doi.org/0.1126/science.abc3189

LEADERSHIP FOR A SUSTAINABLE FUTURE

Sustainability science focuses on ways to meet the needs of the present without jeopardizing the future. It's a deep and complex area of research that encompasses many systems, from the environment to economics, and draws on the strengths of a spectrum of disciplines that meet at the intersection of nature and culture.

In the journal *Sustainability Science*, leaders of sustainability organizations including Christopher Boone, Dean of Arizona State University's School of Sustainability, and Jennifer Dunne, SFI's VP for Science, report on valuable lessons they've distilled from their own successful leadership experiences. The work describes pathways to success for tomorrow's organizations and highlights five areas that can contribute to success, including intellectual resources, institutional policies, financial security, a physical space, and governing boards. Together, the authors propose, these resources can form a foundation for interdisciplinary and transdisciplinary researchers to identify solutions to complex problems.

Read the paper at doi.org/10.1007/s11625-020-00823-9

LITTLE SETS OF NODES STICK TOGETHER

Within real-world networks, groups of nodes often have similar patterns of connections. People in a social network may have many friends within a group/community but few outside it. While there are multiple ways to divide the network into communities that do a comparable job summarizing its structure, those divisions can look drastically different.

In a recent *Physical Review E* paper, network scientists Maria Riolo, SFI Omidyar Fellow, and External Professor Mark Newman (University of Michigan) reported that while working on a community detection algorithm that sampled possible divisions of the network, they noticed little sets of nodes often stick together — even if that set of nodes was never identified as a separate community. "In many cases, the various good divisions of the network could be assembled using a small number of 'building blocks' of nodes that rarely get split up," Riolo says.

Read the paper at doi.org/10.1103/PhysRevE.101.052306

PREDICTING LINKS IN ONLINE NETWORKS

"Networks are a powerful tool for modeling complex biological and social systems. However, most networks are incomplete, and missing connections can negatively affect scientific analyses," write External Professor Aaron Clauset (CU Boulder) and coauthors in a new study published in *Proceedings of the National Academy of Sciences*. After applying 203 link prediction algorithms to 550 real-world networks, the researchers show that social networks are easier to predict than biological ones, and that no link prediction algorithm is best or worst overall. The techniques build on SFI Professor David Wolpert's famous "no free lunch" theorem for machine learning, which proves that if a machine-learning algorithm excels at solving one type of problem, it has to fail at others.

Read the paper at doi.org/10.1073/pnas.1914950117

ARE SCIENTIFIC PAPERS TOO MAINSTREAM?

It's possible to determine whether scientific papers are out-of-the-box, mainstream, or interdisciplinary. From the papers authors cite, you can infer what they read and which "crowd" or "specialty" they belong to. In a recent *PLOS ONE* paper, SFI External Professor Stefan Thurner (Complexity Science Hub Vienna) and coauthors present a bibliographic coupling network to visualize the position of every paper with respect to these crowds.

If your paper falls within the center of a cluster, it's mainstream. If it's at the surface of a cluster, it's an out-of-the-box paper. If it's between clusters, it's interdisciplinary. "Our measures allow us to see general trends during the past 100 years within physics literature," says Thurner. "Surprisingly, we found a trend across the past decade toward more mainstream papers and less willingness to publish interdisciplinary and out-of-the-box papers — at least within the physics domain."

Read the paper at doi.org/10.1371/journal.pone.0230325