Summer 2020

Parallax

THE NEWSLETTER OF THE SANTA FE INSTITUTE

Lauren Meyers and Sam Scarpino at the University of Texas in 2014. Both former SFI postdocs now lead national and international efforts to track the spread of COVID-19.

Coronavirus models tap SFI innovations

As a child, Lauren Meyers devoured books about deadly plagues. She had nightmares about the big one that was going to wipe out Earth as we know it.

Earlier this year on Jan. 23, Meyers, an SFI external professor and a professor of integrative biology and statistics at the University of Texas, thought that day might have arrived.

She was working with researchers from the U.S. Centers for Disease Control and Prevention to model the spread of a novel coronavirus moving through the Chinese city of Wuhan.

One of her team's initial studies looked at the timing and location of the first cases of COVID-19 reported outside of China to determine how fast the virus was spreading. The data told a much different story than was being reported on the news.

"There was this moment when we saw that there were so many more cases in Wuhan than anyone realized, and there were likely cases all over the world," Meyers says. "We went from thinking 'what is this little virus?' to understanding that this had the making of a global pandemic — something we had never seen before."

Since then, Meyers, a mathematical biologist, has been working with a team of experts around the clock to build tools for the CDC and other global health agencies to track and mitigate the emerging viral threat.

Her collaborator Sam Scarpino, a former SFI Omidyar Fellow who is now a professor of network science at Northeastern University, is also playing a pivotal role in the global response to COVID-19. His main focus is designing interventions to predict and prevent superspreading events, such as the Mt. Vernon Washington choir practice on March 10 where one person infected 53 other choir members.

Meyers and Scarpino's analyses have helped policymakers on the local, national, and international levels make critical decisions about purchasing medical equipment such as ventilators, implementing social distancing guidelines, and determining when it is safe for people to return to their normal lives.

Much of their work relies on quantitative methods of network epidemiology that Meyers helped pioneer at SFI in the early 2000s. At that time, Meyers, an SFI postdoc, and then-SFI Professor Mark Newman departed from traditional

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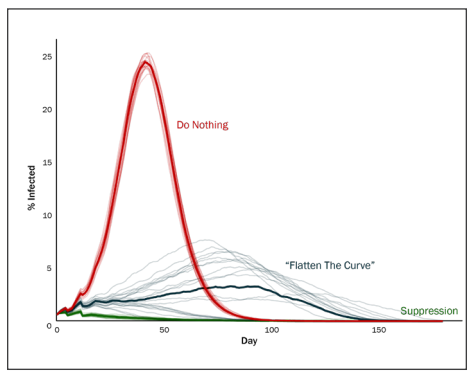
A laboratory for policy

Several months into the biggest public health crisis in a century, policy-makers in the U.S. and around the world are trying to figure out when and how to begin reopening businesses and public spaces. But with so many uncertainties remaining around the coronavirus, including how many people have it, how contagious asymptomatic people are, and whether those who have recovered are immune, it can be difficult for officials to make informed decisions. And the stakes could not be higher: Reopening too soon, or without adequate precautions, could cause a surge of contagion and more deaths.

SFI External Professor Ross Hammond, a senior fellow in economic studies at the Brookings Institution, along with collaborators at Washington University in St. Louis, Missouri, has developed a new agent-based computer model that help policy-makers wrangle with that uncertainty. The simulation model, called Testing Responses through Agent-based Computational Epidemiology, or TRACE, incorporates both knowns and unknowns to produce multiple variations for any particular policy option.

"Unlike many models, we really try to embrace that uncertainty," Hammond says. "We're trying to determine which policies are a good idea to pursue, and we want policies that are robust."

As an agent-based model, TRACE can incorporate



The TRACE model shows that relaxing social distancing with current national capacity for testing and contact tracing "flattens the curve," while a more gradual relaxation of social distancing combined with expanded testing and quarantine policies can yield true suppression.

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SFI science meetings pay slow, substantial dividends

Workshops and working groups are among the defining features of science at SFI. Working groups convene small gatherings, often to tackle a specific question or achieve a stated goal, such as writing a grant proposal or drafting a paper. Workshops include a larger, often more varied, group of participants for focused discussions. Advance descriptions of upcoming meetings fill the pages of this newsletter every four months, but the dividends sometimes follow months or years down the line.

"Bringing people together in workshops and working groups for intensive brainstorming, stimulating talks, and extended conversation is one of SFI's superpowers," says Jennifer Dunne, SFI's Vice President for Science. "Outcomes are not always expected or obvious or immediate. In addition to the myriad research articles and high-impact perspective pieces and successful grant proposals, they include entirely new areas of inquiry."

A working group cohosted by current External Professors Tim Kohler (Washington State University) and Marten Scheffer (Wageningen University) in 2018, called "The Human Niche," showed its first formal payoff this past May with a paper published in Proceedings of the National Academy of Sciences. The study, which received international media attention, estimates that, without dramatic reductions of greenhouse gas emissions, areas that one-third of humans call home will become as hot as the Sahara within 50 years. This is well outside of the temperature range that humanity has preferred for at least the last six millennia.

The paper was just one of four separate research questions to take form during the four-day meeting, says Kohler. "We went into the working group with two papers in mind, and two others emerged from the discussions. We'll be producing papers for the next several years."

The eight participants in "The Human Niche" working group, like at most meetings at SFI, spanned a variety of disciplines. "Everyone had a different area of expertise, with just enough overlap to talk to each other intelligently," says Kohler.

And despite its small size, the group included people who had never met before. One of the less-tangible outcomes from workshops and working groups are the relationships that form between participants. "People form research alliances at working groups, and these tend to endure for quite a long time," says Kohler. In his case, "The Human Niche" introduced Kohler to Tim Lenton, an earth systems scientist from the University of Exeter. "Now when I want to work with someone who has the expertise that Tim has, I know where to go. Two and half years ago, that would not have been the case."

Since its founding in 1984, workshops and working groups have been central to the life of SFI; its very structure and mission emerged during two founding workshops that included more than three dozen scientists, business leaders, and other creative thinkers. In 2018, "The Human Niche" was just one of 27 scientific meetings at SFI.

As COVID-19 brought an abrupt halt to the in-person meetings on campus this year, some groups have found creative ways to continue meeting virtually, while others have postponed until they can safely travel to meet again. "The pandemic has allowed a greater fraction of our

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BEYOND BORDERS

SOCIO-CULTURAL LONGITUDE

Our community is familiar with the considerable challenge posed throughout nautical history of determining longitude at sea. The need for both accurate celestial observation and precise time keeping — accurate data and a precise mechanical model — stymied all efforts at geolocation until the 18th century. In Isaac Newton's 1714 report to the Board of Longitude he wrote, "But, by reason of the motion of the Ship, the Variation of Heat and Cold, Wet and Dry, and the Difference of Gravity in different Latitudes, such a watch hath not yet been made." The watch was made subsequently by John Harrison in 1751 — the celebrated H4.

Over the last several months nations of the world have foundered for want of policy direction. Navigating out of the pandemic and its ramifying consequences has proved too complex for elected leadership. A near-quantum life-form has revealed the limitations of our knowledge and instruments of implementation. Novel factors that are in many ways the complex analogs to those Newton enumerated in his report — his variations of heat and cold, wet and dry, and differences of gravity — have made single-factor policy recommendations fail. So what are these factors? They are not heat and cold but sociability and isolation, not wet and dry but physical and virtual markets, and not difference of gravity but differences of culture. In place of each of Newton's classical complications we substitute complex mechanisms in desperate need of understanding, and for which we do not have a suitable Harrison H4. Of course I mean an H4 science of complex systems.

Before the H4 were several less viable experiments. None from the H1, H2, or H3 models had sufficient sophistication to solve the problem of longitude. Each model introduced a new innovation aimed at solving a single challenge — power reserve, temperature sensitivity, and wear and tear. The H4 addressed all of these with diamond pallets, the "maintaining power system," and temperature compensators.

People the world over have acquired a passing familiarity with epidemic models, critical threshold values for transmission (R0), comorbidities, and exponential growth. But these insights into the pandemic are like Harrison's H1-3; they focus on a few elements of the problem. The pandemic is every bit as much a problem of the non-linear dynamics of markets, the cognitive biases of decision-makers, the collective dynamics of groups, and the coevolution of biological species — humans, mammalian food sources, and viral agents.

My colleague Geoff West and I call this a complexity crisis: a two-fold event. First, it is the failure of multiple coupled systems — our physical bodies, cities, societies, economies, and ecosystems; and second, it involves solutions, such as social distancing, that involve unavoidable trade-offs, some of which amplify the primary failures.

We need models and theories to solve the socio-cultural longitude problem. To provide both citizens and leadership with ideas that

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SFI IN THE NEWS

Nautilus magazine published an essay on "The Hidden Life of Viruses" authored by SFI President **David Krakauer** and External Professor **Dan Rockmore**. The essay also appeared in SFI's Transmission series.

Also in *Nautilus*, External Professor **Pamela Yeh** and Ian MacGregor-Fors published their Transmission about the unprecedented opportunity to study wildlife in cities.

Professor **Sam Bowles** was featured on NPR's Hidden Brain podcast in an episode that asks what we lose when we expect the worst from people.

In *Scientific American*, science writer and former SFI Journalism Fellow **Christie Aschwanden** described how superspreading events drive the majority of COVID-19 cases, quoting External Professor **Lauren Ancel Meyers**, Former Omidyar Fellow **Sam Scarpino,** and Professor **Cris Moore**.

The New York Times also quoted Scarpino in a feature about the role of data in tracking epidemics.

Moore was also was featured in *Bloomberg* and *The Wall Street Journal*, and interviewed on CNN Tonight for his insights into superspreading events, which he originally described in an essay for SFI's Transmission series.

The Times (of London) extolled **Geoffrey West**'s "brilliant book Scale" in a column comparing urban and rural life.

West was also cited in *The Economist*, in an article titled "The 90% economy that lockdowns leave behind."

Miller Scholar **John Kaag**'s book, *Sick Souls, Healthy Minds: How William James Can Save Your Life*, was reviewed in the May print edition of *The New Yorker*. Kaag was also interviewed on WBUR's "To the Best of Our Knowledge."

Nature's "Where I Work" section profiled External Professor **Jessika Trancik** and her new app for mapping greenhouse gas emissions and running costs for commuter vehicles.

A recent *PNAS* paper on the future of the human climate niche was covered in *The New York Times*, *Washington Post*, BBC, *The Guardian* and other outlets around the world. It all started with a 2018 SFI working group hosted by External Professors **Marten Scheffer** and **Tim Kohler** (see "Science meetings," p.1).

Virtual offerings widen ACtioN's network

Members of the Applied Complexity Network (ACtioN) turn to SFI for context and perspective. In March, as much of the U.S. headed for lockdown, leaders from organizations and governments needed a direct transmission of scientific knowledge pertaining to the biology and spread of viruses.

ACtioN's first COVID-specific event was exactly that — an online crash course and ask-me-anything with renowned epidemiologist Derek Smith, who serves on SFI's Science Board and directs the Cambridge Centre for Pathogen Evolution.

Since March, ACtioN members have logged on to several more pandemic-related talks. Through SFI's faculty-authored Transmission series, they have also been able to explore topics such as zoonotic transmission, superspreading events, and disease models for vulnerable populations.

In fact, ramping up ACtioN's virtual offerings, far from closing doors, has actually opened them to increased participation. The number of attendees for ACtioN events has risen 444% in 2020, as compared to 2019. Amongst these attendees, ACtioN members, trustees, and external SFI faculty have all upped their engagement. The online offerings have also boosted the number of member organizations represented by 92%. Member organizations based abroad, such as Singapore's Centre for Livable Cities, have particularly benefited from the increase in virtual offerings.

"With the transition to virtual meetings, ACtioN's meetings became accessible by CLC, despite the 14-hour time difference between the U.S. and Singapore," says Yi Xuan Tan, a Manager with the Centre. "Our researchers are now able to participate and be updated with the latest work by the complexity science community outside of Singapore." She cites Geoffrey West's recent talk on cities, networks, and pandemics as especially useful for CLC participants working on the resilience of urban spaces post-COVID-19.

Like a city, SFI, too, has a network at its core — a structure that actually makes it easier for the Institute to adapt to rapidly changing situations than for other research institutions.

"The science of SFI was made for this moment, but the structure of SFI was also made for this moment," says Will Tracy, Vice President for Applied Complexity. "We are a network of external faculty and of courageous organizations that want to be involved at the frontier of complexity science."

The pivot to virtual hasn't been limited to COVID-specific events. ACtioN normally thrives on in-person connection as members from across the globe converge for Topical Meetings, short courses, and the annual ACtioN Symposium. COVID-19 made such congregations impossible — at least in their traditional form.

The first major test of an all-virtual format for ACtioN's larger meetings came in late May, with "The Complexity of Sustainability and Investing." Originally located in Boston, the two-day Topical Meeting instead unfolded over Zoom, thanks to co-organizer Katherine Collins, an SFI Trustee, and to ACtioN member organization Putnam Investments.

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Tage Erlander, Swedish Prime Minister, uses a videophone to talk to Lennart Hyland." circa 1960s

Easy, hard, impossible
New online course covers "Computation in Complex Systems"

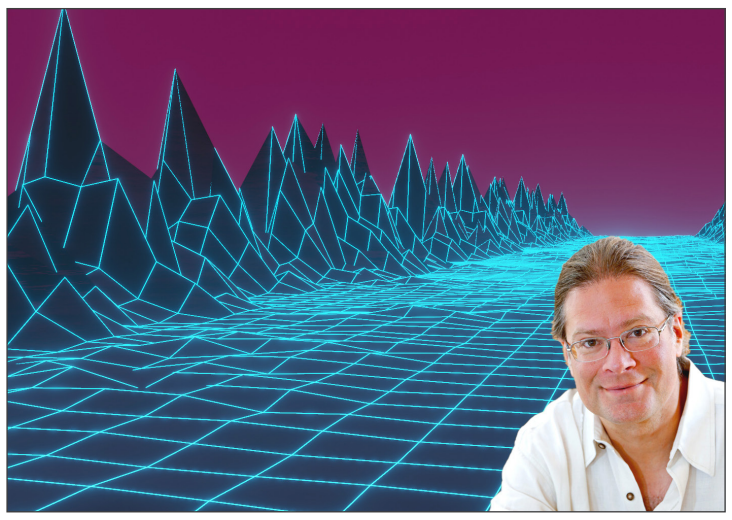
Problems come in three flavors: Easy to answer, hard to answer, and downright impossible. However, it's not always clear which problems belong to which group. Many resist easy labeling: How do we know if it's impossible to find a solution, or if the problem is just stubborn? More philosophically: Is it beyond the reach of human knowledge?

The theory of computation focuses on why some problems are difficult and others aren't. Its ideas reach beyond math and computer science, raising compelling questions in fields ranging from evolution to cellular behavior to social networks.

This summer, SFI's Complexity Explorer — our online educational portal — will unveil a brand-new course on the many faces of complexity, appropriate for learners from any background (and no mathematical heavy lifting required). SFI Professor Cris Moore, who is a mathematician, computer scientist, and physicist, teaches the class, which spans five modules. A teaching assistant will be available to field questions and act as a guide for students.

"Computational complexity is a beautiful theory of why some problems are easy, and others are hard, and others are impossible," says Moore. "It helps us understand why for some problems we can quickly zero in on a solution, or even see if a solution exists."

Complexity affects anything that computes, a group not limited to synthetic machines like laptops and smartphones. "Cells and markets and societies compute, in some way," says Moore. "They process information. But they do it in very different ways than, for instance, computers do."



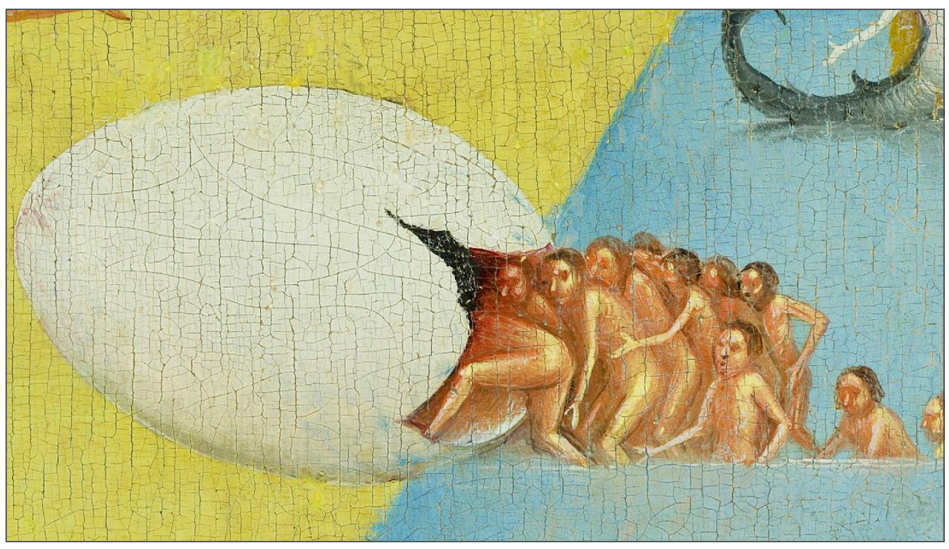
Cris Moore

Students will embark on a journey that's both philosophical and educational. Moore not only unpacks the history and mechanics of the field, but also reveals complexity as a lens through which we can see the world. Beginning with simple problem-solving algorithms, students work their way through interdisciplinary search and optimization problems. They'll also see how researchers think about these problems as vast, bumpy landscapes in which valleys represent possible solutions.

As with other offerings from Complexity Explorer students can take the course on their own timeline. "During the pandemic, we saw that people were looking for online content," says SFI Director for Education Carrie Cowan, "and we responded by making all of our courses available all the time."

With the new class, Cowan says Moore takes a subject that might seem arcane and turns it inside-out, revealing what it says about the nature of curiosity itself. "He really gets into the subject from a philosophical sense," she says. "What is the expanse of what can be known? What is unsolvable?"

The class opens July 15, 2020. Enroll at complexityexplorer.org.



"The Garden of Earthly Delights," Detail, Central Panel - Hieronymus Bosch

Workshop: From mac to mic

First annual remote meeting aims to integrate complex systems and stochastic thermodynamics.

Last month, scientists met remotely to discuss two areas of study that are often at odds. The first, complex systems, typically deals with macroscopic scales, where systems evolve in constrained ways. Stochastic thermodynamics, on the other hand, has to date mostly focused on microscopic scales where systems such as proteins, molecules, or computational circuits can evolve with few constraints.

The researchers are particularly interested in how to use tools from stochastic thermodynamics to analyze complex systems like the economy,or ecosystems.

Thermodynamics has long been investigating the properties of the entropy ("disorder") in large systems that are in thermal equilibrium, or a steady state. One famous result is the second law of thermodynamics, which says that the entropy of an isolated system cannot decrease. A classic example of the second law is an egg which falls off a counter and splats on the ground, increasing its entropy. Time never seems to flow backwards, so the broken egg never reassembles itself and hops back onto the counter, which would decrease its entropy.

However, at small scales, on the level of small numbers of atoms, the laws of conventional, macroscopic thermodynamics can begin to break down, says David Wolpert, a professor at SFI and a co-organizer of the meeting. For example, the second law goes somewhat awry; it's often impossible to tell whether a movie of a small number of atoms is running forward or backward.

For years, stochastic thermodynamics experts have been looking at the transition between these two regimes, an intermediate scale where entropy only usually increases, and where events usually seem to move forward in time. They now have theorems to exactly quantify this transitional regime.

The three-day virtual workshop held between SFI and Complexity Science Hub Vienna aimed to bring these newly hatched tools of stochastic thermodynamics to bear on the wide variety of problems in complex systems. "We started exploring what might come out if you start joining techniques from these fields," says Wolpert. "It actually also serves a larger purpose, by making these communities more aware of one another, interacting with one another."

Talks came from researchers studying both stochastic thermodynamics and complex systems. "I have the feeling that stochastic thermodynamics is related to complex systems," said SFI External Professor Stefan Thurner, a complex systems theorist and President of CSH Vienna. He proposed that stochastic thermodynamics could be used to calculate properties of "small" complex systems. Other researchers looked for similar connections. Sosuke Ito, a researcher at the University of Tokyo, drew parallels between entropy and Fisher information, a concept used to understand the speed of information transfer in a complex system.

Holding the meeting virtually also allowed dozens more participants than would otherwise have attended, and the organizers plan to make it an annual virtual event. "What happens outside the conference room is better in real life," says Jan Korbel, a researcher at the CSH Vienna and meeting co-organizer. "What happens inside the conference room is better in a virtual workshop."

Science meetings *(from page 1)*

extended community to observe and participate in virtual working groups as well as seminars. When we open back up to visitors and in-person meetings, we want to retain aspects of the enhanced access that online activities allow," says Dunne.

To stay up-to-date on the latest research publications resulting from SFI science meetings, visit www.santafe.edu/news.

Policy laboratory *(from page 1)*

variations in age, contact networks, activity patterns, and likelihood of infection, all critical factors in determining how to contain COVID-19.

For example, a state that's considering focusing on testing and contact tracing to ensure a safe reopening may want to know how extensive testing would need to be if asymptomatic carriers of are contagious, versus if they are not. Or officials may want to know how accurate tests would need to be, or what kinds of social distancing measures might still be needed to minimize risk as businesses reopen. Whatever the question may be, the model, which simulated 10,000 different combinations of factors, has a simulation for that.

With such precise modeling of complex policy scenarios, the TRACE project, which Hammond describes as a "policy laboratory," can help decision-makers set effective policies that suppress the virus while allowing for a gradual relaxing of social distancing.

The next step for the new model, unveiled in May, is applying it to real-world decisions.

"We've been in touch with policy-makers ranging from U.S. states to the White House's committee on reopening to foreign governments around the world," Hammond says. "They're all interested in this model."

Beyond Borders *(cont. from page 2)*

they might transform into robust policy vectors. Some of those ideas are already at hand but insufficiently known and SFI has a duty to communicate these insights more effectively. But my deepest hope is that the crisis has made abundantly clear that we live in a complex world that requires truly integrated systems thinking. And that SFI will be valued not only because its science is at the forefront of rigorous methodologies, but because its problem domain is the prime meridian of the modern world.

— David Krakauer
President, Santa Fe Institute

For more, read Krakauer and West's "Complexity Crisis" op-ed in Nautilus *magazine, online at nautil.us.*

Postdocs make most of remote collaboration

LeeAundra Keany pulls no punches when asked for her opinion on remote conferencing. "It's become a skewed form of communication," she says, "in part because we expect it to be the same as in-person, but the technology just isn't there yet."

An executive communications coach with more than 25 years of experience, Keany works annually with a group of SFI and James S. McDonnell Foundation postdocs to help them better communicate their research in settings like job interviews and presentations. This year, she shared especially timely tips for minimizing some of the inherent irritations that come with remote conferencing technology — e.g. reducing the perceived disconnect between participants, and being mindful of how speakers compensate when they don't receive the nonverbal feedback they would get in person.

Like many events in the COVID era, the biannual Postdocs in Complexity conference has moved online. Instead of three continuous days of professional development and networking in Santa Fe, the conference sessions have been broken up into hour-plus online segments, staggered over days and months.

"The shorter, more frequent sessions enable the postdocs to interact and keep up to date on research projects until they can meet in-person," says Hilary Skolnik, SFI's Postdoctoral Fellows Program Manager. In March, as campuses around the world announced their closures due to COVID-19, Skolnik made the difficult decision to cancel the postdocs' seventh conference in Santa Fe, which was scheduled for late March. The only way to proceed safely was online, in one-to-two-hour sessions.

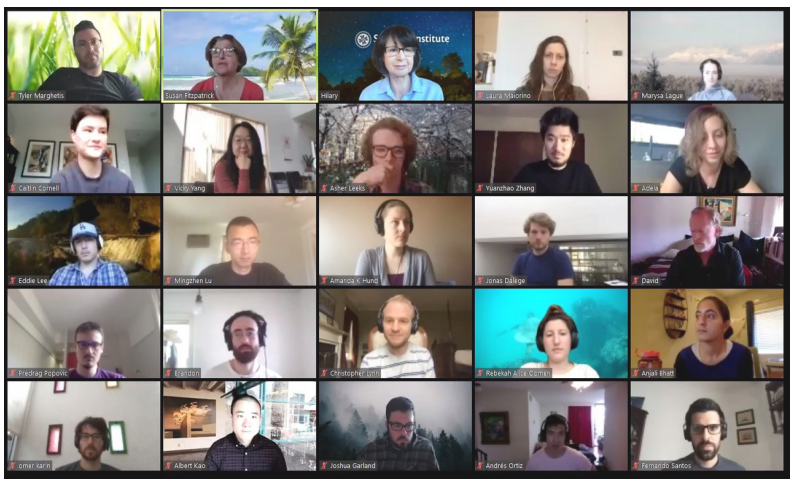
Since then, the postdocs have dialed in to video conferences to present flash talks; attended an online overview of grant-getting with SFI's Director of Sponsored Research; joined the workshop with Keany on how to communicate more effectively with video conferencing technology; and worked through the first online iteration of the beloved "research jams," in which small groups of postdocs convene informally to discuss research questions.

"My hunch is that we think and say different things when we're connecting through the internet than when we're sitting or standing side by side, looking at a whiteboard together," says SFI Omidyar Fellow Tyler Marghetis, a cognitive scientist who studies embodied aspects of communication and reasoning. "It's actually an interesting research question to think about — how the content and the structure of communication changes when people are in prolonged physical distance."

Like many SFI researchers, Marghetis has realized advantages to working from home. It's been an opportune time to revisit long-term goals and wrap up lagging research projects.

But when it comes to in-the-moment collaboration, he says "nothing's ever going to replace the joy and inspiration of being together in a beautiful place for an extended period of time. There's something magical about the unplanned accidents that occur when you're all together."

Until it's safe to open up to those chance, in-person encounters, the postdocs will be making the most of remote collaboration.



This year's JSMF-SFI postdoc conference looks a little different from the preceding six.

COVID-19 insights *from page 1*

epidemiological theory to develop models to help predict and control the spread of walking pneumonia. Unlike traditional epidemiological theory, which assumes every individual in a population has an equal chance of spreading a disease to everyone else, Meyers and Newman's network approach incorporated the fact that some people are more likely to transmit or get a virus than others.

"Network modeling allows us to explicitly capture the complex and changing patterns of interaction between people that fuel the spread of a disease," Meyers says. "For example, it takes into account that nurses and doctors have many potential disease-causing contacts on a daily basis while somebody who is retired at home will have fewer opportunities to spread the disease."

Since then, Meyers has gone on to use network science techniques developed at SFI to track outbreaks, epidemics, and pandemics like Ebola, SARS, and influenza.

She and Scarpino worked closely with the State of Texas in 2009 in the aftermath of the H1N1 influenza epidemic, using the lessons learned to develop a number of models that gave policy makers the ability to determine how best to respond to an emerging pandemic.

Fast forward to 2020 and the methods they developed are now being used on a global scale to help direct the response to COVID-19.

"The network modeling techniques that were developed at SFI enable us to look at how human contact patterns shape the way diseases spread around the globe," Scarpino says. "The way we move around cities, where we go to school, where we go to work — all of these interactions provide the fuel for epidemics."

ACtioN *from page 2)*

"More people have reached out to us about that meeting and how valuable it was than essentially any other I can remember," says Casey Cox, Director of the Applied Complexity Network. "What we're learning is that we're able to get more people from more industries involved when we go virtual."

"Every single week, you can be well-informed about what's happening," says Charlie Messina, a Distinguished Fellow with new ACtioN member Corteva Agriscience, and a former attendee of SFI's Complex Systems Summer School.

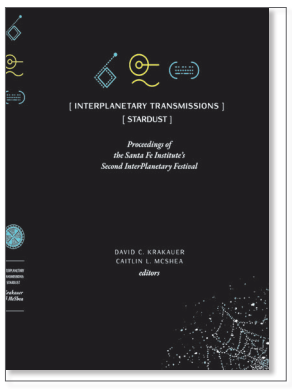
"There are some topics that you may want to participate in and attend virtually," says Messina, "and there are some others like AI or sustainability or Emergent Engineering, for which I'll travel to Santa Fe to have that more one-on-one discussion, and discuss opportunities to follow up."

To be sure, those face-to-face meetings will remain integral to the ACtioN community.

"There's a depth of conversation that absolutely benefits from being on a quiet mountaintop like Santa Fe," says Tracy. For that reason, ACtioN's more intimate events — such as the scheduled roundtable on the evolution of the nation-state, to be hosted at a small hillside venue outside Florence — will be postponed to 2021 rather than brought online.

The key moving forward will be striking the right balance between widely accessible virtual events and the cloistered retreat of SFI's hallmark gatherings. As SFI President David Krakauer puts it, "SFI is a twenty-first-century organization that just happened to be founded in the twentieth century." Going forward, it will be crucial to retain the depth and breadth of in-person, "twentieth century" conversations. But virtual opportunities — timely, cutting-edge, and with a low carbon footprint — are certainly here to stay.

SFI Press releases new book — *InterPlanetary Transmissions: Stardust*



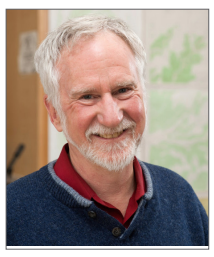
The InterPlanetary Festival has served as a zealous, if cautionary, simulation engine for new societal structures, economic paradigms, and sustainable practices. *InterPlanetary: Stardust*, (SFI Press, 2020) the newest book from the SFI Press, is a record of the proceedings of the second annual InterPlanetary Festival which drew more than 8,000 people to the Railyard Park in Santa Fe, New Mexico June 14-16, 2019.

It contains transcripts of the festival's panels on "World Building," "Creative Black Futures," "Time," and "Extremophile Cities," paired with panelist-written introductions. Many of the panels explored how a single idea, decision, or even random event can have lasting, broad impacts. What better challenge than space travel, the festival organizers wonder, to unite humanity and find creative solutions to Earth's biggest challenges?

The paperback ($9.99) and e-book ($2.99) are available at sfipress.org/books and on Amazon.com

ACHIEVEMENTS

External Professor **Melanie Moses** has been named a new council member of the Computing Community Consortium. Comprised of 20 members, the council is selected by the Computing Research Association in consultation with the National Science Foundation to "help catalyze and enable ideas for future computing research."



Tim Kohler, is one of "The 5 most popular scientific papers of May 2020," according to *Nature Index News*. Its online attention score of 3082 ranks it amongst the top research outputs for the journal *PNAS* (#22 out of 84,837).

The "**Future of the human climate niche**" paper (see p.1, p.6), which was conceived during an SFI working group and co-authored by External Professors **Marten Scheffer** and

External Professor **Mahzarin Banaji** has been elected as a member of the American Philosophical Society. She joins the ranks of Joyce Carol Oates, Albert Einstein, Thomas Jefferson, SFI Trustee Cormac McCarthy, and approximately 1,000 others honored for their "extraordinary accomplishments in all fields."

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Summer 2020
THE NEWSLETTER OF THE SANTA FE INSTITUTE

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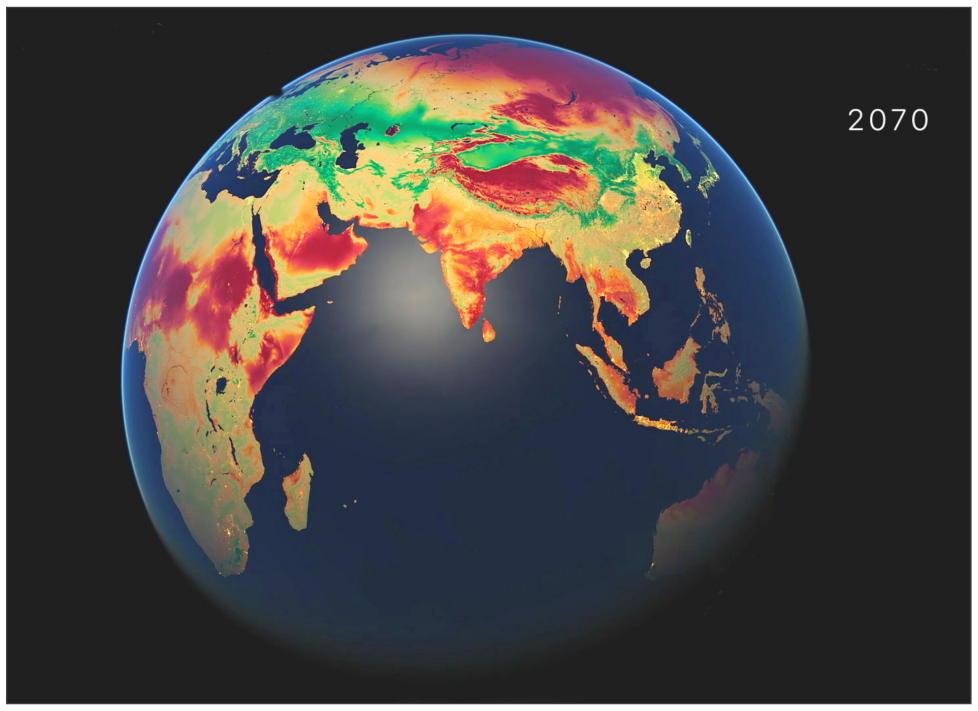
RESEARCH NEWS BRIEFS



The Earth in 2070, as simulated from data published in "Future of the human climate niche" in PNAS. View the full animation at Globaia.org.

THE FUTURE OF THE HUMAN CLIMATE NICHE

Areas of the planet home to one-third of humans will become as hot as the hottest parts of the Sahara within 50 years, unless greenhouse gas emissions fall, according to research by an international research team of archaeologists, ecologists, and climate scientists. The study, which was published in the *Proceedings of the National Academy of Sciences*, resulted from a 2018 SFI working group on climate change and the human "niche" (see "Science meetings," p.1). If the current scenario of rapid heating continues, 3.5 billion people would live outside the temperature and humidity combinations in which humans have thrived for 6,000 years.

Read the paper at doi.org/10.1073/pnas.1910114117

WHAT'S AN INDIVIDUAL? INFORMATION THEORY MAY PROVIDE THE ANSWER

Despite the near-universal assumption of individuality in biology, there is little agreement about what individuals are and few rigorous quantitative methods for their identification. A new approach, published in *Theory in Biosciences*, may solve the problem by defining individuals in terms of informational processes. SFI President David Krakauer, SFI Professors Jessica Flack and Nihat Ay, and their colleagues look to structured information flows between a system and its environment. "Individuals," they argue, "are best thought of in terms of dynamical processes and not as stationary objects."

Read the paper at doi.org/10.1007/s12064-020-00313-7

SWING VOTERS, SWING STOCKS, SWING USERS

The notion of a swing voter is limited because people don't always fall neatly onto one side or another. A new technique could help identify prime candidates for changing election outcomes, or lead to a better understanding of how institutional and environmental factors shape the emergence of social structure. SFI Program Postdoctoral Fellow Eddie Lee, the lead author, describes it as "a generalizable approach for identifying pivotal components across a wide variety of systems." These include social media (like Twitter), biology (like the statistics of neurons), and finance (like fluctuations of the stock market). Lee and his colleagues from Cornell University, Illinois Tech, and CodeX published their work in the *Journal of the Royal Society Interface*.

Read the paper at doi.org/10.1098/rsif.2019.0873

INFORMATION DROVE DEVELOPMENT OF EARLY STATES

Sophisticated information processing is key to the way societies function today. And it turns out it was also critical to the evolution of early states. A team of SFI researchers dug into what's called the Seshat Global History Databank, a massive assembly of historical and archaeological information spanning more than 400 societies, 30 regions, and 10,000 years of human history. Their findings, published in *Nature Communications*, show that the ability to store and process information was central to sociopolitical development across civilizations ranging from the Neolithic to the last millennium.

Read the paper at doi.org/10.1038/s41467-020-16035-9

WHAT ANCIENT CITIES TELL US ABOUT MODERN CITIES

Today's modern cities, from Denver to Dubai, could learn a thing or two from the ancestral Pueblo communities that once stretched across the southwestern United States. For starters, the more people live together, the better the living standards. That finding comes from a study published in the journal *Science Advances* and led by SFI External Professor Scott Ortman, an archaeologist at the University of Colorado Boulder, and Jose Lobo at Arizona State University. As part of the Social Reactors Project, which holds regular working groups at SFI, Ortman and Lobo took a deep dive into data from the farming towns that dotted the Rio Grande Valley between the 14th and 16th centuries. Modern metropolises should take note: As the Pueblo villages grew bigger and denser, their per-capita production of food and other goods seemed to go up, too.

Read the paper at doi.org/10.1126/sciadv.aba5694

HUMAN PORTRAITS REVEAL SHIFT IN CULTURE, COGNITION

Human cognition and cultural norms have changed the composition of human portraits, according to a new analysis of European paintings from the 15th to the 20th century published in *Cognitive Science*. The study, led by SFI Omidyar Fellow Helena Miton, examined "bias" in 1,831 paintings by 582 unique European painters. Miton and her co-authors from Central European University and the Arctic University of Norway found evidence that forward bias — where painters put more open space in front of their sitters than behind them — was widespread. They also found that the bias became stronger when cultural norms of spatial composition favoring centering became less stringent. "Cognitive factors cause greater spontaneous attention to what is in front of — rather than behind — a subject," Miton says. "Scenes with more space in front of a directed object are both produced more often and judged as more aesthetically pleasant."

Read the paper at doi.org/10.1111/cogs.12866