Kyle Harper joins SFI Fractal Faculty

Roman historian Kyle Harper is using technological leaps in the natural sciences to revitalize the study of human history. A tidy example of his approach comes from a 2018 project. Harper, who calls himself a “heretic of the humanities,” had for years been studying the Nazareth Stone, a two-foot tall, one-foot wide gray marble slab inscribed around the first century with a brief Greek decree that can be summed up as “Leave This Tomb Alone!” Historians had long thought the Nazareth Stone might be the earliest physical trace of Christianity. That fall, Harper, a 2013 Guggenheim Fellow, wrote in a piece for the LA Review of Books that, “The original circumstances behind the Nazareth inscription may remain forever beyond our grasp.” But that winter, Harper called a geology colleague and asked if isotope analysis might decipher the stone’s origin. A few months later, their cross-disciplinary collaboration had “put the nail in the coffin” of a century-old historical debate. The Nazareth Stone came from the Greek island of Kos — not Nazareth — and didn’t reference Christ but the tomb of a fallen tyrant. “It’s a seductive story,” says Harper. And worthwhile research, but it’s also far narrower in scope than the big questions he believes a new approach to history can solve.

Harper, a 42-year-old historian at the University of Oklahoma, joined the Santa Fe Institute’s Fractal Faculty in 2022. He is a part of a group of historians trying to move their field beyond the study of “the narrow slice of time when humans produced documents.” E.O. Wilson called this approach “consilience,” a conversation between disciplines. “Why do physicists get the Big Bang? Geologists get Earth history? Biologists: evolutionary history? The sacred model of history confines historians to the study of writing and states,” Harper says. “That’s a very arbitrary way of divvying up the past.” Nor is it one he feels is well-suited to answering the big questions: questions of the cosmos, climate change, humanity’s future.

Harper is the author of four books. His past two, The Fate of Rome: Climate, Disease, and the End of the Empire (Princeton, 2017) and Plagues Upon the Earth: Disease and the Course of Human History (Princeton, 2021), demonstrate how the hard sciences can forge novel perspectives on historical questions. “Sometimes new logical leaps in the natural sciences to revitalize the study of human history.”

In December 2022, SFI opened applications for its Postdoctoral Fellows to apply for funding through the Lou Schuyler Internal Grants program to explore a question related to industrial ecology and waste. But it was exactly those boundary-pushing questions that drew Lou and Hank Schuyler to SFI. As longtime friends of the Institute, Lou and Hank enjoyed attending community lectures and interacting with SFI researchers — and particularly with Postdoctoral Fellows. “One of the things that Lou loved most was hearing the postdocs talk about their projects,” says Hank.

SFI Postdoctoral Fellows play an important role in engaging the broader community beyond academia. In the past year, five current SFI postdocs talk about their projects. > MORE ON PAGE 4

Lou Schuyler Internal Grants fund new postdoctoral research

In the summer of 1993, seven undergraduate students from colleges across the U.S. came to Santa Fe for a 10-week immersive research experience. They began a tradition of bold and rigorous summer undergraduate research that has evolved and grown over the past 30 years. Since that first summer, more than 250 undergraduates have explored complex systems during their summers at SFI gaining essential skills and a unique perspective to inform their scientific and professional futures.

“My summer at SFI was amazing: the environment was small, welcoming, and vibrant. I was exposed to ideas across many fields, ranging from economics and anthropology to biology and mathematics, each with their own technical languages albeit with common concepts and ideas,” recalls Mahesh Mahanthappa (’93), professor of chemical engineering and materials science at the University of Minnesota.

“This forced me to learn how to communicate across disciplines and by using analogies (sometimes anthropomorphic) — a skill that I value to this day.”

While undergraduates had conducted research at SFI prior to the establishment of a formal program, Research Experiences for Undergraduates (REU) — later renamed the Undergraduate Complexity Research (UCR) Program — was a step toward a structured training path for early-career researchers at SFI. The UCR program provides an entry point to SFI research. Many students remember their summer at SFI as the first time they found a scientific “home,” an intellectual environment where they were not forced into one or the other disciplinary silo. Others credit their SFI mentors and colleagues as having transformative effects on their careers.

“I would not be a research mathematician now if I had not met Professor Nancy Kopell from Boston University, a mathematical biologist, at the Santa Fe Institute during the summer that I was there as an undergraduate,” says Megumi

Lou Schuyler (image: Kate Joyce)
Why are sustainable practices often elusive?

For at least 200,000 years, humans have been trying to understand their environments and adapt to them. At times, we have understood them often, we have not. When we get it wrong, the results can be disastrous. However, in both success and failure, humans can learn from our experiments and adapt.

“Our ability to respond to a future disaster is only as good as our ability to remember past challenges and to care about the future,” explains Societal Impact Fellow David Carroll. 

Perhaps too much has been written about Jorge Luis Borges’ story, “The Library of Babel.” But to my knowledge, much of this contemporary thinking has been scholarly in futility and the impossibility of originality. The great power of infinity — as obtained through the different principles of https://www.britannica.com/sociology/infinity and Russell — is that it allows us to transform our thinking about the nature of reality, to create new possibilities.

Perhaps it is the nature of reality, then, or the nature of human understanding. Perhaps we need to think about the nature of our ability to adapt to the future. Perhaps we need to think about the nature of our ability to adapt to the future. Perhaps we need to think about the nature of our ability to adapt to the future. Perhaps we need to think about the nature of our ability to adapt to the future. Perhaps we need to think about the nature of our ability to adapt to the future. Perhaps we need to think about the nature of our ability to adapt to the future. Perhaps we need to think about the nature of our ability to adapt to the future. Perhaps we need to think about the nature of our ability to adapt to the future. Perhaps we need to think about the nature of our ability to adapt to the future. Perhaps we need to think about the nature of our ability to adapt to the future. Perhaps we need to think about the nature of our ability to adapt to the future. Perhaps we need to think about the nature of our ability to adapt to the future. Perhaps we need to think about the nature of our ability to adapt to the future. Perhaps we need to think about the nature of our ability to adapt to the future. Perhaps we need to think about the nature of our ability to adapt to the future. Perhaps we need to think about the nature of our ability to adapt to the future. Perhaps we need to think about the nature of our ability to adapt to the future. Perhaps we need to think about the nature of our ability to adapt to the future. Perhaps we need to think about the nature of our ability to adapt to the future.
Most people think of a disease outbreak when they hear the word “contagion.” But it’s a concept that extends beyond biology. It could be an infectious disease, a fad, an online meme, or even a positive behavior in a population.

“From the mathematical perspective, a contagion is a thing that spreads,” says Laurent Hébert-Dufresne, a former SFI Postdoctoral Fellow, now an associate professor in computer science at the University of Vermont.

In April, Hébert-Dufresne and Juniper Lovato, who was a former director of education at SFI now the director of partnerships and programs at the University of Vermont’s Complex Systems Center, will organize a workshop titled “Dynamics of Interacting Contagions.” At the three-day event, around 35 experts from diverse fields, such as psychology and vaccinology, will present work and engage in brainstorming sessions to explore the science behind the complex interplay of contagions.

“SFI is a unique place that brings together people from different fields, and that results in interesting conversations,” says Hébert-Dufresne.

Many disciplines use the paradigm that “one pathogen equals one contagion” to study how things spread. However, this framework fails to capture phenomena such as outbreaks and misinformation. For example, multiple pathogens are responsible for making people sick during a flu season, explains Hébert-Dufresne.

Understanding how different contagions interact can help us untangle large-scale outbreaks.

Similarly, a lot is going on with social contagions, too. Lovato says that several factors determine the impact of a rumor, such as its content and people’s ability to either trust or get duped by it. The organizers hope the discussions at the event will yield a scientific publication, among other outcomes.

While the pandemic did not inspire the workshop — it was supposed to be held in 2020 and was postponed because of the public health emergency — Lovato believes understanding how different contagions interact can help us untangle large-scale outbreaks. For example, anti-vaccination sentiments can influence the rate of disease spread during these crises. Currently, researchers don’t fully understand the mechanisms of contagion spread. “If we want to study a world where there are hundreds of millions of pieces of misinformation online and hundreds of pathogens that pose a danger in the real world, we just don’t have the right tools to do it,” Hébert-Dufresne says.

The workshop will be a starting point for discussing what these research tools could look like in the future. “I’m pretty confident we can build the framework that’s needed to study interactions between contagions in a more systematic way,” says Hébert-Dufresne. “And I think we have the right group to do it.”

If we could rewind Earth’s clock, would social behavior emerge yet again, and could we expect to find it elsewhere in the Universe? If agents are very limited in their ability to process information — to make choices or be ‘thoughtful’ — or in how much they interact with one another, the system falls into asocial outcomes, says Miller. “Surprisingly, even though these systems are driven by small evolutionary changes, the movement from asocial to social (and back again) can happen very quickly — revolutions by evolution.”

Understanding these thresholds of social behavior might not only explain how social life came to be, but also give us insights into social upheavals such as political movements and revolutions, the rapid acceptance of new social norms, and even the emergence or collapse of an entire social order. Such events can lead to profound and rapid transitions that ultimately define our collective future.

New book from SFI Press explores origins of sociality

Earth is full of examples of social behavior. When individual bacteria, for example, cooperate to produce antibiotics, and even self-driving cars can make productive choices about their interactions with other individuals, that’s sociality. We can trace social behavior back to the unicellular organisms that became the building blocks for life on our planet. And humans, by becoming social, gained a great advantage in the evolutionary race for survival. If we could rewind Earth’s clock, would social behavior emerge yet again, and could we expect to find it elsewhere in the Universe? Probably yes,” concludes a new book from SFI Press.

In Ex Machina: Coevolving Machines & The Origins of the Social Universe, SFI External Professor John H. Miller (Carnegie Mellon University) melds ideas from the study of games, the fundamentals of computation, and Darwin’s theory of evolution to look at dynamic social systems through a computational lens. The novel approach he writes, is like a time machine that allows us to observe and analyze the architect of social behavior — a question that cannot be answered using knowledge from one field alone.

“This work, at its core, embraces SFI’s way of doing science,” says Miller, who is an economist, political scientist, and social psychologist and vaccine specialist. “It is to do it,” Miller says. “Different scholars have very different notions about whether it can occur across species, if it requires special forms of intelligence, and so on.” His ultimate definition was fairly general — “a reflex to dog owners everywhere,” he says — and it allows the possibility that social behavior could have emerged early in the history of life on Earth.

To answer questions about the emergence of sociality, Miller uses finite automata, which are simple computer programs that can respond to inputs produced by other automata and evolve inside of a computer. The computations captured by the finite automata illustrate how much interaction and “thought” it takes for a system to become social, providing rich insights into the complex and multifaceted nature of social behavior. Miller began working on the core ideas presented in the book at SFI when he was a postdoc — the Institute’s first — more than thirty years ago. But only recently, aided by dramatic advances in computer power, could he realize the project.

The book became his path to discovering a way for Miller to explore and understand, with a deeper vision, what it takes to make a system social. It also provided an opportunity to answer questions about the origins of social behavior, which Miller had raised in his 2009 book with Scott Page, Complex Adaptive Systems.

This new project offers readers unique and technical insights into the emergence of social behavior in a system. He reports that systems can change from asocial to social, or vice versa, as they cross certain thresholds.

From pathogens to fads: Interacting contagions

In his book The Wirol and the Enrie, Mark Fisher says of capital that it is “at every level an eerie entity: conjured out of nothing, capital nevertheless exerts more influence than any allegedly substantial entity.” For Fisher, eeriness surfaces when events occur without any indication of a guiding, conscious agent — a negative elaboration of Adam Smith’s metaphor of the invisible hand. While Smith believed that the free market would lead to individuals acting in ways beneficial to their own societies, Fisher believed that capitalism more or less deprives individuals of any agency and is in the process of bringing about an end to history and innovation. Whatever one’s opinion of capitalism, it has become increasingly evident that adequately complex alternative to our current situation will be far superior to ideological improvisations from above — where the hand is visible, oppressive, and far worse than eerie.

With a nod to SFI’s new research theme on emergent political economies, this installment of What We’re Reading focuses on books in which capitalism plays a significant role. How has our history been shaped by strange forms of labor and trade, and how, in turn, does capital shape our personal relations? Do we still prefer squares to circles? What is the role of capital in our aesthetic judgments? Each author submits a subtitle to these questions, which might occasion a sense of both the detriments and benefits of capitalism, along with inspiration for new frameworks that may transcend any political disposition.

One Weird Rodent

Understanding how different contagions interact can help us untangle large-scale outbreaks.

Laurence Gonzales

Former Miller Scholar

Beaverland: How One Weird Rodent Shaped America, by Leila Philip

In search of a ray of ecological hope, I stumbled on a hole in my learning: I knew nothing about beavers. I recently corrected that with Beaverland, the fine new book by a Guggenheim Fellow. The book opened my mind to beavers’ tremendous importance to the health of ecosystems as well as to American history and economy, and even transatlantic trade.

Laurence Gonzales

Deer to preoccupy ourselves with business accomplishments, matters of resource, information, and energy: the cute, the interesting, and the zany. Spanning the fine arts, television, and literature, Ngai describes the drive to protect and destroy our objects simultaneously (the cute), the effort to promulgate information without internalizing it (the interesting), and the urge to preoccupy ourselves with business accomplishing nothing in particular (the zany).

Renée Tursi

Manager, Office of the President

Trust, by Herman Diaz

Diaz’s absorbing novel, with its story—within-a-story structure that upends our trust, features a con- sensual central figure money. Steeped in a contemporary form of Henry James’s and Theodore Dreiser’s moral realism, the book opens with a man trans- fixed by the “ciphers of the ticker tape” that, as his “form of communion,” supplant human connection. We go on to question how the world is shaped by forces that remain abstract and analogous — like stocks, or novels — but are still acutely felt.
The sacred model of history confines historians to the study of writing and states. That's a very arbitrary way of divvying up the past.

The students' research projects in the early years tended toward mathematics and computer science, with significant interest in the then-emerging field of machine learning. Today, project themes still reflect those foundations but also include a generous representation of evolution and ecology as well as social systems and institutions. The backgrounds of participants have likewise diversified over time, with a broader range of fields of study and colleges represented.

What is next for undergraduate research at SFI? “We want to reach students who might not use the terms ‘complexity science’ or ‘transdisciplinary’ but who are drawn to SFI’s approach to understanding complex adaptive, hard-to-predict systems,” said SFI Director for Education Carrie Cowan, “even if they don’t know it yet.” Under the guidance of UCR program directors and SFI Professors Chris Kempe and Melanie Mitchell and the dedicated membership of SFI researchers, undergraduate researchers will continue to bring new ideas and talents to SFI.

SFI’s REU/URP program has been supported over the past 30 years through a combination of funding from the NSF REU program, faculty grants, institutional funds, and several significant donor gifts.

**LOU SCHUYLER FUND**

In addition to Mingzhen Lu’s industrial ecology project, the first round of funding is also supporting projects on historical exchange networks, led by Complexity Fellow Helena Minton, and on visualizing human interaction in high-dimensional landscapes, led by former postdoc Yuanzhao Zhang.

“I’m pivoting from studying cultural evolution at rather micro scales (e.g., collections of individual paintings) to getting into larger historical dynamics, which is a bit different and also means that usual funders do not see me as an expert on the topic,” says Minton. “The grant allows me to produce a first high-impact, proof-of-concept paper to start demonstrating my competence in this new line of research.”

Zhang’s project builds on work he started with former SFI Postdoctoral Fellow Tyler Milhouse and summer UCR student Katherine Li. The grant will allow him to purchase more powerful computers and help the research, unconfined by the financial restrictions, that he says will make this project much easier.

Carter expects this second round of funding to attract a variety of novel proposals. “There’s a tremendous need and these are high-quality applications,” she says. "In the extreme case it is not difficult to see that the continued operation of such motives, uncontrolled by any higher principles, uncorrected by the perpetual and necessary pressure of social improvement, must lead to the standard of thought and to the objects of knowledge, and to render void and ineffectual whatever soever elements of a noble faith may still survive.”

— David Krakauer
President, Santa Fe Institute

**BEYOND BORDERS**

Algorithms, accumulating limitless hexagons of online information, where every artist born and unborn is somewhere in the endless permeation that came before. And the search index seems to provide the necessary order to turn mere facts into fancy. It is a challenge for a dawning science to think through the implications of solving problems by exploiting practicably searchable ‘effective infinities.’

In reference to the objects of knowledge, and to render void and ineffectual whatever sover elements of a noble faith may still survive.
Toward a theory of regeneration

Abraham Trembley, a mathematician from Geneva, Switzerland, first reported on biological regeneration in 1740 when he observed a bisected Hydra — a freshwater polyp — reconstitute itself. In the centuries that have followed, science has identified a host of species, from starfish to salamanders, with regenerative capabilities. But despite the years of study into the phenomenon, science still lacks a comprehensive theory of regeneration.

All biological complex adaptive systems, which range from multicellular organisms to ecosystems, will inevitably totter, either from aging cells or external forces like lack of control or fire. In this moment of uncertainty, two paths emerge.

“If a system does not regenerate, it will fail,” says SFI External Professor Manfred Laubichler (Arizona State University). “However, if we better understand regenerative dynamics, we may be able to steer distressed systems toward regeneration and away from failure.”

Whether a system veers in the direction of regeneration or failure — death, in the case of cells or organisms, or system collapse, for ecosystems or communities — depends largely on its robustness, or its ability to remain stable in the face of disturbance. The relationship between regeneration, robustness, and failure is the focus of an upcoming SFI working group scheduled for February 22–24, 2023. Laubichler is organizing the meeting alongside SFI Science Board Member Susan Fitzpatrick and Jane Maienschein (Arizona State University). The participants will discuss regeneration, robustness, and failure through the lens of an information-theoretic framework, which is an approach to understanding complex systems through mathematical representations.

“There is a certain amount of information that a system holds — an essential amount of information that is needed to regenerate,” explains Fitzpatrick. “We want to know if that information can be quantified or measured.”

In an era of unprecedented stress — from climate change, habitat loss, novel viruses, and more — science needs a theory of regeneration.

Carlos Gershenson writes Balance on sabbatical

When political decision-makers confront the hardest problems that human communities face — climate change, political pandemics, for example — they often face challenges that emerge from complex systems. Yet many helpful conceptual frameworks from complexity science do not circulate in public forums. For SFI Sabbatical Visitor Carlos Gershenson, the time is ripe to bring complexity science to public life.

Gershenson, a research professor at the Universidad Nacional Autónoma de México, has come to SFI to finish work on a book ten years in the making. Called Balance, it will bring some of the most salient concepts from complexity science to a broader public audience.

Each of the book’s 10 chapters will elaborate on one concept or framework from complexity science, including synchronization, antifragility, criticality, and the slower-is-faster effect. To make these concepts accessible to a broad audience, Gershenson discusses them through familiar illustrations. For example, to describe the slower-is-faster effect, he invites readers to imagine runners in a marathon. If they start too quickly, they won’t achieve their best times. Finding optimal speed is a matter of balance.

“By generalizing the slower-is-faster effect,” Gershenson says, “scientists can apply the framework to problems in traffic flow, crowd control, and resource management.” As he works on each of the chapters, Gershenson is offering seminars at SFI to engage with scientists and refine his explanation of each core concept.

So far, when he’s had a chance to work with SFI scientists, Gershenson has found the process immensely helpful. Since he’s interested more in testing presentations for the public than sharing new research, he anticipates that the community will help tell the story by pointing out holes in the narrative or unnecessary detours.

Ultimately, Gershenson anticipates that his work will help “decision makers of the future take complexity into account in their decisions.” He also hopes that, with the discussions at SFI, he will help scientists translate their work to the world.

Charles ‘Chuck’ Stevens: mentor, man of science, generous soul

Charles Stevens, a preeminent neurobiologist who revealed fundamental architectures in the brain and whose experimental techniques paved the way for decades of molecular neuroscience, passed away on October 21, 2022, in San Diego, CA.

At the time of his passing Stevens, 88, was a distinguished professor emeritus at the Salk Institute for Biological Studies and a fellow of SFI’s Science Board and External Faculty. He was also a long-time member of the National Academy of Sciences and the American Academy of Arts and Sciences.

“Chuck had a procedural curiosity like almost no one I have ever met before,” says SFI President David Krakauer. “Rather than read about a topic from outside of his orbit he would dedicate a year to applying distant ideas and methods to a data set from his own work. And there was almost no area of inquiry that might not illumine his subject, from feed-back control to information theory, compressed sensing to statistical mechanics.”

When he first joined SFI in 1996 as a member of the Science Steering Committee, Stevens was revered in neuroscience circles for his foundational work in synaptic transmission Stevens’ postdoctoral fellow Erwin Neher; further developed this work and went on to win the 1991 Nobel Prize in Physiology or Medicine with collaborator Bert Sakmann.

A consummate man of science, and a mentor throughout his career, Stevens shared his methods with research collaborators and mentees. Among Stevens’ many distinguished mentees is SFI External Professor Vijay Balasubramanian (University of Pennsylvania), who says Stevens helped him move from physics into computational neuroscience.

“He mentored so many people,” says Balasubramanian. “He was a generous soul. And he never tried to take credit. Chuck always had a focus on the intellectual depth and content of the things he thought about. That’s what he really cared about.”

Like many SFI scientists, Stevens’ work bridged physics and biology. Moreover, he excelled as both an empiricist and a theoretist, and made great strides toward understanding the fundamental architectures of the brain across a variety of animal species.

During his summers at SFI, he convened with Geoffrey West, SFI Distinguished Shannan Professor, on the subject of scaling laws — the physical, quantitative constraints that govern biological traits across species.

“He became intrigued by our work on scaling laws and we spent quite a bit of time struggling with what we might learn about the brain, and even cognition, by extending the ideas to neurological systems,” says West. “He was one of my favorite people for talking science and for getting feedback on almost any issue.”

Stevens and his colleagues at the Salk Institute went on to elucidate several fundamental scaling laws for the brain that revealed how brain structures can grow, adding more neurons, without having to re-organize.

“In order for evolution to work, neural circuits have to have what the computer scientists call a scalable architecture,” Stevens told PNAS in a 2012 interview. “That means that you have to be able to make the computer more powerful just by making it bigger — you don’t have the luxury of redesigning it; and so the question that I’m asking is: What are the design principles that brains use to give their circuits a scalable architecture?”

Many SFI colleagues recall Stevens’ remarkable work ethic. He was known for his 10–12-hour workdays during his summer visits and, simultaneously, his willingness to engage with everyone he met around the institute. He often enjoyed a glass of wine with his labs, and Balasubramanian recounts that Stevens spent many lunch breaks with his wife, Jane Stevens (née Jane Robinson), with whom he had three beloved daughters.

“Chuck and I were really in different fields, but his ability to translate difficult concepts into simple terms almost made me think we were in the same field,” says SFI Science Board Member Simon Levin (Princeton University). “His writings were elegant, deep, and pedagogical, and I learned much from them. He was a giant in his field, and I always enjoyed our interactions at Santa Fe. He will be missed.”

Carlos Gershenson (image: Katherine Mast)
Collective Intelligence, a new online open-source journal, launched its inaugural issue in August 2022. The editors* hope the journal will help stimulate the discovery of the fundamental principles that underlie collective intelligence — a phenomenon found in complex systems, from swarms of ants and crowds of humans to bacteria in biofilms and networked computers. When these groups solve problems together, they often (but not always) make “smarter” choices than their individuals would if working alone.

As a phenomenon, collective intelligence has fascinated scientists and scholars since at least the 1700s. But as a field of study, it remains relatively underdeveloped when compared to other areas of research that inform complex-systems science.

The journal is dedicated to collective intelligence across scales and systems from “adaptive matter and physical systems, to molecular and neural systems, hybrid human-AI systems, sports teams, economies,” and beyond, says SFI Professor Jessica Flack, one of the four editors-in-chief.

The lineup of authors for the first issue illustrates the spectrum and ambition for the source journal, launched its inaugural issue in June 2022. The editors* hope the journal collectively intelligence offers the potential for better design of the systems we depend on to solve complex, shared problems,” the editors write in their introduction to the first issue. “Starting a new journal … can accelerate our understanding of how to do better.”

Flack is also organizing a Collective Intelligence Short Course & Symposium (to be held in Santa Fe June 20–23, 2023). The Symposium & Short Course will search for unifying principles in collective intelligence by tackling its foundations, and explore radical ideas for harnessing collective potential.

“Collective Intelligence Editors-in-Chief: Jessica Flack, Panos Ipeirotis (New York University), Geoff Mulgan (University College London), & Scott Page (University of Michigan, SFI), with Founding Editor Thomas Malone (Massachusetts Institute of Technology) *

RESEARCH NEWS BRIEFS

ECONOMICS IN NOUNS AND VERBS

In the last 50 years, economic theory has come to be based almost solely on mathematics. This brings logical precision, but according to a new paper by SFI economist Brian Arthur, it restricts what economics can easily talk about. Algebraic mathematics is “a language,” Arthur writes, “that allows quantitative nouns only, but doesn’t allow verbs — actions.” So economics does very well with quantities, ratios, and prices but fails to properly deal with processes, formation, and creation.

With the advent of computers, new opportunities emerge to study that which cannot be contained in equations. Algorithmic models, Arthur points out, can easily include actions and processes, so the use of such tools can bring sorely needed verbs into the language of economics. Such a process-based economics would fill gaps in our understanding and help answer poorly understood questions: how economic actors navigate (and change) a fundamentally uncertain shifting landscape, how innovation works, how novel institutions form, and how economic development works.

Read the study: “Economics in nouns and verbs” at doi.org/10.1016/j.ejheo.2022.10.036

COMPETITION FOR NUTRIENTS & INVASION RESISTANCE IN MICROBES

Does a diversity of species protect ecological communities from invasion? Recent work by SFI External Professor Andreas Wagner (University of Zurich) takes up this long-standing question for complexity science, at a microscopic scale. In his paper in Molecular Ecology, Wagner reports that microbial communities do indeed “become more species-rich, show higher biomass, and become more invasion resistant,” as they develop in reaction to invading outsider species that compete for nutrients.

Because of the challenges involved in observing species at the microscopic scale, invasion amongst microbes has been relatively understudied as compared to macroscopic ecological communities. To get around these challenges, Wagner used a computer modeling framework based on genome sequence data and extensive biochemical information for hundreds of microbial strains to explore, in silico, how real-world microbes would react and grow. In addition to finding that microbial communities become more diverse in response to invasion, he also found that certain combinations of species occurred more often than chance would predict. This could mean that certain “attractor” communities do better than others at fending off invaders.

Read the study: “Competition for nutrients increases invasion resistance during assembly of microbial communities” at doi.org/10.1111/mec.16565

E-PARALLAX

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