SFI’s April symposium explores complexity of new data worlds

Optimists look to new, large, complex datasets to help spot business trends, prevent disease, and combat crime. Skeptics know that floods of data stream into science, business, and government already, and increasingly overwhelm their current systems of analysis and application.

Science in particular has begun to probe the possibilities and limits of Big Data — and is making headway in building new analytic tools, finding new correlations, and achieving theoretical progress. But what’s next on the data frontier?

Data, statistics, and machine learning are insufficient. Fundamental science is required for robust prediction and explanation,” says SFI President David Krakauer. As complexity scientists, our role is to ask how the sciences of complex systems can augment the power of data analytics. What new ideas, frameworks and methodologies will result from connecting powerful computing platforms with powerful unifying theories, and how might these influence business practice and policy?”

Crakauer is co-organizing the April 20-21 symposium, “The Complexity of New Data Worlds,” with Science Board Co-Chairs Daniel Schrag (Harvard) and Mercedes Pascual (University of Chicago).

“Of significant interest to complexity science,” says Krakauer, “is how several data sources can be combined and then best be analyzed to reach new forms of consensus in the policy, security, and environmental realms.”

For example, it is now possible, for the first time in human history, to track individual movements and interactions using cell phones, geocaching of photos, and mining of social media activities. What happens when your online activities are further synced with the world of bus schedules, stock markets, weather, and other people’s movements and interactions?

In addition, machine learning and artificial intelligence promise vastly improved capabilities for analyzing new combinations of data. These computational tools present opportunities for predicting both behaviors and consequences, and raise questions as to how they should be used to augment decision-making in policy and public planning.

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Return of the Y2K bug

If you find yourself in the south this spring, you’ll have a chance to witness a predictable plague. A species of Magicicada emerges after 17 years underground in swarms so vast they overwhelm their predators. Nearly each year sees an emergence of a given subgroup in the U.S. Numbers vary by region; this year, Brood VI will rise in the mountains of Georgia and South and North Carolina (and elsewhere in patches) as it last did in the year 2000.

Despite extraordinary variation in brood size and distribution, boundaries between them remain sharp and steadfast, according to more than a century of records. Meanwhile, pistachio farmers in California are keen to find ways to disrupt their crop’s synchrony for economic reasons, explains External Professor Jon Machta, a statistical physicist at University of Massachusetts, Amherst. The trees’ two-year pattern of high and low yields often fall into phase across orchards, frustrating growers who prefer a more uniform production and income.

How and why these ecological systems synchronize is what the “Origins of Large-Scale Synchronous Phenomena in Ecology” working group will explore April 18-20. This third annual meeting builds on their earlier work that considered variations, measures, and indicators of synchrony — that is, spatially extended populations all behaving in the same way in time — and “extends it to more realistic situations,” says Machta, by developing models based on those in statistical physics and nonlinear dynamics.

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Postdocs prep for 72 more hours of science

Last April, 15 SFI postdoctoral fellows rented a house at the edge of Santa Fe and hunkered down for a novel, ambitious task. In just three days, they would choose a project, conduct research, and write an academic paper. It was 72 Hours of Science — 72h(S) for short. Now, they are getting ready to do it again May 8-11.

Each postdoc arrives with an idea for a new project — something they haven’t brainstormed with anyone else — and the group votes to choose a single idea. The goal is to find an interesting research project that is topically broad but also narrow enough to tackle in three days. What results is truly collaborative, owned equally by all the authors.

“Last year, our project managed to touch on evolutionary biology, social science and epidemiology. It used everyone’s expertise,” says Chris Kemps, an SFI Omidyar Fellow who has become the de facto spokesperson for the group. “This year, we might be a bit more ambitious. The project will still require everyone’s effort, but may not draw on each person’s particular field.”

While the fast-paced nature of 72h(S) isn’t the direction anyone wants to push science overall, the experience of working so intensely on one project together strengthened relationships and initiated new collaborations among SFI’s postdocs, says Kemps. “It gave everyone the opportunity to collaborate with everyone else.”

Most of SFI’s current postdoctoral fellows will be participating for the second time, but for SFI’s two newest fellows, this is an event they’ve anticipated for months. “We have no idea what we’re going to do, but I’m looking forward to seeing how other postdocs approach problems,” says Joshua Garland, an Omidyar Fellow. “Every day at SFI, you get lots of different opinions. 72 Hours of Science is like super-concentrated SFI.”

“At SFI, everybody has tons of crazy ideas all the time, but it’s hard to get enough people together to act on those ideas,” says Elizabeth Hobson, an ASU-SFI fellow. “This could be a way of tackling those and doing some really innovative science.”

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INSIDE … Complexity extends to business … The dangers of simplicity in a complex world … MORE
When he heard SFI President David Krakauer on a popular podcast last year, Toby Shannan didn’t know exactly how SFI could help him, but the interview prompted a realization. Some of his company’s biggest challenges were the byproducts of complexity.

Shannan is the vice president for customer support at Shopify, which provides services for businesses and entrepreneurs who want to set up shop on the internet. Shopify joined SFI’s Applied Complexity Network (ACiON) in late 2016. Building an online storefront requires combining domain support, web design, filters, shopping carts, social media, and more into an integrated interface that becomes the customer experience: it’s a classic “whole is greater than the sum of the parts” phenomenon, says Shannan.

Shopify’s challenge is to simplify how its 480,000 customers solve their problems as new online services and technologies become available. The company makes good choices in a universe of software possibilities, says Shannan, by picking out products that are likely to lead to a greater degree of client satisfaction — and fewer calls to support.

Before the podcast interview, he had been mulling over a concept for a heuristics-based decision tool to assess the complexity of a candidate software product — essentially an objective way to ask: Is there math for scoring a product based on how difficult it is to use?

“When he discussed the idea with SFI VP for Strategic Partnerships Wil Tracy, Tracy invited...”

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New SFI Postdoctoral & Omidyar Fellows

ANDY ROMINGER
A macroscopic view of life

“The goal of understanding and predicting biodiversity dynamics comes at a critical moment when human systems are disrupting those very dynamics,” explains new Omidyar Fellow Andy Rominger, nearly summing up his motivations to elucidate the profound connections across ecology and evolution and to unify them in “a simple set of universal governing mechanisms.”

This pursuit has guided him through his undergraduate degree in biological sciences at Stanford University and his Ph.D. in environmental science, policy, and management from UC Berkeley. He brings his recent experience as a postdoctoral scholar with the Berkeley Initiative in Global Change Biology to SFI with the intention to create “a foundation for how global change may drive future shifts in ecology and evolution.”

Rominger’s approach uses principles from statistical physics and data science to confront theory with real-world data. He advocates the hypothesis that universal patterns of biodiversity emerge from a blend of statistical mechanics of large systems and non-equilibrium dynamics bestowed by evolutionary history onto biological systems.

JACOPO GRILLI
Ecology’s underlying principles

What are the simplest rules and most minimal assumptions that lead to complex phenomena? It’s a question that has driven incoming Omidyar Fellow Jacopo Grilli through his undergraduate and masters’ studies in physics at the University of Milan, and later at the University of Padova, where he obtained his Ph.D.

Since 2015, Grilli has worked as a postdoctoral scholar at the University of Chicago’s Department of Ecology and Evolution. “My work focuses mainly on community ecology,” he says. Engaging both conceptual problems and data-driven projects, he aims to bridge theoretical results with observed patterns. “I want to understand how the interplay between ecological interactions and stochasticity shapes biodiversity,” he says.

He is also interested in genomics and cell physiology. He has explored how scaling patterns across organisms and environmental conditions suggests the existence of underlying general principles. And, he studies the connection between stress response and recovery and aging, using the nematode C. elegans as a model organism.

Grilli looks forward to the interdisciplinary opportunities available at SFI. “I like to collaborate with people from a diversity of backgrounds, from mathematics to experimental biology,” he says. “The Omidyar program provides the possibility of intellectual and scientific freedom simultaneously with a high quality and adjustable leadership training. It perfectly meets what I need at this stage of my scientific career.”

He plans to join SFI this summer.

MICHAEL PRICE
The roots of economic choice

Humans make economic decisions all the time: what type of toothpaste to buy, whether to borrow for a new house, what to pray to huns, and even when to reproduce. Our brains — and therefore how we make decisions — are the product of millions of years of evolution.

Michael Price, a 2017 ASU-SFI Center Postdoctoral Fellow, is exploring ways to link economic and evolutionary theories to better understand human decision-making processes.

Price worked at Raytheon Space and Airborne Systems after earning his B.S. in physics from Harvey Mudd College. As part of his Ph.D. in anthropology from Stanford University, he studied economic decision-making in households in an eastern Indonesian village.

He has continued his research on the evolution of economic preferences at Pennsylvania State University. Understanding the evolutionary roots of personal preferences may seem far from innocuous, says Price. “But it leads to some surprising conclusions with important practical implications for how to address vexing real world problems such as the persistence of extreme poverty and inequality.” While at SFI, Price hopes to expand his research for a systems-level look at wealth and poverty, risk-taking behavior, and the interplay between people, institutions, the environment, and disease.

Price plans to join SFI this summer.

KEYAN GHAZI-ZAHEDI
A theory of morphological intelligence

For the average person, lifting a taxon is no great feat of concentration. The stiffness of the human hand and the friction of its skin allow us to grab fragile objects without the need to focus on precisely controlling the position of each finger. During such tasks, the brain outsources some its computation to the body and environments — postdoctoral fellow Keyan Ghazi-Zahedi aims to understand exactly how these computations are distributed among brain, body, and environment.

“Biology provides us with numerous examples of functions that are normally attributed to the brain but result, at least partially, from the interactions of the body with the environment,” says Ghazi-Zahedi. “Unfortunately, there is no theory that accounts for the different kinds of morphological contributions to intelligence.”

Finding such a theory is what motivates his research, both at SFI and at his home institutions in Germany.

Ghazi-Zahedi currently is a senior researcher at the Information Theory of Cognitive Systems Group at the Max Planck Institute for Mathematics in the Sciences and a lecturer at the University of Leipzig. He earned his Ph.D. in neuroinformatics from the University of Osnabrück, having conducted his Ph.D. project at the Fraunhofer Institute for Autonomous Intelligent Systems. He also holds an M.Sc. in computer science from the University of Tubingen.

Ghazi-Zahedi plans to spend May through October at SFI.

Complexity postdocs regroup to build on collaborations

This July, two cohorts of early-career complexity scientists will regroup at SFI for open collaboration and some open air.

The second Postdocs in Complexity Conference brings together many of the same participants who attended the first conference in January. Fifty-four of these postdoctoral fellows are based at SFI and 32 are James S. McDonnell Foundation (JSMF) fellows who hail from academic institutions all over the globe. The goal of these two annual conferences is to build community and seed collaborations amongst the rising stars of complex systems science, and to establish best practices for the emerging field.

Where the January conference focused primarily on leadership and career-building topics, the July conference will hone in on research, giving the fellows more free time to collaborate and brainstorm ideas.

“This second meeting will be great for collaboration,” says ASU-SFI fellow Elizabeth Hobson. She and JSMF fellow Eleanor Brush are working together on an agent-based model of neural signals and learning. “Now that we all know each other from the first meeting, we can turn some of our shared interests into new projects.”

Jakob Burgie (JSMF) and Joshua Garland (SFI), who met at the January conference, have been collaborating on developing new techniques aimed at extracting and analyzing the information locked away in deep polar ice cores.

Hilary Skolnik, SFI’s Postdoctoral Fellows Program Manager, says that given this meeting’s focus on research, she expects many more collaborations to result from the July conference.

As part of the second conference, the postdocs will share their research by giving lightning talks — 5 minutes, with 5 minutes for Q&A. They’ll also take a field trip to Kasha-Katuwe Tent Rocks National Monument, southwest of Santa Fe.

The productive “research jam sessions” from the January conference are making a comeback in July. The hour-long sessions prompt postdocs to collaborate on questions that transcend individual disciplines.

“It gives them a chance to work together to come up with some novel solutions to problems they may be facing,” Skolnik says. Also on the agenda are Carnegie Mellon’s Carol Frize and Geoff Kaufman. Their program, BasiBusiness@CML, focuses on diversity and implicit bias.

“It is an issue that is facing academic selection more than ever, and one that doesn’t seem to be addressed often enough,” Skolnik says. “We believe that it is important to raise awareness for everyone but especially for our participants, many of whom will be leaders in their fields and will be hiring and managing research and administrative staff in the future.”
**SFI names Paul Hooper Director of Education**

SFI has named evolutionary anthropologist Paul Hooper as its new Director of Education. Hooper, a former Omidyar Fellow, joined SFI’s education office January 10, 2017 to produce and direct the Institute’s iconic summer schools, mentorships, courses, and online educational resources.

“I am simply thrilled to lead SFI’s educational mission to bring the best of complexity science to the world,” Hooper says.

Hooper’s research centers on the co-evolution of human economic systems, demography, and social structure. During his Omidyar fellowship from 2012 to 2014, he traveled to Bolivian Amazonia twice a year to study health and social support among the Tsimane forager-farmers, returning to SFI to mathematically model the social structures he observed.

In his new role at the Institute, he says he’s eager to introduce the next generation of complexity scholars to some of the tools and concepts that advanced his own research.

“We are all very enthusiastic that Paul has agreed to join SFI and direct education,” says President David Krakauer. “Paul has a unique combination of educational experience, complexity knowhow, creative ideas about new forms of educational activity and outreach, and the trained anthropologist’s eye and skills for navigating through what is surely one of culture’s more complex institutional structures — the educational system.”

Before re-joining the Institute in his new role, Hooper was an assistant professor of anthropology at Emory University in Atlanta, Georgia. He holds a Ph.D. in evolutionary anthropology from the University of New Mexico, and earned his A.B. in near eastern studies from Princeton University. 

**New data worlds (cont. from page 1)**

“Such configurations suggest new forms of prediction no longer based on fundamental mathematical structures but instead on the complex systems that generate new questions: How trustworthy are predictions that arise from these tools? What new challenges do they present for privacy? What new social and technical dynamic scales of security they portend?”

An increase in data availability also holds implications for addressing skepticism in science, evolution, climate change, and financial instability.

“The abundance of data and improved prediction certainly add us in reducing our uncertainty in any of these areas,” says Schrag. “But we know well that more data does not equal more consensus. We should like to understand whether, and how, these new data worlds interact with widespread public skepticism and political ideology.”

“These questions and opportunities align well with the collective expertise of the SFI research network in machine inference, environmental science, research policy, forecasting, and complexity education,” adds Krakauer. “By convening thoughtful data scientists with complex systems spanning a range of disciplines, we aim to foster conversations and research efforts that integrate their approaches in new and useful ways.”

**Toby Shannan (cont. from page 2)**

Toby Shannan (cont. from page 2) is attending an upcoming ASCOT meeting in Austin, TX. “This is exactly the kind of insight we want our members to bring to us,” Tracy says. “Toby saw something in his everyday life that had some clear connections to complexity, and this was a chance to share it with our community.”

At the Austin meeting, Shannan’s talk was paired with one by SFI external professor Simon DeDeo in a marbling of scientific and business concepts, says Tracy. DeDeo presented recent social science research, inspired by information theory, that explores the relationships between human behavior and how they choose to adopt or reject something new. DeDeo says Shannan says he found a lot of open-minded people at SFI who were genuinely interested in shared problems in science and business. “It was a chance to think more deeply about the problem with people who know a little bit about the underlying science,” he says. “It’s also inspired him to ponder the vocabulary of complexity.”

“I guess initially I kind of felt under the spell of complexity as a catchall for the problems we had at the meeting,” Shannan says. “As I read some of the scientific papers and gained a more technical understanding of the science, I began to make more tangible connections.”

“It occurred to me that the interdisciplinary nature of complexity science extends to business,” he says. “That’s not true for most of science. The vocabulary of complex systems will be quite useful in the world of businesses as it deals with increasingly rapid change it’s absolutely going to happen.”

**SFI ON THE arXiv**

**Prime Preprints and unresearched papers**

Progress toward solving a stubborn problem

In recent work, a team of researchers including SFI Omidyar Fellow Joshua Grochow used the tools of algebraic complexity theory to chip away at what’s widely considered to be one of the most challenging open problems in mathematics. “P versus NP” asks whether problems with solutions that can be quickly verified (“NP” problems) can also be solved quickly (“P” problems).

In their work, Grochow and his collaborators showed that certain techniques won’t solve P versus NP, but it is “an important milestone on the way.”

“Towards an algebraic natural proofs barrier via polynomial identity testing” by Joshua A. Grochow, Mrinal Kumar, Michael Saks, and Shubhangi Saraf is available on the pre-print server arXiv.org.

A well-timed glitch

Three theoretical astrophysicists, including SFI External Professor Paul Hooper, worked on a neutron star, of an astronomer’s telegram.

The American Physical Society has named SFI External Professor Raisa D’Souza a fellow for her work in the statistical physics of complex systems. D’Souza is professor of computer science and mechanical and aerospace engineering at UCLA. Her research focuses on mathematical models of self-organization, phase transitions, and the structure and function of networked systems. The number of APS fellows elected in a given year is less than one-half of one percent of the APS membership.

The White House has appointed Jerry Savelle, an SFI external professor and past president, as chair of the federal Cultural Property Advisory Committee. The Committee, created to support the United States’ role as a signatory to a 1970 UNESCO convention restricting illicit import and export of culturally important items, works under the U.S. Department of State to advise the White House on responses to international requests for help in protecting archaeological excama.

Jennifer Dunne, SFI’s Vice President for Science was named Fellow of the Ecological Society of America in recognition of her contributions to theoretical astrophysics, including extension to paleo food webs. Dunne’s research encompasses analyses, modeling and theory related to the structure, dynamics, and function of complex ecological networks. Dunne was also profiled in Nature and on the front cover of Science.

Can one follow a path through a graph that touches each node once and only once, ending where it began? This Hamiltonian game illustrates an important distinction in the P vs. NP problem: whether finding the right path (P) is the same as recognizing the right path after it has been found (NP). (Image: Royal Irish Academy)

**SFI Extern Profes**
New books by SFI authors

From Bacteria to Bach and Back: The Evolution of Minds (Norton, 2017) by SFI External Professor Daniel Dennett delves into the mystery of why we have minds, and how they emerged from a material process of natural selection. Drawing on concepts from computer science and biology, Dennett depicts how the human act of sharing memes yields tools for acting outside of genetic instinct. Comparison between these memes, and the process of exchanging them, can create a cultural evolutionary process that forms our creative and comprehending minds.

43 Visions for Complexity (World Scientific, 2017) edited by External Professor Stefan Thurner collects visions for complexity science in the next decade, in the form of short essays by acclaimed scientists and thinkers. Many SFI faculty contributed to the volume, taking up topics such as “society’s major challenges” and “the data-driven dark ages.” It is the third volume in a series dedicated to exploring complexity.

Better together? Working group seeks principles of collective behavior

In biological systems, function emerges from interactions among semi-independent components. An example is the brain — a huge society of neurons capable of producing coherent, robust behavior at the whole organism level. Another example is a group of fish that can switch quickly between a loose spatial configuration ideal for foraging to a tight group formation ideal for escaping predators. A theory for how individual components come together to produce functionally useful patterns at the aggregate level remains elusive.

A first question we might ask is: How collective is the system? Is the system reducible to its parts, or do components come to depend on each other such that an extent that they cannot be considered independently of each other? And, similarly, is a functional pattern at the aggregate level highly sensitive to small changes in compo-

These and similar questions will be the focus of a working group, “Quantifying Collective Behavior in Living Systems,” being held at the Santa Fe Institute May 3-5. The working group is organized by ASU/SFI researcher Bryan Daniels, ASU Professor and SFI External Professor Marfred Laubichler, and SFI Professor Jessica Flack.

“The goal of the working group is to ask whether there are common principles of collective behavior across a diverse set of systems,” said Daniels. “How do groups maintain stable, robust behavior at the aggregate level but stay adaptable such that they can change when the environment requires it? Are there quantitative ways we can measure this across different systems?”

The hope is that ideas in the working group might allow for a common language for researchers studying collective information processing in multiple disciplines. A mutual area of interest involves finding tipping points — being able to quantify and explain what causes systems to switch between functional states at the aggregate level or to move from being in exploitative and robust mode to an exploratory and adaptable mode.

In addition to understanding how fish switch as a group between schooling and foraging, unifying principles of collective behavior might help explain apparently large shifts in political view points in elections or how societies that seem so democratic can suddenly show signs of authoritarianism.

“How that unfolds is very much the kind of question we’re interested in,” said Daniels. “Maybe the political decision-making process looks similar to how neurons make decisions in the brain or how fish school.”

Religious practice may strengthen social bonds

Religiously oriented people are more accepting of one another and are less likely to be antagonistic. One recent study examined liệu co-workers studied the role religious faith plays in understanding how they do so. A paper published in the journal Animal Behavior calls for further study of this “audience effect” across (non-human) animal species, by going beyond simple behavioral metrics and instead analyzing animal signals using methods similar to those used in human language research. ASU/SFI fellow Elizabeth Hobson co-authored the paper with Brittany Cooper, the lead author and Hobson’s mentee.

COLLECTIVE BEHAVIOR ENDANGERS BISON

Collective decision-making can be beneficial for social animal groups, but not if members have bad information. A new study co-authored by Omidyar Fellow Andrew Berdahl in Ecology Letters. When part of a herd of bison found prime grazing land on a farm beyond the binder of Canada’s Prince Albert National Park, where they lived, others followed. The exposure to hunting led to a 12 percent annual adult mortality, showing that just one individual can be the agent of bad information for many in a fusion-fusion society.

INFORMATION AS ENGINE FUEL

In a paper published in Physical Review E, External Professor Jim Crutchfield and colleagues describe an engine that burns information: “Informatomes (thermodynamic fuel)” they write. “And we can build engines that run on it.” How the engine synchronizes with its environment is key to their design, which uses computational information to convert “disorganized thermal energy to useful work.”

CHEMICAL REACTION BREEDS LIFELIKE BEHAVIORS

Creating a life-like system from non-living components is a central pursuit in the field of synthetic biology. In research published in Nature Scientific Reports, External Professor Juan Pérez-Mercader and colleagues describe creating a synthetic reaction out of a homogenous chemical “soup.” The vesicles that result display several emergent properties associated with life: they appear to grow, self-replicate, move toward a light source, and experience selection.

A MACROSCOPE VIEW OF CANCER

The vast majority of cancer research focuses on how tumors form in cell cultures and special strains of laboratory mice. But cancer is a larger-scale phenomenon. The complexity of how evolution and environments interact to produce cancer risk is the subject of a new study published in Ecology Letters, authored by External Professor Michael Hochberg and a colleague. Their macroscopic framework for cancer risk considers three interacting causes: the number of stem cell divisions in a body, changes in cellular function, and heritable transformations to the cancer phenotype.

SEARCH SMARTER NOT HARDER

If an engineer drilling for oil or an animal foraging for food searches and doesn’t find what they’re looking for, when should they abandon their search area and strike out for new territory? In a paper published in Physical Review E, SFI Professor Sidney Redner and colleagues propose an optimal search strategy. Using a model that respects two opposite actions — moving on immediately when the search turns up empty versus remaining in one area indefinitely — the team says the best strategy is remain in one area for a time that equals the time it would take to re-establish in a new territory.

LIFE’S LOWER LIMITS

What are the lowest energetic limits for life? In a study published in Frontiers in Microbiology, SFI’s Chris Kempes, Eric Libby, and David Wolpert analyze cellular processes and maintenance budgets across sizes and species of bacteria. They find a surprisingly constant maintenance cost per unit volume, with the smallest cells devoting almost all of their energy to protein repair and very little to replication. The authors’ ongoing investigation could help us understand ecological constraints on other planetary bodies in our solar system, as well as on our own.

A woman lights an oil lamp to celebrate Diwali, the Hindu festival of lights. (Image: Eleanor Power)
In a study published in Ecology and Society, External Professor and Past President Jeremy Sabloff and colleagues look at cities in the Maya lowlands, tracing patterns of trade and networking, and changes in decision-making practices in relation to ecosystem health over the span of about 3,000 years. An early period when interior cities thrived show signs of ecological decline; while a later period when coastal cities held more influence appears more ecologically sustainable. Understanding the impact these cities, networks and decision-making patterns had on their ecosystems could be useful for modern decision-making on the global scale.

GRAND CHALLENGES FOR STUDY OF CULTURAL EVOLUTION

The scientific study of culture is currently going through a theoretical synthesis similar to what the field of biology experienced in the 20th century, wrote External Professor Peter Peregrine and colleagues in a paper published in Nature Ecology and Evolution. Darwinian principles will soon be applied as consistently to the study of culture as they are to that of biology, the paper hints. But what do researchers view as the biggest scientific questions facing the field? A survey of 236 Cultural Evolution Society members returned 422 different “grand challenge” ideas, revealing five major themes. These include knowledge synthesis, culture definition, pro-sociality, environment, and cultural transmission.

WHAT’S CUING SALMON MIGRATION PATTERNS?

Why salmon move in pulses is the subject of a new paper published in Animal Behaviour. Authors Andrew Berdahl and colleagues question the folk wisdom that sockeye salmon in southwest Alaska are independently cued off common environmental triggers when they migrate in pulse-like groups. Instead, the authors present a model based on social cues, which reproduces the timing and migration patterns observed in real fish.