JSMF-SFI Postdocs in Complexity Conference

Santa Fe Institute Santa Fe, New Mexico January 9–13, 2017

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A gathering of postdoctoral fellows from the James S. McDonnell Foundation and the Santa Fe Institute
Organized by David Krakauer and Hilary Skolnik

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WELCOME

Welcome to the JSMF-SFI Postdocs in Complexity Conference, the first of two postdoc conferences this year that will bring together the James S. McDonnell Foundation (JSMF) postdocs and the Santa Fe Institute (SFI) postdocs.

Through the conference, the two groups hope to develop a strong network, build collaborative research, establish best practices for complex systems science research, and introduce many of the JSMF postdocs to the Santa Fe Institute. An additional goal of the conference is to prepare participants to communicate their high quality, innovative research effectively to the scientific community and become thought leaders who shape the future of science.

Getting the two elite groups together as a meta-community has long been a wish of SFI President David Krakauer and JSMF President Susan Fitzpatrick. Krakauer says, "Susan and I are very optimistic about this meeting, where we get to jointly generate a critical mass of incredible talent in the field of complexity science, something that no university is currently equipped to accomplish and which might in the long run have a significant impact on the research landscape."

About the Santa Fe Institute

Located on a mountaintop at the edge of New Mexico's 400-year-old capital city, the Santa Fe Institute sits at the center of the Complexity Science universe. A small resident faculty and staff facilitate collaboration among artists, writers, leaders, and more than 100 external faculty from the world's best universities. SFI has been deeply involved with the development of several key aspects of complex systems science, including agent-based modeling, evolutionary computation, machine learning, scaling theories, big data analytics, and structural network analysis.

Awards bestowed upon members of our highly interdisciplinary community include: Nobel Prizes in Physics; the Nobel Memorial Prize in Economic Sciences; the National Medal of Science; MacArthur "genius" Fellowships; the Pulitzer Prize; the Guggenheim Fellowship; the Hugo Award; and placements on the *Time* 100 and *Wired* 50 lists.

Founded in 1984, the Santa Fe Institute is a private, not-for-profit, independent research and education center.

AGENDA January 9–13, 2017

Arrival day, Monday, January 9th

6:00 pm Welcome Reception - Hotel Santa Fe

Day 1 Tuesday, January 10th

8:15 am Shuttle from Hotel Santa Fe to SFI

8:30 Breakfast

9:00 Introduction and Overview of Complex Systems at SFI and Goals for the Program

9:45 SFI Science Overview

10:15 Break

10:30 Talks and Panel Discussion: Being Complex in a Simple Academic World

Noon Lunch

1:00 pm What I Know Now that I Wish I'd known as a Postdoc: Talk and Q&A with former SFI postdocs

2:00 Research Jam Session I *(hosted by SFI postdocs)*
Participants divide into four groups, each hosted by the originator of the topic

3:30 Tea

4:00 Research Jam Session II *(hosted by JSMF postdocs)*

5:30 Cocktails at SFI with postdocs/faculty

6:15 Dinner at SFI

7:15 Art Meets Science: An Evening with SFI Miller Scholar Neal Stephenson

8:30 & 9:00 Shuttle to Hotel Santa Fe

Day 2 Wednesday, January 11th

8:15 am Shuttle from Hotel Santa Fe to SFI

8:30 Breakfast

9:00 The Art of Public Speaking I

10:45 Break

11:00 The Art of Public Speaking II

Noon Lunch

1:00 pm Research Jam Session III *(hosted by SFI postdocs)*

2:30 Optional field trip: Meow Wolf

5:00 Return to Hotel Santa Fe. Dinner on your own in Santa Fe.

Day 3 Thursday, January 12th

8:15 am Shuttle from Hotel Santa Fe to SFI

8:30 Breakfast

9:00 Research Jam Session IV *(hosted by JSMF postdocs)*

10:30 Break

10:45 Talks and Panel Discussion: Submitting Successful Transdisciplinary Grant Proposals

12:15 pm Lunch

1:45 What I Know Now that I Wish I'd known as a Postdoc: The Challenges of Collaborating Across Disciplines
Talks and Q&A with former SFI postdocs

3:00 Tea

3:30 Talks and Panel Discussion: Alternatives to Traditional Academia

5:00 Shuttle from SFI to Hotel Santa Fe

5:45 Meet in lobby to walk to dinner

6:00 Conference dinner La Choza

8:00 Shuttle from restaurant to Hotel Santa Fe

Day 4 Friday, January 13th

8:15 am Shuttle from Hotel Santa Fe to SFI

8:30 Breakfast

9:00 Introduction to SFI's Applied Complexity Network (ACtioN)

9:15 Research in a Corporate Environment: Talks from representatives from ACtioN member organizations

10:15 Break

10:30 Conversation: Scientists as Policy Advisors

Noon Join the ACtioN at SFI
Meet, mingle, and lunch with ACtioN members to discuss career opportunities

1:00 pm Negotiation Skills I

3:00 Tea

3:15 Negotiation Skills II

4:30 Postdoc Discussion: Future Directions and Connections

5:00 Closing Remarks

5:30 Shuttle to Hotel Santa Fe

Enjoy self-organized small group dinners at one of Santa Fe's fine restaurants

RESEARCH JAMS

RESEARCH JAM SESSION I *(hosted by SFI postdocs)*
Tuesday, January 10 2:00 pm

1. Measures of statistical complexity for branched processes
YOAV KALLUS (presented by ARTEMY KOLCHINSKY)

Measures of statistical complexity of temporal sequences, such as excess entropy, have been useful in quantifying the complexity of the system that gave rise to the sequence and these measures have been generalized to spatial patterns in 2 and 3 dimensions. Branched processes, such as the developmental program of a multicell organism or L-system plant models suggest a new domain where complexity measures might be useful.

2. Self-reinforcement & bias in federal clerkship flows
DAN LARREMORE

It's known that Supreme Court justices tend to come from just a handful of schools historically, and more or less Harvard, today. But their clerks, as well, tend to come from a handful of elite law schools. However, Supreme Court clerks must complete a clerkship in at least one of the lower courts before becoming Supreme Court clerks, and there exist so-called "feeder" judges with whom one should clerk to increase the chances of working with the Supreme Court. Can we quantify these and learn about how feeder relationships form and are reinforced?

3. Musings on adaptation and aging in laws and immune systems **MARION DUMAS AND CHRIS KEMPES**

An adaptive system such as the immune system learns from experience. When an infection hits, the system fights it, and then for some time it becomes better protected against a similar infection, and may slowly revert back to the ground state. The common law system is also partially adaptive, allowing modification of the law in the light of experience. We could imagine making legal systems much more adaptive however, using principles derived from other CAS such as the immune system. However, in thinking about this possibility, one issue arises: do adaptive systems remain adaptive over long periods of time or must they be reset to remain adaptive? One argument is that the more a system adapts to its environment, the more entrenched it becomes. Adaptation causes the system to select some possibilities and close down others, creating rigidity over time. Is this a general aspect of adaptive systems and does it require a resetting of the system (in the case of the immune system this would be birth and death of organisms)?

4. Social systems in space **CHRISTA BRELSFORD**

How can we use known spatial heterogeneities in the daily routines of individuals to start to understand how human social systems work, especially in urban environments? What are the most important questions we could ask about how social behavior influences, and is influenced by, urban systems and urban structures? This research jam is mostly a brainstorming session to think about what kinds of research ideas I want to build into my next set of projects.

RESEARCH JAM SESSION II *(hosted by JSMF postdocs)*
Tuesday, January 10 4:00 pm

1. Characterizing the structure and dynamics of the genetic population structure of the malaria parasite* Plasmodium falciparum *using temporal networks **SHAI PILOSOF**

Populations of the malaria parasite *Plasmodium falciparum* are structured such that the population is divided into groups of strains which are more similar to each other genetically than to other strains. This structure affects malaria epidemiology and evolution with consequences for disease risk. Researchers represent the structure using a temporal network in which nodes are malaria strains and edges encode the genetic similarity between strains. The goal is to characterize these networks and understand how they respond to interventions such as bed-nets or anti-malarial drugs. I would like to brainstorm on:

(1) How to characterize the dynamic population structure.

(2) Network models/methods to study disturbance to network structure and the resilience of networks to perturbations.

These topics can be viewed at the broader context of network-related questions and are thus relevant for other postdocs working on temporal networks.

2. When is stability good? Understanding species persistence in complex landscapes **TBD**

Local stability is generally seen by ecologists as a good thing for ecological dynamics, in the sense that stable dynamics should be less prone to volatility and, hence, should improve species persistence. However, stability is only a proxy for species persistence, and not necessarily a good one. Additionally, when species occur as metapopulations, between-patch variation in densities is generally seen as a good thing, because it dampens overall variability in density (portfolio effect). Recent theoretical studies suggest that instability can lead to among-patch variability (hence larger portfolio) in local population abundances when a predator-prey system is considered, where populations are embedded in a complex network of patches and their connections (through migration). The question thus is, when is instability a good thing for species persistence given that populations are inherently spatial entities?

3. *Storm tracks and the mean atmospheric flows on Earth: a "chicken and egg" problem?*
TALIA TAMARIN

One major difficulty in researching mechanisms that control the motion of storms comes from the following problem: Analyzing observational data shows that the mean atmospheric jet is deflected toward the poles. Hence, it is often argued that the storms propagate poleward since they are being advected by the mean flow. However, is it the storms that "follow" the time-mean flow, or is the time-mean flow just a result of these transient poleward propagating storms? Can we come up with a way to determine cause and effect: do changes in the mean circulations drive changes in the storm tracks, or the opposite?

4. *Casual talks on causality in complex systems: What's cause and effect if the effect causes its cause, know what I mean?*
JAKOB RUNGE

In this jam I am looking for inspiration on whether and how one can use statistical graphical models to understand complex dynamical systems. For example, can one reconstruct a graphical model that actually helps to explain emergent phenomena such as El Niño or brain states? What is the cause of such a thing?

RESEARCH JAM SESSION III *(hosted by SFI postdocs)*
Wednesday, January 11 1:00 pm

1. *Evolution of predictions about future environments, not just adaptations to current environment* ARTEMY KOLCHINSKY

The genetic information and developmental program of an organism induces certain patterns of variation in the organism's offspring, and such patterns of variation can be seen as a "prediction" about future environments. For example, imagine that "skull size" and "jaw size" are developmentally linked and are thus correlated phenotypic traits; this can then be seen as a prediction that future environments will favor either small-skulls-and-small-jaws or large-skulls-and-large-jaws. To what extent can we understand biological evolution as involving such predictions about future environments? Can such predictions themselves evolve, e.g., based on the history of past environments? Finally, can this process be considered in a general way (e.g., as a network of evolving elements with a large range of time-scales), and used to think about adaptation in a broad range of biological/cultural/economic/etc. systems?

2. *Is it possible to quantify (and/or leverage) a self-fulfilling prophecy?* JOSHUA GARLAND

Can we systematically quantify when an event was caused by a belief in that event occurring? For example, the outcome of a sporting event is decided as a result of a lower-ranked team losing faith in their ability to win as a direct consequence of the opposing team's ranking being higher. When a prediction directly or indirectly influences the outcome of an event, this is known as a self-fulfilling prophecy. In such cases—where there exists a positive feedback mechanism between belief and outcome—can this be quantified and ultimately leveraged? What methods can be used to partition the influence of belief, action on those beliefs, and system dynamics on an outcome? If such a quantification is possible, this has implications for the control and understanding of systems like traded financial markets, political elections, sporting events, and many others.

3. *Scaling of local governments in metropolitan areas*
MARION DUMAS AND CHRIS KEMPES

Many social outcomes systematically scale with the size of cities: economic growth, patents, or crimes scale super-linearly, while energy consumption from infrastructure, sub-linearly. It turns out that local governments in the US scale with a metropolitan area's size and in a strongly sub-linear way. Why? And what can it reveal about the organizational structure of governments? Is local government capacity (measured by number of governments, number of employees, and budget), once adjusted for the city's size, related to a city's crime rate or economic growth? The study of these relationships will tell us about possible feedbacks between city size, government capacity, and a city's socioeconomic outcome, which has important implications for public finance and redistribution across cities.

4. *Evolutionary hide and seek in multiple dimensions*
ANDREW BERDAHL

Mimicry is common in biological systems. Mimics presumably gain some benefit from being assumed to be something else (e.g., something poisonous), without having to pay the cost of being that thing (e.g., producing the poison). There is evolutionary pressure for the copied to shake the tail, for the copier to follow, and for a third party (e.g., predator) to be able to distinguish between the two. This chase takes place in potentially higher-than-one dimensional space (colour, size, shape etc) and the copied party has the ability to increase this dimensionality. The dynamics of random walks are highly-dependent on the dimensionality of the space and so too might be the outcome of this evolutionary game of hide and seek. It would be fun and interesting to develop a general theory and model for such situations and try to relate them to empirical data. More generally, there are probably some exciting overlaps with evolutionary chase in pathogen-immune system dynamics.

RESEARCH JAM SESSION IV *(hosted by JSMF postdocs)*
Thursday, January 12 9:00 am

1. *Modeling flow-induced failures on networks*
XIANYUAN ZHAN

Functional failure processes on many flow-propagating networks are related to flow overload, such as flooding on river networks and congestion on traffic networks. However, even for flow-induced overloading failures, different networks react in drastically different ways, e.g. flooding in river networks creating smaller streams, which directly change the network structure; while congestion on road network increases link travel times and

reduces the amount of flow that can pass the link. Some research questions related to this are:

(1) Is there any deep commonality among the seemingly different flow-induced failure processes for different flow-based networks?

(2) Is it possible to develop general model/theory on flow-induced failures for all types of networks?

(3) What are the existing complex network theories/techniques that can be used to simultaneously capture flow propagation, mechanisms of overloading failure (e.g. flooding on river networks creates new edges; congestion on road network only reduces travel time) as well as the structural properties of the network?

2. *The interaction between human attitudes and the spread of infectious diseases* PETER FENNELL

The 2015 measles outbreak in the state of California, for example, was largely due to unvaccinated individuals, and scientists have long been warning that anti-vaccine sentiments would lead to large epidemic outbreaks of this sort.

With this in mind, we propose a data-driven study how sentiment and attitudes towards vaccines can signal potential outbreaks of infectious diseases. We aim to correlate geo-located data from online social networks with infectious disease surveillance data (such as that collected by the California Health and Human Services agency), to analyze the potential of online social networks as warning systems for outbreaks of certain diseases. Specific questions of such a study include the role of social contagion in individuals' attitude towards vaccination, how attitudes can change following a large outbreak, and suitable epidemic spreading models that can account for geo-located data.

3. *Inferring ant behavior* KARNA GOWDA

Ant colonies accomplish a myriad of sophisticated tasks through the collective behaviors of individuals. But what are these behaviors, and how do they give rise to a cohesive colony? This jam will focus on how to draw inferences about ant behavior from a long and detailed record of ant positions over time in a controlled experimental colony.

4. *Approaches for Identifying a Typology of Functions* ELIZABETH ROBERTO

I study residential segregation in cities. I measure segregation by constructing a set of "local environments" around each location in a city that range in size from 0 to 10km. I measure segregation for every location with each size of local environment, which produces a function for each location—segregation as a function of distance. I would like to develop a typology of these functions. I am interested in learning how other fields would approach this task. So far, I have tried functional data clustering, and I would be interested in feedback from others who have used similar methods, as well as suggestions of other approaches to try.

NOTES

PARTICIPANTS

JSMF Postdocs
Yohai Bar-Sinai
Allison Barner
Sergey Belan
Eleanor Brush
Yi-Ju Chen
Babak Fotouhi
Jean Gibert
Karna Gowda
Albert Kao
Daniel Koll
Rémi Louf
Helen McCreery
Jasmine Nirody
Lisa O'Bryan
Jeffrey Peters
Shai Pilosof
Oren Raz
Andrew Rhines
Maria Riolo
Elizabeth Roberto
Grant Rotskoff
Jakob Runge
Lauren Shoemaker
Michele Starnini
Talia Tamarin
David Zeevi
Xianyuan ZhanSFI

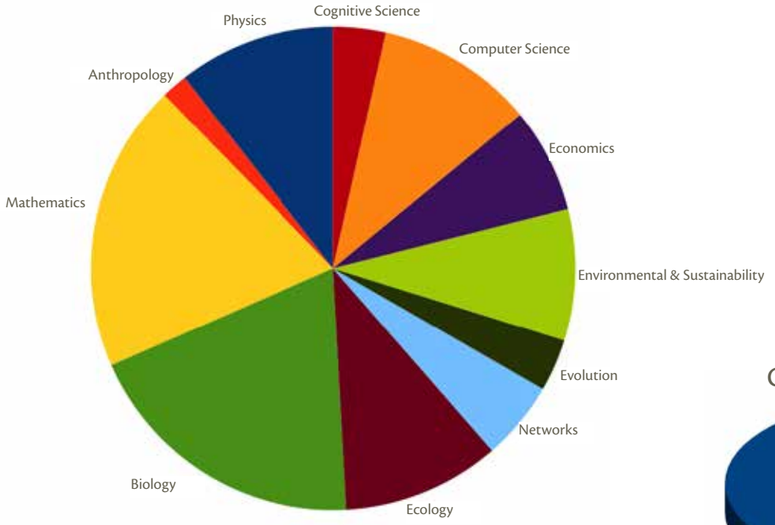
SFI Postdocs
Andrew Berdahl
Christa Brelsford
Caterina De Bacco
Marion Dumas
Joshua Garland
Justin Grana
Josh Grochow
Laurent Hebert-Dufresne
Elizabeth Hobson
Chris Kempes
Artemy Kolchinsky
Dan Larremore
Eric Libby
Eleanor Power
Brendan Tracey

Speakers
Samuel Arbesman
Dave Bacon
Liz Bradley
Brent Dolezalek
Jennifer Dunne
Susan M. Fitzpatrick
Michele Girvan
Nancy Houfek
Elisabeth Johnson
Marc Lipsitch
LeeAundra Keany
David Krakauer
John Miller
Ole Peters
Van Savage
Cosma Shalizi
Neal Stephenson
Will Tracy
Lisa Troyer

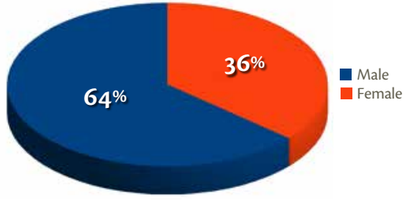
Administration
Bruce Bertram
Hilary Skolnik
Tim Taylor

Postdocs Unable To Attend
Leonora Bittleston
Peter Fennell
Vanessa Ferdinand
Samuel Fey
Clara Granule Martorell
Yoav Kallus
Mor Nitzan
Caitlin Stern
Carolina Tropini

Fields of study represented



Gender breakdown



PARTICIPANT PROVENANCE

POSTDOCS

Yohai Bar Sinai

JSMF

Yohai Bar Sinai studied for a double bachelor's degree in physics and mathematics at the Hebrew University in Jerusalem. He obtained his master's degree, specializing in physics of liquids and soft matter, from the École Normale Supérieure and Paris 6, studying the interplay of growth and mechanical stresses in growing leaves. He carried out his Ph.D. research at the Weizmann Institute of Science working on complex dynamics of frictional interfaces and fluctuations of disordered and inhomogeneous materials. He is currently a postdoctoral fellow at the School of Engineering and Applied Science in Harvard University, working in the group of professor Michael Brenner.

Allison Barner

JSMF

Allison Barner is a community ecologist whose work sits squarely between the worlds of experimentation and ecological theory. For her Ph.D. from the Department of Integrative Biology at Oregon State University, she used complementary experimental and mathematical approaches to understand how diverse communities of species are formed, persist, and change. Though mainly experimental and field-based, this work reinforced not only the importance of species interactions in the persistence of ecosystems, but also the difficulty in detecting these interactions. Further, most ecological studies focus on a single type of static interaction among species, even though species are highly interconnected with one another through a diverse set of flexible interactions. The inability of ecology to integrate realistic interactions into theory remains a limiting frontier in our understanding of ecosystems and their response to change, and is the focus of Barner's James S. McDonnell Foundation postdoctoral work at University of California, Berkeley with Carl Boettiger. She is interested in understanding ecological networks from a broader theoretical perspective..

Sergey Belen

JSMF

Sergey Belen is a Ph.D. candidate in theoretical physics at the Moscow Institute of Physics and Technology. His dissertation research focuses on the statistical physics of the highly non-equilibrium hydrodynamic systems such as turbulent aerosols and polymer solutions. Previously he earned his bachelor's degree (2011) and master's degree (2013) in applied mathematics and physics, both from Moscow Institute of Physics and Technology, under the supervision of Vladimir Lebedev. In his graduate and undergraduate studies Belen worked on the modeling of scattering and guiding properties of plasmonic structures and metamaterials. More recently, Belen has become fascinated by the interdisciplinary problem of self-organized consensus, which is usually formulated as follows: one has a group of autonomous agents which communicate among each other and update their states repeatedly to reach an agreement on a certain quantity of interest. He looks at the consensus problem from a statistical mechanics point of view. Belen's current research efforts concentrate on the development of statistical models that are analytically tractable and capable to describe the consensus.

Andrew Berdahl

SFI

Andrew Berdahl is fascinated by the striking patterns and behaviors exhibited by large groups of animals such as schools of fish and flocks of birds. These groups are canonical examples of complex systems—rich group-level phenomena arising from interactions between many relatively simple constituents. A benefit of grouping is that the group, as a whole, may act as a large sensory array and a distributed computer. This collective intelligence can help organisms in groups climb gradients associated with resources or improve their ability to find their way during migrations. Berdahl combines experiments, empirical data, computer simulations and theory to explore collective sensing and navigation in mobile animal groups. He focuses on both the mechanisms behind the emergent group-level behaviors and also the implications of such group-level behaviors for population and ecosystem dynamics. Berdahl received his Ph.D. from Princeton University in the department of Ecology & Evolutionary Biology. Prior to that he studied physics, first at the University of Waterloo where he earned a B.Sc. and then with the Complexity Science Group for a M.Sc. at the University of Calgary.

Christa Brelsford

SFI

Christa Brelsford received her Ph.D. at the School of Sustainability at Arizona State University, focusing on evaluating the effectiveness of water conservation policy in Las Vegas, Nevada. Prior to that she earned an M.A. in the Climate and Society program and a B.S. in civil engineering, both from Columbia University. Her work broadly focuses on urban infrastructure systems and water demand. As the world's urban population doubles over the next century, the new infrastructure necessary to house and care for all of these new residents will be almost equivalent to all of the urban infrastructure that has been built in the history of our species. We need to develop both a better empirical understanding of spatial patterns and evolution in cities, and also better theories about urban function in order to cope with our rapidly growing urban population. Brelsford uses empirical methods, especially spatial analysis and remote sensing, to link individual choices to aggregate outcomes in order to build better theories about the function of cities and urban water systems. These theories can then be used to support more effective and sustainable public policy.

Eleanor Brush

JSMF

Eleanor Brush received a B.A. in mathematics in 2010 from the University of Chicago and a Ph.D. in quantitative and computational biology in 2015 from Princeton University, where she worked with Simon Levin. She studies the evolution of social systems. Brush's approach is to develop and analyze mathematical models inspired by biological systems and grounded in empirical data, using methods from a number of fields, including stochastic calculus, dynamical systems, evolutionary game theory, and information theory. For her thesis, she studied how social groups maintain cohesion and perform collective computations, despite the conflicts of interest between their members. This included studying how flocks of birds or schools of fish can reach consensus about where to go and how primate social groups construct power structures. She is currently focusing on the interaction between learning and evolution. Her goal is to understand when learning accelerates or impedes speciation. Brush is also researching the evolution of signals that animals use to recognize other members of their social groups or their species. When not doing science, she likes hiking, running, doodling, cooking, and bird watching.

Yi-Ju Chen

JSMF

Yi-Ju Chen is a postdoctoral fellow at the Kavli Institute for Brain and Mind at the University of California, San Diego. She is interested in how biological systems compute and learn, given the constraints of maintaining and controlling these complex networks, and the biophysics of their information-carrying substrates. Her research focuses on how the neural representation of an odor along the few stages of the olfactory system might be screened in odor mixture or changed by neuroplasticity, and how odor sensitivity/distinguishability are determined by the properties of the system. Chen received her B.S. in physics and electrical engineering from National Taiwan University in 2008, and her Ph.D. in physics from California Institute of Technology in 2015. During her Ph.D., she applied statistical mechanics and polymer physics to study how in the early stage of bacteriophage infection, the translocation of the viral genome is subjected to the dense DNA packaging within the virus and the macromolecular crowding inside the bacterial cell. She also studied the stochastic process in genetic regulatory motif, addressing how the looping of the DNA, its mechanical properties, and its interaction with transcription factor govern the kinetics of the motif's state transitions.

Caterina De Bacco

SFI

Caterina De Bacco works with Santa Fe Institute professor Cris Moore on problems at the interface between computer science and statistical physics. Her research interests range from combinatorial optimization, inference, message passing and random walks on networks. She is interested in developing novel models and deriving fundamental limits to finding hidden structures behind noisy and incomplete datasets. Her approach combines Bayesian likelihood maximization with techniques borrowed from linear algebra such as low rank matrix approximation and non-negative tensor factorization. Applications range from clustering of sparse high dimensional data to community detection in networks with multiple types of edges. Starting from the theoretical findings, part of the challenge will be to develop efficient algorithmic ideas that are applicable to a broader range of problems and in different settings.

Marion Dumas

SFI

Marion Dumas seeks to understand how institutions work and how they shape social change. Dumas is interested in how norms and rules evolve, and in measuring the quality of deliberation in different institutional environments. Through this work she hopes to eventually understand how political institutions shape social learning, and how political conflict can be structured to improve social learning. A third direction of her work is to understand how technological innovation can be directed to address collective problems. Currently, Dumas is studying the evolution of environmental laws in the United States using a comprehensive dataset of all court cases over the last 40 years. Dumas also investigates how relationships between firms in supply chains affect the ability of these firms to coordinate their search for radical innovations. In turn, she is interested in the implication of these coordination challenges for how institutions can direct technological innovation towards the decarbonization of the economy. Dumas earned a Ph.D. in sustainable development at Columbia University, with specialization in economics and political science. She also studied ecology at the ETH Zurich and earth sciences at MIT.

Babak Fotouhi

JSMF

Babak Fotouhi's research resides at the intersection of natural and social sciences. His graduate studies were in physics and engineering, where he studied the mathematics and statistics of complex networks. He worked on the temporal evolution of the structure of networks, and on modeling diffusion processes and the mutual influence of structure and agency on social networks. His interest in sociological problems led him to subsequently obtain an M.A. in sociology, which added new content to his research. These new research directions include theoretical and methodological problems that involve social networks, as well as the evolution of cooperation in social and biological systems. Currently, he is a postdoctoral researcher at Harvard's Program for Evolutionary Dynamics, and a fellow at Harvard's Institute for Quantitative Social Sciences. He strives towards harmony between natural and social components in his research (either in parallel, or in some projects, combined). He would like to maintain this balance both during his current research and on his future academic path.

Joshua Garland

SFI

Joshua Garland's research aims to develop rigorous models that bridge the gap between theory and observation—data that may be wildly lacking in the eyes of mathematics, but may still contain valuable information about the system. Said differently: when perfect isn't possible, how can we adapt mathematics to describe the world around us? In studying complicated, ill-sampled, noisy systems, Garland's work focuses on understanding how much information is present in the data, how to extract it, to understand it, and to use it—but not overuse it. Specifically, Garland is working toward developing a parsimonious reconstruction theory for nonlinear dynamical systems. In addition, he aims to leverage information mechanics (e.g., production, storage and transmission) to gain insight into important yet imperfect systems, like the climate, traded financial markets, and the human heart. Garland's hope is this combination of new mathematical theory, analysis, and application can eventually shed a little more light on universalities like emergence, regime shifts, and phase transitions. He received his Ph. D. from the University of Colorado for introducing a new paradigm in delay-coordinate reconstruction theory.

Jean Philippe Gibert

JSMF

Jean Philippe Gibert is a James S. McDonnell Postdoctoral Fellow in Complex Systems at the University of California, Merced, under the supervision of Justin Yeakel. He holds a B.Sc. from the Universidad de la República, in his hometown, Montevideo, Uruguay, and a Ph.D. from the University of Nebraska, Lincoln. He is broadly interested in understanding how species traits affect biological interactions within complex networks of interacting species as well as how these processes are mediated by environmental factors such as temperature. He is currently developing new ways of scaling up intraspecific variation across levels of biological complexity, by assessing how variation in predator traits affect predator connectivity and trophic level within food webs. He has shown that several structural features of food webs can be predicted by predator levels of intraspecific variation, and is now working on testing these results with empirical data. He enjoys working at the interface between mathematics, computational methods, data and applied problems, and his scientific work has taken him all over the world, including Argentina, Brazil, France, and the U.S. He enjoys playing soccer, the guitar, and taking walks in the park with his wife and two dogs.

Karna Gowda

JSMF

Karna Gowda is currently a Ph.D. candidate in applied mathematics at Northwestern University. His fascination with complex systems began with the ants he kept and observed as a child. Gowda has not moved far beyond this as an adult—he studies ant behavior, transitions in terrestrial ecosystems, and evolution in microbes. In his Ph.D. thesis work, Gowda is using mathematical modeling and satellite imagery to study ecological transitions dryland vegetation. His work focuses on probing the limitations of mathematical modeling in predicting long-term ecosystem dynamics, and on assessing long-term dynamics using aerial imagery. Additionally, Gowda is studying ant behavior in a colony context using data of individually tracked ants in a controlled environment. Gowda intends to conduct his postdoctoral research on experimental microbial ecology. He is broadly interested in how adaptation occurs in an ecological context, and specifically to what degree the outcome of adaptation may be predicted by environmental conditions and ecological interactions. Gowda intends to join an experimental lab, where he will conduct evolution experiments with microbial communities and develop theories which yield insight into the processes he observes.

Justin Grana

SFI

Justin Grana's interest in game theory—the standard quantitative tool for analyzing interactive decision makers—began when he was a graduate student in economics. While game theory has proven successful in providing a foundation for modern microeconomics, it is often inadequate in addressing scenarios in which the sequence of actions and events is random. Together with Santa Fe Institute professor David Wolpert, Grana is focusing on how to expand the tools of game theory to better analyze scenarios in which the sequence and timing of events and actions is random but also relevant to the decision makers. By developing such a tool, he hopes to better understand systems of interacting decision makers that were previously too difficult to analyze with traditional tools. His recent research has focused on applying new game theoretic tools to understand computer network attack and detection scenarios, aircraft collision avoidance in the presence of mechanical failure, and collusion in an economy subject to random shocks and informational frictions. Grana received a B.S. in economics and B.A. in Spanish from Xavier University in Cincinnati, OH and received his Ph.D. in economics from American University in Washington DC.

Joshua Grochow

SFI

Joshua Grochow strives towards unifying ideas that can help us understand a variety of complex systems from many different fields. He thinks that this may involve deeper mathematics than has typically been used so far to understand complex systems, and possibly even mathematics that hasn't been invented yet. Grochow sees computational complexity—the study of the fundamental limitations of the power of algorithms—as an excellent starting point from which to build a theory of complex systems. Individual algorithms can behave in just as complicated a manner as nearly any system out there; indeed, most complex systems are studied by computer simulations, which are really just the output of some algorithm. Much of Grochow's research so far has been in using deep mathematical ideas from areas such as geometry and symmetry (technically: algebraic geometry, group theory, and representation theory) to better understand the behavior and limitations of algorithms. At the Santa Fe Institute, he has started to bring some of this deep mathematics to bear on more general complex systems.

Laurent Hebert-Dufresne

SFI

Laurent Hébert-Dufresne earned his Ph.D. in theoretical physics from Laval University in Québec where he got involved in network theory through a simple applied problem that resided on a complex canvas: disease propagation on social networks. To understand disease propagation, we must not only understand how one individual infects another, but also the complex patterns that link these individuals to the rest of the population. Using tools from statistical physics and other methods of mathematical modeling, his research attempts to find overarching principles that could lead to a more complete view of complex networks. He hopes to find a better perspective to study networks than as an ensemble of points and lines. Switching focus toward the systems that produce these networks, such as looking at the hierarchical structure of society rather than at local social networks, he aims to find better ways to quantify the global role of each element in the systems. This implies adopting broader definitions of what networks can be; whereas most traditional methods simply construct them like puzzles, piece-by-piece based on limited information.

Elisabeth Hobson

SFI

Elisabeth Hobson studies how the social interactions of individuals lead to the wide range of complex animal societies we observe in the field and lab. Her research focuses on how and why animals structure social relationships, how feedback between structured interactions among individuals and emergent collective social dynamics shape social behavior, and how different social structures evolve. Hobson uses a combination of observational, experimental, theoretical, and computational techniques to determine how the behavior of individuals leads to the formation of group-level social structures. Much of her work to date has focused on avian sociality, where she investigated how individuals interact in social birds such as parrots. In her future work, she plans to continue her work with parrots, while also expanding her taxonomic focus to understand broader patterns in the evolution of sociality. Prior to joining the Santa Fe Institute, Hobson completed a postdoctoral fellowship at the National Institute for Mathematical and Biological Synthesis (NIMBioS) at the University of Tennessee. She holds a Ph.D. in biology from New Mexico State University and a B.A. in environmental studies from McGill University.

Albert Kao

JSMF

Albert Kao is a biologist at Harvard University trying to understand how distributed systems are able to sense and process information, and make consensus decisions from conflicting options. This broad interest has led him to study diverse topics including neural systems, fish schooling, and the wisdom of crowds. An overarching goal is to uncover both similarities (or general principles) in distributed computation, and also differences in how different systems solve the same problems. Currently, he is studying how slime mold networks search and move around their environment. By recording a long time series of slime mold behavior in high resolution in a variety of environments, he hopes to uncover the strategies that slime molds use to gather information about their environment and act on that information. The strategies that slime molds use may be analogous to the strategies of other distributed systems, such as plants or fungal networks.

Chris Kempes

SFI

Chris Kempes' goal is to find theories and principles that apply to a wide range of biological scales and hierarchies. Kempes generally focuses his work on biological architecture—which may include phenomena ranging from explicit biological morphology to metabolic and genetic network structure—as an intermediate between organism physiology and environmental conditions. Mathematical and physical theories lie at the heart of his methodologies to predict how evolution has shaped architecture and how this, in turn, forms a foundation for reliable predictions of environmental response and interaction. His work spans the scales of genetic information architecture to the morphology of microbial individuals and communities to the regional variation of plant traits and their feedback with climate and available resources. In so doing, he aims to connect these first-order trends to the limitations imposed by environments in order to predict specific evolutionary events and consequences. Several collaborations with experimentalists and theorists have led to models that inform experiments and assimilate empirical data in fields including single-cell experimental biology and forest dynamics.

Artemy Kolchinsky

SFI

Artemy Kolchinsky studies how information is organized and processed in biological, neural, and physical systems. He previously investigated information-theoretic methods for analyzing distributed organization, which can be used to decompose systems into weakly-coupled 'modules', and to identify which regions act as integrative hubs. In recent collaboration with Santa Fe Institute professor David Wolpert, Kolchinsky is researching fundamental constraints on the energy required to process information, whether done by a living cell, a digital computer, or any other device. He is also attempting to use statistical physics to define a notion of semantic information, i.e. information that doesn't simply reflect correlations but rather the amount of meaningful content for a given system. Kolchinsky holds a Ph.D. from Indiana University, Bloomington with a specialization in complex systems and a minor in cognitive science.

Daniel Koll

JSMF

Daniel Koll, originally from Germany, Tanzania, and Kenya, is currently finishing his Ph.D. at the University of Chicago before starting as a James S. McDonnell Foundation postdoctoral fellow at MIT this fall. The last decade has seen an explosion in the number of discovered exoplanets and we might soon find a potential "Earth 2.0." At the same time, many challenges still lie ahead for observational astronomers and theorists hoping to understand these new planets. One of them is to understand rocky planets around small and dim host stars, which we know are ubiquitous but about which we know little else. In his thesis he is studying the potential atmospheres and atmospheric circulations of these exoplanets, and the extent to which they are distinct from Earth. One interesting result for researchers in complex systems is that there are strong analogies between atmospheric circulations and the classic Carnot heat engine, which promises not only to help us understand exoplanets but could also help us better understand our own world.

Dan Larremore

SFI

Dan Larremore's ongoing applied research includes the evolution of antigenic variation of malaria parasites— variation that allows them to evade the human immune system almost indefinitely. He studies this ongoing evolution in human hosts as well as its roots in chimpanzee and gorilla parasites. He also continues to examine hierarchy and its emergence in university faculty hiring networks, from the concepts of prestige to gender inequality. Finally, he studies the dynamics of the mammalian neocortex, which appear to be positioned precisely at the critical point of a phase transition at which properties such as dynamic range and information entropy are maximized. From a purely theoretical perspective, Larremore's work focuses on clarifying the widely used and misused configuration model, as well as community detection using the stochastic block model. Prior to the Omidyar Fellowship at the Santa Fe Institute, Larremore earned a B.S. in chemical engineering from Washington University in St. Louis, a M.S., and a Ph.D. in applied mathematics from the University of Colorado at Boulder, and joined the Center for Communicable Disease Dynamics in the Department of Epidemiology at the Harvard School of Public Health as a postdoctoral fellow.

Eric Libby

SFI

Eric Libby's research into single-celled organisms combines mathematical approaches with experimental observations to find the evolutionary conditions that can lead single cells to form groups capable of reproduction, i.e. primitive multicellular organisms. Understanding the origins of multicellularity is not simply a dig into the past but also an exploration into what types of collective entities can be formed from individuals. In this way, research into the origins of multicellularity is intimately connected with research into cooperation, self-organization, the human microbiome, tissue construction, and the stability of communities and ecosystems. Libby completed a postdoctoral fellowship in mathematical microbial evolution at the New Zealand Institute for Advanced Study. Before that he earned a Ph.D. in quantitative physiology from McGill University and a B.A. in computational and applied mathematics from Rice University.

Remi Louf

JSMF

Remi Louf is a philosopher and physicist by training, who has turned his analytical and quantitative mind towards the study of urban phenomena. After obtaining his Ph.D. in theoretical physics at the Institut de Physique Théorique (IPhT) in Paris, he obtained a James S. McDonnell Foundation Postdoctoral Fellowship Award in studying complex systems to pursue his research at the Centre for Advanced Spatial Analysis (CASA) at University College London. Louf's research revolves around the foundations of urban science. He designs sound empirical methods to get accurate and comparable pictures of cities, and proposes a simple model to isolate and understand the underlying mechanisms. He is currently passionate about the definition of cities, the quantification of urban form, the modifiable areal unit problem and residential segregation. He firmly believes that a quantitative understanding of the mechanisms at play in our societies will help us design more efficient policies.

Helen McCreery

JSMF

Helen McCreery is currently a Ph.D. candidate in the Ecology and Evolutionary Biology department at the University of Colorado, with bachelor's and master's degrees in environmental engineering. Broadly speaking, McCreery is interested in emergent coordination and problem solving in groups. She currently studies coordination in ants, focusing on cooperative transport, which occurs when groups cooperate to move large objects, like dead crickets and other food sources, back to their nest. McCreery uses both theoretical and field approaches to examine how groups break deadlocks to make consensus decisions, and she extends this work to look at group-level problem-solving strategies for obstacle navigation. During her Ph.D., she started multi-disciplinary collaborations, including with computer scientists working in robotics. While McCreery's dissertation research focuses on coordination in ant colonies, she looks forward to exploring similar questions in other tasks and study systems in her postdoc. McCreery aims to understand emergent coordination of multiple interacting individuals in complex decision-making processes, and she is eager to explore how diverse groups coordinate their actions.

Jasmine Nirody

JSMF

Jasmine Nirody is currently a Ph.D. candidate in biophysics, with a designated emphasis in computational and genomic biology, at the University of California, Berkeley. She obtained her bachelor's in mathematics and biology at New York University and was a fellow of the Mathematical Research Institute for the program "Numerical Bifurcation Analysis of Dynamical Systems" in Utrecht, the Netherlands. Her research lies at the intersection of the physical, biological, and computational sciences; recently, she has also become interested in pursuing engineering applications of her work. The main focus of Nirody's research has been on problems in mechanics, primarily on the study of microscopic and macroscopic motility. In the past, she has studied muscle protein dynamics and locomotion in snakes and geckos. Nirody's dissertation work involved using theoretical (statistical mechanics; differential equations) and experimental (optical trapping; fluorescence microscopy) tools to study the dynamics of the rotary motor that drives locomotion in flagellated bacteria. She has also had the opportunity to work on problems in a variety of fields, including image analysis, dynamical systems in biology, population genetics, and neuroscience.

Lisa O'Bryan

JSMF

Lisa O'Bryan's research interests lie in how patterns of information transmission influence the behavior of complex systems. Her Ph.D. in ecology, evolution, and behavior at the University of Minnesota studied how the vocalizations chimpanzees produce upon the discovery of food influence their patterns social foraging behavior. Her current research project develops methodological and theoretical techniques for applying a complex systems framework to the study of animal communication behavior. She is developing an on-animal data logger that is capable of recording acoustic signals and can be combined with other sensors, such as GPS units and accelerometers. Along with her collaborators, O'Bryan is studying this topic with a population of wild baboons at Tsaobis Nature Park in Namibia as well as with domestic flocks of goats and sheep. As part of this work they are developing new tools for processing, analyzing and modeling these dynamic social data. O'Bryan plans to apply this knowledge towards the understanding of information transfer within less tractable natural systems and the design of effective communication networks within artificial systems.

Jeffrey Peters

JSMF

Jeffrey Peters is an infrastructure economist with experience in transportation, energy, and electricity infrastructure systems. Peters is a James S. McDonnel Foundation Postdoctoral Fellow in Management Science and Engineering at Stanford University; he is also involved in the Energy Modeling Forum. Peters has a B.S.E. in aerospace engineering from the University of Michigan as well as advanced degrees in civil engineering, economics, and a Ph.D. in environmental, resource, and energy economics from Purdue University. At Purdue, Peters was selected as one of 580 young economists invited to attend the Lindau Meeting of Nobel Laureates in Economic Sciences, worked as a research associate at the Congressional Research Service on Capitol Hill, and co-founded TEDxPurdueU. His JSMF proposal is "Interdependent Infrastructure and Economic Systems." The goal of the research is to study both how and why goods move in a complex economy to better understand the economic impact of infrastructure systems and design more efficient, robust, and resilient systems. Peters and his wife enjoy hiking and traveling. They have been to six continents, climbed a volcano, and trekked to Everest Base Camp.

Shai Pilosof

JSMF

Shai Pilosof is a James S. McDonnel Foundation postdoctoral scholar in the lab of Mercedes Pascual, at the University of Chicago. His research interests involve the application of network theory to ecological systems, specifically in the field of disease ecology. Pilosof is interested in the ecological and evolutionary mechanisms underlying the complexity of host-parasite networks. In collaboration with professor Jordi Bascompte during his Ph.D., he showed that the structure of host-parasite networks is associated with host immunogenetic background using a host-parasite network interconnected to a host-gene network (*Nature Communications*, 2014). During his postdoctoral research he has developed a framework for the study of ecological multilayer networks. This framework allows one to study ecological systems with multiple facets of complexity, such as interactions that vary in space and time, or systems that interconnect such as networks of species interaction networks. The next step is to apply this framework to study the temporal dynamics of the (genetic) strain structure of the malaria parasite *Plasmodium falciparum*.

Eleanor Power

SFI

Elly Power is an anthropologist interested in how religious belief, practice, and identity interact with and shape interpersonal relationships. She studies how people work to discern something of the character, moral being, and intentions of their peers through their actions—particularly their religious action. Power investigates how people's actions shape not only people's perceptions of one another, but also form the substance of their relationships and the emergent structure of their social world. When such bonds are crucial to our ability to get by, this ultimately is an investigation into how people's religious lives shape their social and economic lives. Power does this with a combination of qualitative and quantitative methods, primary among which is social network analysis. She is interested in the dynamics of social networks, especially relative to the factors that influence cooperation, competition, trust, and prestige. More generally, Power is interested in investigating questions regarding: the role of religion in society, the interaction between costly signaling and cooperation, gender differences in prestige and social status, and the dynamics of gossip and social censure.

Oren Raz

JSMF

Oren Raz is a James S. McDonnel Foundation postdoc working in the Jarzynski group at the University of Maryland. He did his M.Sc. with Yosi Avron at the Technion, working on theoretical aspects of swimming and pumping at low Reynolds number. He did his Ph.D. as an experimentalist, working with Nirit Dudovich at the Weizmann Institute, on attosecond pulses: how to measure them and extract the physical information about the process of their generation. At the moment he is working on the following problem: many complex systems are modeled as nonequilibrium steady state, driven by the consumption of some thermodynamical resource (e.g. bio-molecular motors driven by hydrolyzing ATP). However, an artificial system (e.g. artificial molecular motors) that uses the same type of driving is extremely difficult to construct in the laboratory. Instead, most artificial nano-system out of equilibrium are driven by periodic changes in some external parameters: temperature, pressure, PH and so on. Are these ways of being out of equilibrium equivalent in some senses? What are the design principles for a driving protocol that can achieve the same outcome as a non-equilibrium steady state?

Andy Rhines

JSMF

Andy Rhines is a postdoctoral fellow in Atmospheric Sciences at the University of Washington. He holds a Ph.D in applied mathematics from Harvard, and a B.A. in physics from Reed College. His research examines how the spectrum of climate variability emerges from the combination of forcing, large-scale dynamics, and local processes. Rigorously testing hypotheses despite the sparsity of historical data in space and time requires developing analytical tools that bridge the gap between models and the heterogeneous climate datasets used to validate them. These tools have found applications in topics ranging from Greenland's hydrologic cycle to modern temperature observations and model projections of climate extremes. Rhines' work is presently focused on developing simplified stochastic models to understand how large-scale atmospheric processes interact with the land surface to produce non-Gaussian temperature variability, and on improving predictions of rare climate extremes such as heat waves and droughts, cold snaps and floods. This research contributes to our understanding of the processes that will dominate climate impacts in the coming century.

Maria Riolo

JSMF

Maria Riolo received a Ph.D. in applied and interdisciplinary mathematics from the University of Michigan. She is currently researching methods to efficiently describe the information contained in networks, both in the context of network compression and the generation of ensembles of related networks.

Elizabeth Roberto

JSMF

Elizabeth Roberto is a postdoc in the Department of Sociology at Princeton University. Her research interests include social stratification and inequality, urban sociology, complex adaptive systems, and quantitative methods. She received a James S. McDonnell Foundation Postdoctoral Fellowship Award for studying complex systems, which funds her postdoctoral research on the spatial dynamics of social inequality. She uses innovative methods to examine how a city's topography and regional context shape spatial patterns of residential segregation. In particular, she examines how spatial boundaries, including municipal borders and physical barriers, structure urban space. She demonstrates that spatial boundaries are a key mechanism that facilitate and maintain residential segregation. Her research contributes to a deeper understanding of the causes of segregation in U.S. cities by explaining how the institutionalization and maintenance of spatial boundaries perpetuates and exacerbates residential segregation. Roberto holds a Ph.D. in sociology from Yale University, and an M.P.A. and B.A. from George Washington University. She previously worked as a Presidential Management Fellow and Research Analyst at the U.S. Department of Transportation, Brookings Institution, and Government Accountability Office.

Grant Rotskoff

JSMF

Grant Rotskoff is a Ph.D. student in the Biophysics Graduate Group at the University of California, Berkeley. Working with Phillip Geissler and Gavin Crooks, he studies the relationship between dissipation in nanoscale machines and the nonequilibrium protocols that are used to drive them. He is particularly interested in efficiency and optimal control in nanoscale engines, where fluctuations add a layer of complexity to familiar thermodynamic quantities like work and heat. Before coming to Berkeley, Rotskoff studied mathematics at the University of Chicago. As an undergraduate, he worked with Gregory Voth to develop enhanced sampling methods for large scale, biomolecular simulations.

Jakob Runge

JSMF

Jakob Runge studied physics and mathematics at Humboldt University Berlin and the University of California in Santa Cruz and conducted his physics Ph.D. research at the Potsdam Institute for Climate Impact Research. His thesis was awarded the Carl-Ramsauer prize of the Berlin Physics Society and explored the task of detecting and quantifying causal interactions from time series of complex systems applied to the climate system. He is currently at the Grantham Institute at Imperial College London. The goal of his project is to further develop a statistical theory and practical methods of causal inference from time series of dynamical and nonlinear complex systems focusing on two research questions: (1) Time-scale-dependent causal inference: How are different time-scales, i.e., fast and slow dynamics in subprocesses of complex systems, interacting causally? (2) Extreme-value causality: How can causal effects on average and more extremal scales of two interacting processes be distinguished. Runge's main application focus is the complex system Earth. He is also more broadly interested in abstract formalizations of causal information transfer in complex systems.

Lauren Shoemaker

JSMF

Lauren Shoemaker is a Ph.D. candidate in ecology and evolutionary biology also working on a certificate in interdisciplinary quantitative biology at the University of Colorado, Boulder. As a theoretical community and macroecologist, she is broadly interested in patterns of species diversity across both space and time. Her research examines mechanisms that promote and maintain biodiversity across scales, and focuses specifically on the role of environmental variation and stochasticity. She uses diverse mathematical methods from multiple disciplines, including analytical techniques, partial differential equations, and complex computer simulations. Shoemaker works to integrate theory and empirical tests of complex communities using a combination of small-scale microcosm experiments, large-scale field manipulations, as well as macroevolutionary patterns in paleontological measurements. In her postdoc, Shoemaker is excited to explore how behavior and disease dynamics alter patterns of biodiversity and how they interact with stochasticity and environmental heterogeneity.

Michele Starnini

JSMF

Michele Starnini is currently a postdoctoral fellow at the Universitat de Barcelona, within the group lead by Marian Boguña. His current position is funded by the James S. McDonnell Foundation. He earned his Ph.D. in 2014 at the the Universitat Politecnica de Catalunya, under the supervision of professor Romualdo Pastor Satorras. Starnini's research interests include understanding emerging socio-economic phenomena, such as the epidemic spreading of behaviors or ideas in a population, the dynamics of physical interactions in social gatherings or cooperation and collaboration among individuals. At a more theoretical level, he investigates the behavior of dynamical processes on static or time-varying networks. Recently, he studied the effects of temporal correlations between different kind of social activities performed by individuals, represented as different layers of a multiplex networks.

Talia Tamarin

JSMF

Talia Tamarin is at the Weizmann Institute, in the group of Yohai Kaspi from the Earth and Planetary Sciences department. She was born in Tel-Aviv, Israel, where she also completed her undergraduate studies in mathematics and geophysics. Tamarin obtained a master's degree in physics at Tel-Aviv University with academic distinction, studying the nonlinear interactions of waves in simple atmospheric shear flows. She spent a summer at Oxford University as a visiting student in the physical oceanography group, joining David Marshall and his group to work on the problem of parameterizing unresolved small-scale turbulence in global ocean models. In her Ph.D., she studies the mechanisms that shape our climate and weather system. Specifically, she is presently interested in mid-latitude atmospheric dynamics, investigating what controls the formation, propagation, intensity, and spatial distribution of extra-tropical storms. She also studies the atmospheric response to climate change. Tamarin has recently been awarded a prize in recognition of academic excellence from her institute, and is the recipient of the James S. McDonnell post-doctoral fellowship for the study of complex systems.

Brendan Tracey

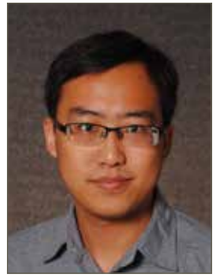
SFI

Brendan Tracey received a B.S. in mechanical engineering from the University of Rochester and completed his Ph. D. in aeronautics and astronautics from Stanford University. He is primarily interested in the application of non-traditional ideas to engineering analysis and design. At Santa Fe Institute, he researches multi-information source optimization (MISO). Traditional optimization techniques seek to find the minimum of a single objective function (black-box or convex). As complexity increases, there are typically a number of different ways to acquire knowledge about the problem at hand. The objective function may be broken down into systems that each have their own internal structure but are also interdependent, as in multi-disciplinary optimization. Alternatively, there may be a tradeoff between simulation time and accuracy, as in multi-fidelity optimization. The question is how to effectively use all of these sources of information to efficiently find a good design. An answer to this question uses techniques from statistics, machine learning, game theory, and single-function optimization. Previously, he has explored the use of these techniques for analyzing epistemic uncertainty in computational fluid dynamic tools and for improving models of turbulence.

David Zeevi

JSMF

David Zeevi, Ph.D. studies at the Department of Computer Science and Applied Mathematics at the Weizmann Institute of Science, under the supervision of professor Eran Segal. His research focuses on designing tools for the analysis of the vast microbial ecosystem that is the gut microbiome, and applying these tools to understanding the relationship between nutrition, health, and gut microbes in human individuals, with the aim of achieving personalized nutrition as personalized preventive medicine. In his Ph.D., Zeevi coauthored several key publications in the field of microbiome research, linking the microbiome to the effects of artificial sweeteners (Nature, 2014) and host circadian rhythm (Cell, 2014); modelling bacterial growth dynamics (Science, 2015); and taking the first step towards personalized nutrition by predicting the glycemic responses of individuals to complex meals (Cell, 2015).



Xianyuan Zhan

JSMF

Xianyuan Zhan is currently a Ph.D. candidate at the Lyles School of Civil Engineering at Purdue University. He has a background in both civil engineering and computer science. Zhan received his B.E. in civil engineering from Tsinghua University, China and his M.S. in transportation engineering from Purdue University. He is also pursuing a dual M.S. degree in computer science at Purdue University. Previously, he has worked as a visiting research fellow at Microsoft Research Asia (MSRA). Zhan's research interests are two-fold: developing advanced data-driven methodologies for urban applications using large-scale data sources, as well as complex network studies in the areas of human mobility/activity patterns and functional failure processes. In his current research, he studies the congestion evolution on road networks, which is a typical example of functional failure process on flow-based networks. He proposes a model to transform the functional failure process into an equivalent dynamic structural process, which allows for joint analysis of network structural characteristics and functional properties.

NOTES

SPEAKERS

Samuel Arbesman

Samuel Arbesman is a complexity scientist whose work focuses on the nature of scientific and technological change. He is currently Scientist in Residence at Lux Capital. He is also a senior fellow of the Silicon Flatirons Center for Law, Technology, and Entrepreneurship at the University of Colorado and a research fellow at the Long Now Foundation. Arbesman's training is in complexity science, computational biology, and applied mathematics. His scientific research has been cited widely, and his essays about science, mathematics, and technology have appeared in *The New York Times*, *The Wall Street Journal*, and *The Atlantic*. Arbesman is the author of the new book *Overcomplicated: Technology at the Limits of Comprehension* (Current/Penguin, 2016) and of the award-winning *The Half-Life of Facts* (Current/Penguin, 2012). Previously, Arbesman was a senior scholar at the Ewing Marion Kauffman Foundation and a research fellow in the Department of Health Care Policy at Harvard Medical School. He completed a Ph.D. in computational biology at Cornell University in 2008, and earned a B.A. in computer science and biology at Brandeis University in 2004.

Dave Bacon

Dave Bacon is a theoretical physicist turned computer scientist turned software engineer. After getting his Ph.D. in physics in 2001 from the University of California, Berkeley, he spent a decade working in quantum computing. During that time he dreamt up ideas in quantum error correction and quantum algorithms and ended up as a research professor in the computer science and physics departments at the University of Washington. Then, in 2011, in a fit of whimsy, he applied for and landed a job as a software engineer at Google. There he helped build from scratch a domain registrar. These days he works in machine intelligence at Google, and pursues quantum computing as a hobby. If you want to hear him monologue, bring up quantum algorithms, the storage of information in a noisy world, privacy in machine learning, the cabin he built in central Washington, or transdisciplinary physics work in machine learning. Otherwise he is quite approachable

Liz Bradley

Liz Bradley did her undergraduate and graduate work at MIT, interrupted by a one-year leave of absence to row in the 1988 Olympic Games, and has been with the Department of Computer Science at the University of Colorado at Boulder since January of 1993. Her research interests include nonlinear dynamics, artificial intelligence, and control theory. Recent research projects include the active use of chaos in engineering design and a variety of autonomous design and analysis tools for nonlinear dynamical systems. Bradley is a member of the external faculty of the Santa Fe Institute and the recipient of a National Young Investigator award, a Packard Fellowship, and the 1999 University of Colorado College of Engineering "innovation in teaching" award.

Brent Dolezalek

Brent Dolezalek is senior program associate at the James S. McDonnell Foundation, and he has been with the James S. McDonnel Foundation in various capacities since 2002. He manages JSMF's advisory panels. Dolezalek received a B.S. in psychology from Washington University in St. Louis and holds a M.S. in industrial organizational psychology from San Francisco State University. He has a long-standing interest in effective use of technology. When not working or playing with his kids, he enjoys programming.

Jennifer Dunne

Jennifer A. Dunne is Vice President for Science at the Santa Fe Institute, where she has been on the faculty since 2007. Dunne received an A.B. from Harvard where she studied philosophy, an M.A. in biology from San Francisco State University, a Ph.D. in energy and resources from the University of California, Berkeley, and a National Science Foundation postdoctoral fellowship in biological informatics. As Vice President for Science, Dunne manages all science-related activities at SFI, including the resident and external faculty, postdoctoral programs, seminar series, scientific visitors, working groups and workshops, sponsored research, and communications.

Susan M. Fitzpatrick

Susan M. Fitzpatrick is President of the James S. McDonnell Foundation, St. Louis, Missouri. The McDonnell Foundation is one of a limited number of international grant-makers supporting university-based research in biological, behavioral, and complex systems sciences through foundation-initiated programs. She is also an adjunct associate professor of neurobiology and anatomy and occupational therapy at Washington University School of Medicine (St. Louis) and teaches neuroscience. Fitzpatrick lectures and writes on issues concerning applications of neuroscience to clinical problems, the translation of cognitive science to educational settings, the role of private philanthropy in the support of scientific research, and on issues related to the public dissemination of and understanding of science. Before joining the James S. McDonnell foundation in 1993, Fitzpatrick served as Associate Executive Director of the Miami Project to Cure Paralysis (1989-1992). She received her Ph.D. in biochemistry and neurology from Cornell University Medical College (1984) and pursued post-doctoral training with in vivo nuclear magnetic resonance spectroscopic studies of brain metabolism/function in the Department of Molecular Biochemistry and Biophysics at Yale University.

Michele Girvan

Michele Girvan is an associate professor in the Department of Physics and the Institute for Physical Science and Technology at the University of Maryland. Her research interests focus on the theory and applications of complex networks. In terms of theory, she has worked extensively on defining and identifying modularity in networks. She currently works on applications of network theory to gene regulation and the spread of ideas. Girvan received her Ph.D. in physics from Cornell University and received undergraduate degrees in physics and math at MIT. Before joining the faculty at the University of Maryland, she was a postdoctoral fellow at the Santa Fe Institute, where she currently serves as a member of the external faculty.

Nancy Houfek

A stage director, award-winning actor, and nationally recognized theater educator, Nancy Houfek presents workshops combining theater, negotiation and leadership techniques. At Harvard, she was Head of Voice & Speech for the Tony Award-winning American Repertory Theater from 1997–2014, Houfek also taught in programs at the Kennedy School of Government, the Harvard School of Public Health, and the Harvard Medical School. She continues her work there with the Radcliffe Fellows, the Smithsonian Center for Astrophysics, the Graduate School of Design and the Derek Bok Center for Teaching and Learning. "The Act of Teaching," a film of her work produced by the Bok Center, has been distributed to faculty development centers nationwide. Since 1999, she has been a facilitator for COACh (the Committee on the Advancement of Women Chemists), offering negotiation and communication workshops to scientists. She has also received seven consecutive awards for excellence in teaching from Harvard University.

Elisabeth Johnson

Elisabeth Johnson, who joined the Santa Fe Institute in 2007, is Director of Sponsored Research Development and Administration, responsible for planning and developing Institute-wide research programs, identifying funding for faculty research projects, preparing proposals, and managing post-award administration. She handles ongoing relations with federal and state funding agencies, as well as private foundations. Johnson came to SFI from UCLA, where she was Director of Corporate, Foundation and Research Relations for the professional schools. Prior to that, she directed the university's Strategic Research Initiative to expand research funding for faculty in the humanities, social sciences, and arts.

LeeAundra Keany

LeeAundra Keany is the founder of Keany Communications. She is an executive communications coach specializing in public speaking, media training, high-level presentation training and executive presence. In her twenty-five years as a coach, she has worked with former heads of state, Nobel Laureates, best-selling authors, award-winning producers, directors and actors, Olympians, high-ranking officials in the U.S. Government, and CEOs of public, private, and not-for-profit organizations. Keany is an award-winning public speaker and speech writer honored by the National Forensics Association. She was a speech writer and aide to former Under Secretary of State G. Mennen Williams and served in former Michigan Governor James Blanchard's administration. Keany has published numerous articles and provides regular expert commentary and analysis on public speaking and debate for major media outlets such as CNN, BBC World Service, NPR, *The Economist*, *The Wall Street Journal*, *The Times* (of London), and *The New York Times*. Keany graduated with a Bachelor of Arts in politics, rhetoric, communications, and journalism from the Honors College at Oakland University. She earned her Master of Arts in politics from New York University.

David Krakauer

David Krakauer is President and William H. Miller Professor of Complex Systems at the Santa Fe Institute. Krakauer's research explores the evolution of intelligence on earth. This includes studying the evolution of genetic, neural, linguistic, social and cultural mechanisms supporting memory and information processing, and exploring their shared properties. He served as Founding Director of the Wisconsin Institute for Discovery, Co-Director of the Center for Complexity and Collective Computation, and Professor of mathematical genetics all at the University of Wisconsin, Madison. Krakauer has been a visiting fellow at the Genomics Frontiers Institute at the University of Pennsylvania, a Sage Fellow at the Sage Center for the Study of the Mind at the University of Santa Barbara, a long-term fellow of the Institute for Advanced Study in Princeton, and visiting Professor of Evolution at Princeton University. In 2012 Krakauer was included in the *Wired* magazine Smart List as one of 50 people "who will change the world." In 2016 Krakauer was included in *Entrepreneur* magazine's "visionary leaders advancing global research and business."

Marc Lipsitch

Marc Lipsitch is Professor of Epidemiology and Director of the Center for Communicable Disease Dynamics at the Harvard School of Public Health. He's authored more than 200 peer-reviewed publications on antimicrobial resistance, mathematical modeling of infectious disease transmission, bacterial and human population genetics, and immunity to *Streptococcus pneumoniae*. His group produced one of the earliest estimates of transmissibility of the SARS virus in real time in 2003, and provided a key estimate of the transmissibility of 1918 pandemic influenza. He has a growing interest in the design of clinical trials for infectious disease control interventions, especially how to design trials that are ethically acceptable and maximally informative. Lipsitch received several outstanding young investigator awards and in 2015 was elected Fellow of the American Academy of Microbiology. He has provided advice on antimicrobial resistance, SARS and influenza to the Food and Drug Administration, the World Health Organization, the Centers for Disease Control, the Congressional Budget Office, the Defense Science Board, several pharmaceutical companies, and the governments of Canada and Mexico. He also serves on several editorial boards for major journals.

Lauren Ancel Meyers

Lauren Ancel Meyers received her B.A. in mathematics and philosophy in 1996 from Harvard University, and her Ph.D. in 2000 from the Department of Biological Sciences at Stanford University. After completing a postdoctoral fellowship from the National Science Foundation, she joined the faculty of the Department of Integrative Biology at the University of Texas at Austin in 2003. Ancel Meyer's research lies at the interface of evolutionary biology and epidemiology. She studies the interplay between disease transmission dynamics and the evolution of pathogens including those responsible for epidemic meningitis, influenza, walking pneumonia, and SARS. Ancel Meyers conducts research in two general areas. The first is mathematical epidemiology. Over the last five years, she has been developing new network-based mathematical approaches for predicting the spread of infectious diseases and collaborating with public health officials in the U.S. and Canada to apply optimal control measures. Her second research area is theoretical evolutionary biology, with particular focus on the impact of environmental heterogeneity on evolutionary dynamics and the structure of complex fitness landscape. *MIT Technology Review* recently named her one of the top 100 global innovators under age 35.

John Miller

John H. Miller received his Ph.D. in economics from the University of Michigan in 1988. He then joined the Santa Fe Institute as their first postdoctoral fellow, followed by an appointment in the Department of Social and Decision Sciences at Carnegie Mellon University, where he served as Department Head from 2002 to 2014 and is currently Professor of Economics and Social Science. His research interests are in complex adaptive social systems and behavioral economics. He currently serves as the chair of the Science Steering Committee at the Santa Fe Institute. He was born and raised in Denver, Colorado—the fourth generation of a family of ranchers. Information on his research can be found at *http://zia.hss.cmu.edu/miller/research.html*.

Ole Peters

Ole Peters is a fellow at the London Mathematical Laboratory and External Professor at the Santa Fe Institute. He works on different conceptualizations of randomness in the context of economics. His thesis is that the mathematical techniques adopted by economics in the 17th and 18th centuries are at the heart of many problems besetting the modern theory. Using a view of randomness developed largely in the 20th century he has proposed an alternative solution to the discipline-defining problem of evaluating risky propositions. This implies solutions to the 300-year-old St. Petersburg paradox, the leverage optimization problem, the equity premium puzzle, and the insurance puzzle. It leads to deep insights into the origin of cooperation and the dynamics of economic inequality.

Van Savage

Van Savage is a professor in the Ecology and Evolutionary Biology Department at UCLA and the Biomathematics Department at UCLA Medical School. He also directs the inter-departmental Computational and Systems Biology major at UCLA. His background is in theoretical particle physics, having received a B.S. from Rhodes College and a Ph.D. from Washington University in St. Louis. Savage conducted postdoctoral research at the Santa Fe Institute, Los Alamos National Lab, Harvard, and Harvard Medical School. A major goal of his research is to quantify and to understand the possible functions, forms, and interactions of biological systems that result in the extraordinary diversity in nature. He has studied a wide range of topics, and aims to understand how much variation around optima or averages is considered healthy or adaptive versus diseased or disturbed states, which are essentially deviations from normal or sustainable functioning. His new findings about the diversity and variation in form and function are revealing flaws in current models, and he is working to develop new theories that incorporate realistic amounts of natural variation.

Cosma Shalizi

Cosma Shalizi is an associate professor in the Department of Statistics at Carnegie Mellon University, with joint appointments in the Machine Learning Department, the Center for the Neural Basis of Cognition, and the H. John Heinz III College. He is also external faculty at the Santa Fe Institute. Shalizi earned an A.B. in physics from the University of California, Berkeley in 1993, and a Ph.D. in physics from the University of Wisconsin, Madison in 2001. He came to Carnegie Mellon in 2005 following postdoctoral positions at the Santa Fe Institute and the University of Michigan Center for the Study of Complex Systems. Shalizi's research interests include statistical inference for complex systems; nonparametric prediction for stochastic processes; causal inference; large deviations and ergodic theory; networks and information flow in neuroscience, economics and social sciences; heavy-tailed distributions; and self-organization.

Neal Stephenson

Neal Stephenson is is an American writer and game designer known for his works of speculative fiction. His work explores subjects such as mathematics, cryptography, linguistics, philosophy, currency, and the history of science. He also writes nonfiction articles about technology in publications such as Wired. He has also written novels with his uncle, George Jewsbury ("J. Frederick George"), under the collective pseudonym Stephen Bury. Stephenson has worked part-time as an advisor for Blue Origin, a company (funded by Jeff Bezos) developing a manned sub-orbital launch system, and is also a cofounder of Subutai Corporation, whose first offering is the interactive fiction project *The Mongoliad.* He is currently Magic Leap's Chief Futurist. He is the New York Times bestselling author of *Reamde, Anathem, Cryptonomicon*, and other novels.

Will Tracy

Will Tracy is the Vice President for Strategic Partnerships at Santa Fe Institute. His academic work lies at the intersection of complex systems and strategic management, with a focus on how boundedly-rational actors approach novel problems. Tracy comes to SFI from Rensselaer Polytechnic Institute, where he was the undergraduate program director for the Lally School of Management and a faculty member. He is proficient in Mandarin Chinese, and formerly served as the Associate Director of CSSS-Beijing, which was jointly administered by SFI and the Institute of Theoretical Physics at the Chinese Academy of Sciences. Before entering academia, Tracy was a Junior Professional Associate at The World Bank, where he focused on Eastern Europe and Central Asia. Tracy also has private sector and entrepreneurial experience in the US, China, and India. He holds a Ph.D. in management with a certificate in human complex systems from UCLA, and a BA (cum laude) in economics from Swarthmore College.

Lisa Troyer

Lisa Troyer is Program Manager for Social & Behavioral Sciences at the Army Research Office, with over two decades of experience as a social and behavioral scientist. She serves as a university professor (currently affiliated with Duke University), consultant, and Department of Defense contractor. She is also the Army's point-of-contact for the Minerva Research Initiative. She has served as a consultant to small businesses, not-for-profit agencies, and Fortune 500 companies, and has worked closely with public sector agencies in emergency response planning, civic engagement, and the advancement of human rights. Troyer received her Ph.D. and M.A. degrees from Stanford and her B.A. from the University of Washington in sociology, with specialties in social psychology, complex organizations, and decision sciences. She has published peer-reviewed articles in top scientific outlets across a range of disciplines, including engineering, social sciences, and physical sciences. She maintains an active research agenda focusing on group dynamics, technology, and organizational culture and performance.

NOTES

Today the network of relationships linking the human race to itself and to the rest of the biosphere is so complex that all aspects affect all others to an extraordinary degree. Someone should be studying the whole system, however crudely that has to be done, because no gluing together of partial studies of a complex nonlinear system can give a good idea of the behaviour of the whole.

—Murray Gell-Mann in The Primer Project International Society for the Systems Sciences seminar, 1997

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