Modern cities’ deep connection with ancient ones

It started with an idea that led to an experiment, then to an SFI-style collaboration, which culminated last month in a significant paper.

The idea, often discussed around SFI, is that based on vast amounts of urban data, modern cities – regardless of their culture or level of development – follow the same mathematical rules: many urban quantities, from average wages to measures of infrastructure, vary predictably with city population size.

Recent theory, published last summer in Science and proposed by SFI Professor Luis Bettencourt to explain these intriguing patterns, treats cities and networks, and with properties that are not specific to modern cities.

When archaeologist Scott Ortman, a former SFI Omidyar Fellow now at the University of Colorado Boulder, heard these findings from the Institute’s Cities & Urbanization team, he was curious whether the same scaling relationships would apply to the settlements of ancient civilizations.

So Ortman did an informal analysis using urban scaling rules and urban data from an archaeological survey done 50 years ago in the Valley of Mexico, the heart of the Aztec Empire. To his amazement, the scaling rules seemed to fit the data from this ancient society that had emerged independent from the influences of European culture.

“This was an intriguing result with potentially deep implications since, let’s be honest, about the only things ancient Mexican cities have in common with today’s cities is that they were created by humans,” says Ortman. He connected with Bettencourt, who responded with similar amazement. Ortman and Bettencourt soon began to develop urban scaling theory in the context of archaeology to see whether Ortman’s initial result stood up to more rigorous scrutiny.

They formed a team to compile and digitize the data from the Pre-Columbian Valley of Mexico and analyze it in greater detail. The team included Jennie Sturm (University of New Mexico) and Andrew Cabaniss (University of North Carolina-Chapel Hill), a former student in SFI’s Research Experiences for Undergraduates program.

Their work shows that the ancient settlement system of the Valley of Mexico is not only consistent with urban scaling theory, but also exhibits spatial properties analogous to those observed in modern cities.

Their findings, published February 12 in PLOS ONE, suggest that the basic principles that organize human settlements are general and may apply to all human settlements regardless of how far apart they are in time, space, or culture.
Nonlinearities
From the editor

What is an SFI “founder”? In research- ing SFI’s early history, I’ve learned it’s a question with no easy answer. During the Institute’s conception from 1982 to 1984, a group of senior leaders of different fields have contributed vast amounts of time, money, and people – people who have considered themselves to be among SFI’s inventors. That was Cowan’s character. He wanted you to not just feel like an insider, but to be an insider, not just to support him, but to do with him something. I wanted you to have many founding contributors, some mentioned in the last issue. Some mentioned in this issue. Some forgotten, to be sure.

What smallish city can get out well over 800 people on a Tuesday evening in the middle of winter – while the Olympics are on television – to watch a movie about particle physics? Santa Fe! I’m referring, of course, to the February 11 SFI/Center for Contemporary Arts screening of the short Little Tony’s Daydream. How many people have considered themselves to be among SFI’s inventors? That was Cowan’s character. He wanted you to not just feel like an insider, but to be an insider, not just to support him, but to do with him something.

As I note on page 3, what was needed in late 1984, and fast, was a setting, money, and people – people who were respected and well known in a cooperative vision. George Cowan was highly inclusive in welcoming perspectives to the table. That’s something many people have considered themselves to be among SFI’s inventors. That was Cowan’s character. He wanted you to not just feel like an insider, but to be an insider, not just to support him, but to do with him something.

SFI Omidyar Fellow Ben Althouse says it is crucial to understand the dynamics of dengue in wild populations “so we can effectively mitigate the morbidity and mortality that result from a virus whose transmission we have little control over.”

The most recent paper, published in the March issue of the journal Virology, examines results from some 54 different dengue virus-studies of non-human primates and provides estimates of how long the virus remains in the blood – and how different viral strains behave.

The longer there’s virus in a primate’s blood, the greater the chance a mosquito will ingest the virus and then transmit to another host – human or monkey,” Althouse explains.

Their analysis finds that the differences among the 11 species of apes and old world and new world monkey species tested are minimal.

Although says the new estimates might help improve prediction of dengue epidemics in wild populations – which in turn might help lessen the degree of spillover to people living near their wild primate kin.

Co-authors include Derek Cummings and Anna Durbin of the Johns Hopkins Bloomberg School of Public Health, Kathryn Hanley of New Mexico State University, Scott Weaver of the University of Texas Medical Branch, Galveston, and Scott Halstead.

When wild primates, people, and the dengue virus converge

Despite remarkable human progress in containing infectious diseases over the last five decades, the incidence of the mosquito-borne disease – dengue fever – has increased thirty-fold in that time. Some 390 million people are infected worldwide every year.

A successful dengue vaccine would reduce the incidence of dengue fever in humans. But wild primates can’t be vaccinated, so even with a human vaccine the virus would continue to infect both wild and human primate hosts, as the mosquitos feed on both populations.

SFI Omidyar Fellow Ben Althouse says it is crucial to understand the dynamics of dengue in wild populations “so we can effectively mitigate the morbidity and mortality that result from a virus whose transmission we have little control over.”

That’s why Althouse and his collaborators are examining how the virus circulates in the wild — beyond the reach of vaccines — and the relationships among the virus, the mosquitos that carry it, and the primate hosts (including humans) it infects.

Adaptation
continued from page 1

Moreover, he says, the role of individual genes in the process of adaptation is affected by their positions in these networks.

Scarpino, an integrative biologist investigating the evolution and spread of infectious diseases, co-organized SFI’s first SFI working group in late February to explore the role of adaptation in molecular evolution.

The meeting’s co-organizer and mathematical ecologist Jesse Laska of Columbia University, with his background in fundamental ecological and evolutionary processes, and the levels of communities and genomes, brought deep theoretical and statistical expertise to the discussions.

Co-organizer and integrative biologist David Des Marais of Harvard University brought an experimental perspective. His research examines how plants adapt to local climates, focusing on the genetic and physiological bases of their stress responses.

Other participants included SFI Omidyar Fellow Freda Fenn, who investigates how evolutionary mechanisms operate at various levels of organization, and Eric Libby, who researches how single-celled ancestors transitioned to simple multicellular organisms and what those in-between forms might have looked like.

The group took the first steps in answering testable questions, such as where selection acts within molecular networks, and how the stability of an environment affects molecular evolution as a population adapts to a new location or conditions.

“Our results, we hope, will serve as a foundation for developing new theory and interrogating it with experiments and data,” says Scarpino.
Mirta Galesic has been selected as next SFI Cowan Chair in Human Social Dynamics

Mirta Galesic has been selected as SFI’s next Cowan Chair in Human Social Dynamics. Galesic plans to join SFI in January 2015 as a full-time resident professor for a five-year term. Currently a research scientist with the Center for Adaptive Behavior and Cognition at the Max Planck Institute for Human Development, Galesic holds a PhD in psychology from the University of Zagreb, Croatia, and an MS in survey methodology from a joint program at the University of Maryland and the University of Michigan.

“Galesic will extend SFI’s intellectual landscape in new, exciting directions,” says SFI Chair of the Faculty Jennifer Dunne. “Her expertise and research in psychology, social cognition, decision making, and uncertainty will synergize with the types of research currently pursued by our resident faculty, postdocs, and external faculty.”

In 2010, SFI’s founding president George Cowan endowed the George A. and Helen Dunham Cowan Chair in Human Social Dynamics to attract leading social scientists to SFI who have applied rigorous quantitative methods in their fields and who offer perspectives that are complementary to existing SFI research.

Three inaugural Cowan Professors will end their three-year, part-time appointments with SFI in 2014: Mahzarin Banaji, Robert Boyd, and Ricardo Hausmann.

“Bringing these three scientists to SFI has been a great success,” says Dunne. “Their research agendas address a diversity of interesting topics — experimental psychology, the evolution of social behavior, and economics and development — and they have brought new ideas and methods to SFI.”

Galesic’s selection marks a shift in the focus of the program. “In the past we looked to bring eminent, later-career scholars to the Institute for shorter periods of time,” Dunne says. “For this next period of Cowan Chair funding, we decided to bring a promising early-career scientist to be a full-time resident professor, someone who will both augment our research and be immersed in the daily life of the Institute.”

By John German

It was November 1984. The fledgling Institute had just held a pair of workshops during which some 60 invitees had heard the “game plan” for a completely new kind of research and education center.

The two workshops, themed “Emerging Syntheses in Science,” featured a rollicking discussion and an abundance of enthusiasm. “There was a sense of excitement, a sense of exploration, and sense of being at the cutting edge,” says Pines. “We believed our game plan had been validated.”

Perhaps more important, he says, the meetings “attracted a lot of people who would later become important contributors.”

The founders began to delineate the important details — people, money, and space — that would give the Institute a tangible presence in the world of science.

The new Institute would need a board of directors. In March 1985 during the Institute’s first board meeting, Murray Gell-Mann was elected Chairman of the Board, with Ed Knapp (former head of Santa NSH) as Vice Chairman. Predictably, George Cowan was confirmed as SFI’s first president; Pines was vice president.

“We aspired to a good building and a lot of funding,” says Pines.

The reality was more sobering. By the end of 1986, the Institute’s total annual budget had grown to just $79,000.

SFI@30

Something from nothing: SFI emerges and synthesizes

Editor’s note: This is the second in a series of articles recounting the history of the Santa Fe Institute. Special thanks to SFI Co-Founder In Residence David Pines for his recollections and perspectives. For a more detailed version of this article and more stories about the Institute’s past, please visit www.santafe.edu/sfi30.

Tracing the metabolic chemistry of early life

To better understand the emergence of life, former SFI Omidyar Fellow Roger Braakman and External Professor Eric Smith are taking a careful look at Aquifex aeolicus. Being restricted to extreme, near-boiling hot springs (a consistent feature of Earth’s geology) makes unusual bacterium’s metabolic network has evolved less than those of other species. This makes it a great model system for studying the early evolution of metabolism, they say.

The pair is using a technique called phylometabolic analysis, which combines the building of gene-based family trees of relatedness (called phylogenies) with reconstruction of chemical metabolic networks. This lets the researchers “see not just what information is changing, but how specific driving forces are changing the underlying chemical networks encoded by those genes,” explains Braakman.

Their research, published February 5 in PLOS ONE, highlights three main drivers of evolution: optimizing kinetics, either by replacing generalist enzymes with multiple, specialized enzymes or by fusing successive enzymes in a pathway together to minimize diffusion; and optimizing thermodynamics by choosing pathways that use less energy. These drivers, they say, evoke a major tradeoff in evolution — speed versus efficiency — and suggest that early ancestors probably started with a smaller assortment of enzymes, each of which could weakly catalyze many different reactions.

By identifying how the chemical subsystems of metabolism have changed, researchers might infer phenotypic features of the universal common ancestor, notes Braakman, and even link the competition for resources across different branches of the tree of life to the evolution of the major elemental cycles in the biosphere.

At the gene level, robustness and evolvability go hand in hand

In a February 20 study in Science, SFI External Professor Andreas Wagner and postdoctoral fellow Joshua Payne, both of the University of Zurich, argue that at the gene level, robustness and evolvability, which might seem incompatible, are two sides of the same coin.

Their study focused on 104 mouse and 89 yeast transcription factors — proteins responsible for regulating gene expression. To do their jobs, transcription factors interact with DNA sequences called binding sites. Payne and Wagner found that the more sites a transcription factor can bind to — and the more one can “hop” from one compatible site to the next through single mutations — the more robust the transcription factor’s function.

That robustness makes it easier for a population of, for example, mice or yeast to find new, potentially useful mutations. When their transcription factors are robust, each member of a group can perform the same biological functions despite great diversity in the underlying binding-site DNA. In turn, their offspring as a group will have an even greater diversity, most maintaining the original transcription factor’s functions, some with harmful mutations, but some with new, valuable functions.

Modern archaeology’s 25 defining challenges

A recent paper in PNAS spells out the 25 defining challenges now before archaeology. The paper is the outcome of an NSF-funded program led by Arizona State University archaeologist Keith Kirch.

Kirch and his team solicited suggested challenges from professional archaeologists around the world in the academic, consulting, and government sectors; then assembled a group of scholars to augment, vet, and prioritize the suggestions. This expert group met during a two-day working group at SFI in summer 2012 to develop the final challenges. SFI co-authors include Tim Kohler, Peter Peregrine, Jerry Sabloff, and Henry Wright.

Recession web searches suggest health & wealth closely linked

During the Great Recession suggest that health and wealth may be more strongly connected than previously thought, according to a recent study in the American Journal of Preventive Medicine by SFI Omidyar Fellow Ben Althouse and his collaborators.

By monitoring health-related search terms and direct resources to precautionary measures. This technique is quicker, cheaper, and more efficient than traditional survey-based methodologies, he adds.
SFI@30: Providing opportunity since 1984

For 30 years the Santa Fe Institute has provided creative scientists a place to study, think, and connect. Here, diverse people, fields, and curiosities come together in a kind of “ideas reactor,” producing bursts of insight that can shake the foundations of science and, perhaps, suggest innovative solutions to some of humankind’s most perplexing problems.

Insights generated at the Santa Fe Institute have helped change the course of economics, immunology, and education, to name a few. Our researchers have made foundational contributions to emerging fields, too, from network science and information theory to cultural evolution and wealth inequality.

Since its founding in 1984, more than 60 similarly focused institutes have arisen around the world. We’re proud that a significant number of them were founded or influenced by scientists who are part of our ever-expanding circle.

We’re also proud that in 30 years, thousands of bright young minds have been introduced to complexity thinking at our summer schools, camps, and after-school programs, helping ensure that our signature approach to science is perpetuated well beyond the walls of our campuses and far into the future.

Without the opportunity created at SFI, we might not not have learned to use cell phone data to track and predict the spread of malaria in the developing world. We might not have gained a deeper understanding of our recent global financial crisis, insights that can help our leaders prepare for future economic instabilities. We might not know that all the world’s cities, regardless of size, are the product of the same underlying human social processes, an insight that is suggesting new ways to make our rapidly urbanizing world more sustainable.

By contributing to SFI, you are providing opportunities for scientists to explore the frontiers of emerging fields, discover new truths, and improve our world for future generations. You’re helping bring abundant curiosity and new ideas together in bright sparks of insight. It’s a reaction we can all be proud of. Please join us by making a gift to our 30th anniversary campaign.

Warm regards,

Nancy Deutsch, Vice President for Advancement

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EDUCATION NEWS

‘Majesty of Music & Math’ goes global with new multimedia website

In April, a new online resource for investigating the connection between math and music will be available on SFI’s website. The site will offer video segments from the Majesty of Music and Mathematics concert – a November 2013 special event in Santa Fe created by SFI and the Santa Fe Symphony. The site, intended for teachers, students, or anyone interested in the mathematics of music, includes lesson plans and project ideas for 6th-12th grade classrooms.

SFI Education and Outreach Program Coordinator Juniper Lovato, who is leading the project, has worked with local musicians, the Symphony, Big Sky Learning, and Institute faculty to develop the site’s content. Students from New Mexico Highlands University are designing and building the site, and Santa Fe High School students will test the curricular content.

“I think it helps students who are interested in either music or math talk about these things and collaborate with each other, and it’s great to see how other institutions in Santa Fe are getting excited about this,” Lovato says. “The project really embodies the Institute’s interdisciplinary and collaborative spirit.”

The website is made possible through generous support from the Sydney and Andrew Davis Foundation.