

SFI Bulletin

SANTA FE INSTITUTE • WINTER 2002 • VOLUME 17 • NUMBER 1



Leveling the Field

COOPERATIVA
EL JOVALITO
Hecho por Ricardo
y Iglesia Hernandez
FICON panados por
los compañeros
GRASIAS POR UN RECUEDO
De mi trabajo:
1992



SFI Bulletin

WINTER 2002 • VOLUME 17 • NUMBER 1

The *Bulletin* of the Santa Fe Institute is published by SFI to keep its friends and supporters informed about its work. The *Bulletin* is free of charge and may be obtained by writing to Ginger Richardson at the address below.

The Santa Fe Institute is a private, independent, multidisciplinary research and education center founded in 1984. Since its founding, SFI has devoted itself to creating a new kind of scientific research community, pursuing emerging synthesis in science. Operating as a visiting institution, SFI seeks to catalyze new collaborative, multidisciplinary research; to break down the barriers between the traditional disciplines; to spread its ideas and methodologies to other institutions; and to encourage the practical application of its results.

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COVER

The map on the cover, one of 24 drawn for Elisabeth Jean Wood by Salvadoran peasants, was drawn by Ricardo Hernandez, an active member of the cooperative whose land it describes. The map shows property rights and land use in the area around Mount Taburete before the civil war in El Salvador. A companion map he drew documents postwar land claims and land use, including properties occupied by the cooperative and the destruction of coffee trees. The map was electronically restored by Carolyn Resnicke of SFI.



EDITOR'S NOTE

Each edition of the *SFI Bulletin* presents an arbitrary snapshot of the Institute's work. Although I believe any catalog of SFI's current research interests is usually provocative, I'll be the first to admit that few issues of our magazine embody a central theme.

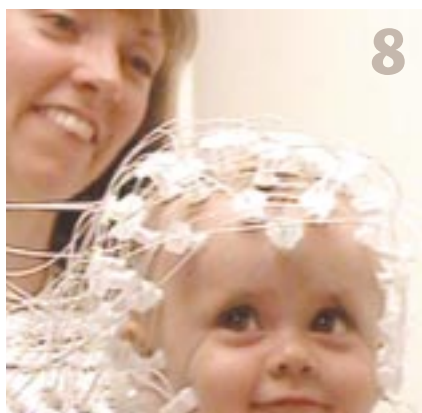
But reading this issue before we went to press, I was struck by how nearly all the features describe work that's grounded in very real and current world problems. I'm not sure if this is coincidence or if the events of September 2001 and beyond have grounded my editorial sensibilities more in today's world. In any case, Sam Bowles' work on intergenerational inequality moves beyond standard economic models to address broader issues within the behavioral sciences that have limited not only our understanding of society, but also our capacity to enhance the quality of social life. Jeff Brantingham's project on the Tibetan Plateau looks at the fundamental structure of human behavior throughout evolution. Elisabeth Jean Wood's research is bent on finding out what factors permit peace to come to countries caught in the vise of civil war. An explicit aim of the SFI consortium on increasing human potential is to find out how improved learning can create a better society.

Each of these topics is extraordinarily complex, and the related issues may not be solved or even fully addressed soon. But the greater SFI research community is exploring them, with interesting findings yet to come.





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PHOTO: ELISABETH JEAN WOOD

Civil War: Political Violence and Robust Settlements

by Lesley S. King

Some of the most devastating and protracted conflicts in history have not been between opposing nations but between factions within the same nation. Clashes such as those in Bosnia, Angola, and the Middle East illustrate the fact that civil war has become a growing threat to contemporary civilization. In fact, 95 percent of all conflicts since the end of the Cold War have been civil wars. One SFI visiting research professor, Elisabeth Jean Wood, is bent on finding out what factors permit peace to come to countries caught in the vise of civil war. She brings to the topic scientific objectivity laced with compassion borne of experiencing the ravages of war first hand.

Wood's passion for civil war arose out of an interest

“I was often pretty confident that it was okay to travel in an area because people would warn me ahead of time if it wasn’t.”

in human rights. After attending Cornell, where she studied physics, and Oxford, where she pursued mathematics and philosophy, she lived for a year with Peruvian nuns in a shantytown outside Lima. As she watched the poverty and suffering of indigenous people displaced by violence in the Peruvian highlands, her compassion deepened. “I

became curious about the origins of violence and the prospects for negotiated settlement,” she says.

At the time she was a dedicated scientist, en route to pursue a Ph.D. in theoretical physics at U.C. Berkeley. In the process of completing the courses and exams, she put her fluent Spanish to use as a volunteer translator and paralegal for Latin American refugees seeking political asylum. Realizing that the social sciences were her true intellectual passion, she embarked on a Ph.D. in political science at Stanford, a pursuit that ultimately led

her to New York University, where she is an associate professor in the Department of Politics.

She believes her background in physics helps her work today. “It’s an excellent intellectual background to have, both for the specific training in modeling, mathematics, and statistics and the general socialization in analytical thought,” she says. “If you learn to be analytical in one subject, you can bring that to another subject.”

Wood brings that interdisciplinary training to her work on civil wars, which ranges from ethnographic research exploring political violence to mathematical modeling of civil war dynamics. She sees many connections between these research areas and SFI research. “The Institute’s work on agent-based modeling, social networks, robust processes, collective behavior, and emergent properties of social interactions could contribute significantly to scholarly understanding of political violence and the prospects for negotiated settlement of civil wars,” she says. Wood is working with SFI External Faculty members Joshua Epstein and Peyton Young of the Brookings Institution to develop research on these themes, drawing on Epstein’s agent-based simulations of political violence and Young’s work in stochastic evolutionary game theory.

ON THE FRONT LINE

Wood’s passion for analysis has taken her to the front line of civil

war: one in particular, the conflict in El Salvador that lasted from the late 1970s until 1992. Often the scholarly analysis of war relies on examining official documents such as police records or government statements. In El Salvador, Wood used what little written documentation was available, but she also sought a clearer picture of the causes of the war and its dynamics.

She spent 25 months during and after the war interviewing peasants, landlords, insurgent commanders, military officers, government officials, and others who in

a variety of ways participated in the conflict. This meant often spending weeks at a time living with families in the war-torn Salvadoran countryside. She found that given the right introduction and assurances of confidentiality, everyone—irrespective of their political loyalties—wanted to tell



PHOTO: RICHARD WOOD

Left: This woman was interviewed by Wood during the civil war. She lived in Tenancingo, a small town in central El Salvador, at the time of the photo. Before the war, she and her extended family lived in a hamlet just north of the town and participated in Christian communities led by lay catechists trained in liberation theology. Many members of her family were killed by government forces during a period of indiscriminate violence that culminated in the bombing of Tenancingo by the Salvadoran Air Force during an occupation of the town by guerrilla forces.

Above: During her research on the civil war in El Salvador, Wood interviewed military commanders of both sides. In the photo, she is discussing the war in the department of Usulután with a guerrilla commander.

their story. “The people here are suffocating from the cries and shouts that we cannot speak,” said one peasant during an interview. “It suffocates. It does me good to talk to someone—I can’t speak to people here about these things.”

The work was time-consuming, involving open-ended questions, often interviewing the same people over and over until a clear picture emerged. “Getting people’s trust, cross-checking stories with other sources, was demanding, but always essential,” Wood says. “It’s not an easy research method, but for some questions and circumstances it’s the only one.”



EVERYBODY WITH THEIR OWN REASONS

During the research, safety for all involved was crucial. Wood took many precautions

to keep her sources confidential and safe from reprisal. Meanwhile, her network of contacts with both sides and some “luck” kept her safe. “I was often pretty confident that it was okay to travel in an area because people would warn me ahead of time if it wasn’t,” she says.

However, conducting research across the divides of war was demanding. “Sometimes in one day I’d interview four people across the political spectrum,” she says. “It was often stressful to hear a poignant story of the suffering inflicted by one party to the civil war and then go interview representatives of that party.”

Though many observers of El Salvador’s human rights abuses have taken sides in the conflict, Wood’s research philosophy helps keep her objective. “Everybody has their own reasons and history that brought them to their political opinions, convictions, and loyalties,” she says. “You may disagree with their position or their present presumptions, but it’s important to understand how they came to have those allegiances.”

FORGING DEMOCRACY

In order to complete her first book, *Forging Democracy From Below: Insurgent Transitions in South Africa and El Salvador* (Cambridge University Press, 2000), Wood also conducted research in South Africa.

As the war drew to a close, tensions over property rights in Usulután deepened: landlords attempted to reclaim their properties and peasants to defend their land claims under the terms of the peace agreement. In September 1991, a coalition of peasant cooperatives blocked the coastal highway to protest incursions by landlords and government agencies on occupied properties.

Even though the countries are very different, particularly in their level of development and degree of racial cleavage, she chose to work with El Salvador and South Africa because the conflicts shared a few important characteristics. Both were instigated by the underclass, and both culminated in a durable peace and a transition to democracy.

These common factors in a context of overall difference allowed Wood to find common causal processes. She identified two that make up what she terms an “insurgent path” to democracy. The first is that the sustained insurgency produced a form of recognized leadership or what she calls an “insurgent counter-elite.” These people emerged as actors with whom the ruling elite had to negotiate if violence was to end.

The second has to do with the interests of the economic elite. South Africa’s white elite controlled much of the country’s economic resources and political power. In El Salvador, coffee growers and other elites controlled the country’s economic resources, and military officers commanded its political power. A robust settlement was eventually possible in both countries as the enduring insurgency disrupted elite economic holdings so much that, as Wood says, “The elite’s interests could be more successfully pursued by a democratic transition than by continued authoritarian recalcitrance.” In other

PHOTO: JEREMY BIGWOOD

words, “The economic payoff to continued fighting began to decline.”

In contrast, in other civil wars such a structural basis for negotiated resolution does not exist. For example, the issue of “war commodities” may prove insurmountable, as in the case of countries such as Angola and Columbia where “there are groups that don’t want to settle because of the extraordinary profits they enjoy as a result of their control of such commodities,” says Wood. In Angola, for example, the government controls vast oil resources, while the insurgents control diamond mines. Thus, both sides have lucrative resources, which they would not necessarily control should the war end: neither has incentive to compromise.

SELF-ORGANIZING PEACE

In response to the critical question, why are some civil wars more amenable to enduring negotiated resolution than others, Wood has developed a mathematical model to capture these contrasts in a single framework. The model explores just what qualities make a compromise possible and more importantly robust. “Each party needs an adequate share of the postwar ‘pie’ and confidence that they would, in fact, get it,” she says.

Though many authors have stressed the importance of intervention of third parties such as the United Nations in order to achieve durable settlements, the failed agreements in Colombia, Angola, and the Middle East tell a different story. International agencies can offer “carrots,” such as reconstruction aid and favorable trade agreements, and wield “sticks,” such as cutting off military aid or imposing economic sanctions. But such incentives are seldom influential or persistent enough to make the difference between war and peace.

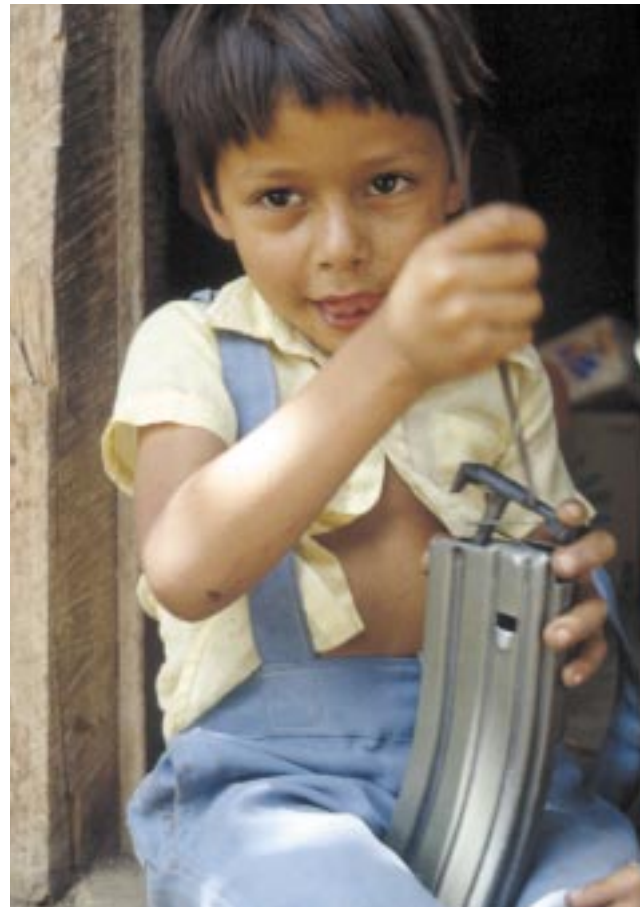
“Durable settlements are often grown from the bottom up rather than the top down,” she says. “International action can help, but to get a durable settlement, the warring parties have to have their own reasons to resolve the conflict—it must be self-enforcing.” It must be in the interests of each party to adhere to the peace agreement as long as the other also adheres.

In Wood’s game-theoretic model, the parties to a civil war compare the expected payoffs of continued war



Top: Peasant activists confronted government forces under the eyes of United Nations observers during the September 1991 demonstration. The photo shows an officer attempting to restrain his troops. Below: During the civil war, many civilians were displaced from their homes, suffered grievous psychological and physical harm, and/or were killed. According to the Truth Commission established under the peace agreement to investigate violence against civilians, 85 percent of such violence was carried out by government forces and their paramilitary

PHOTOS: JEREMY BIGWOOD



The distributional logic of conflict and settlement: payoffs in the civil war game

		Party B	
		Fight	Compromise
Party A	Fight	ω_a, ω_b	$\lambda_a, 0$
	Compromise	$0, \lambda_b$	$\phi\alpha, \phi(1-\alpha)$

The payoffs (row player first) to peace depend both on ϕ (that is, the postwar “pie”) and α (the share going to Party A). Whether A will prefer compromise thus depends on ω_a , (the payoff to both waging war), λ_a , (the payoff to A if A pursues war and B peace), ϕ and α . If peace is to be sustainable, $\phi\alpha$ must be greater than λ_a and $\phi(1-\alpha)$ must be greater than λ_b . To implement a transition from war to peace, peace must be sustainable and both parties’ estimate of the probability that the other party will compromise must exceed a critical threshold defined in terms of the parameters of the payoff matrix. From E.J. Wood, “Ending Civil War: A Model of Robust Negotiated Settlements.”

to the peace dividend. The payoff to each depends on the strategies that both pursue. The distributional outcomes of the post-war rules of the game—the split of the postwar “pie”—form an essential part of this incentive structure (see box above). A durable settlement to an ongoing war is possible when compromise is a mutual best response. For peace to be the outcome, the postwar share must be sufficiently great that each party compromises if the other does and both parties must believe sufficiently strongly that the other party is pursuing peace as well.

The timing and structure of the settlements in El Salvador and South Africa had these characteristics. Insurgents gained political power while assuring economic elites through constitutional clauses that economic change would be moderate. Implementation of the compromises took place over a period of time, each side relinquishing something, with a period to adjust in between. For example, in El Salvador the insurgents didn’t put down their arms immediately. They disbanded in stages, as did the government forces. “Because it was staggered, each step was verified, each side’s belief that the other side was indeed compromising was reinforced,” says Wood.

Another important factor illuminated in the model has to do with the divisibility of stakes. Wood shows

how greater indivisibility (the less divisible the pie), reduces the likelihood of enduring resolution by reducing the range of possible and robust settlements. A good example of this is when one side in the conflict is demanding to name the sole language, a stake that seems to be indivisible. However, sometimes an acceptable compromise can be found that renders an indivisible good divisible. In South Africa the parties settled on naming 11 national languages, which though fair, resulted in a bureaucratic nightmare—now all government documents must be printed in each of those languages.

With the model, which allows Wood to compare the robustness of different settlements, she hopes to aid resolution of other conflicts. “I hope that my work might clarify which conflicts are ripe for resolution so that resources might be steered toward those,” she says.

HIGH RISK COLLECTIVE ACTION

The close contact with Salvadorans while researching those issues led Wood to write her newest book, *Insurgent Collective Action and Civil War in El Salvador* (Cambridge University Press, 2002). In it she examines why many rural Salvadorans actively supported insurgent groups, despite the extremely high risks of doing so.

Social scientists often argue that participation in rural insurgency is due mostly to hopes of material gain. However, Wood found that was not the case. Even though many of the people had little cause to believe that material benefits were contingent on their support for the insurgency, they still participated. “Many Salvadorans rebelled for moral and emotional reasons,” she says. One reason was to express outrage at state violence, often suffered by their immediate families.

Another reason many Salvadorans participated was pride in becoming agents of historically significant change, what Wood terms “pleasure of agency.” They wanted to get land and a more adequate livelihood, but they also wanted to show the disdainful Salvadoran elite that they were capable human beings. Wood found this to be true even when the likelihood of victory was “vanishingly” small. “Insurgent campesinos were motivated

in part by the value they placed on their role in making history,” she says.

REDRAWING BOUNDARIES

Part of the beauty of Wood’s research is documenting the process of social transformation in the countryside. “We felt the poverty in our own flesh,” said a peasant in one of Wood’s interviews. “The pain that we are now suffering in our bodies is the labor of the birth of something new.”

To explore the changes in El Salvador, Wood convened groups of peasants to draw maps on large sheets of butcher paper of their localities before and after the war. The maps are different in purpose from most maps, which are often made by those in power to assert and consolidate their holdings. “But maps aren’t just strategic tools,” says Wood, “they’re also cultural constructions,” meaning they help define not only land boundaries, but what’s important within a culture.

Such a practice was new to the peasants Wood worked with, and many embraced it. “The mapmakers put great importance on the land claims of their cooperatives,” says Wood. “They took particular care to indicate the borders of the properties they were in the process of claiming.” The many maps drawn helped Wood understand the social transformation the war brought. What’s most notable, as Wood says, is “how land that was once a few large farms on the maps

became a complex tapestry of cooperatives with a few medium-sized properties cultivated by landlords or their tenants woven in.”

Though in both countries the human costs were enormous and not all promises were fulfilled, the

process of insurrection and the resulting transition to democracy increased political equality. Such transformation is meaningful for a social scientist such as Wood not only for the opportunities for analysis it offers but for the hope rendered. She believes that SFI’s interdisciplinary mission and diverse research tools will help her and other researchers see civil war in new ways, with results that could have important impact. “The reason to study violence and suffering,” says Wood, “is to understand its origins, processes, and—ideally—to contribute to its cessation.”

“Each party needs an adequate share of the postwar ‘pie’ and confidence that they would, in fact, get it.”

PHOTO: BENNY GOOL/TRACE IMAGES



A demonstration by leftist trade unionists outside Cape Town, South Africa. In El Salvador and South Africa, long-standing insurgencies by politically excluded and economically marginalized people eventually forced peace agreements that initiated democratic rule. In 1994, inclusive elections were held for the first time in both countries.



Journey to the Center of the Brain

by Lesley S. King

PHOTO: BENASICH LAB: CMBN, RUTGERS

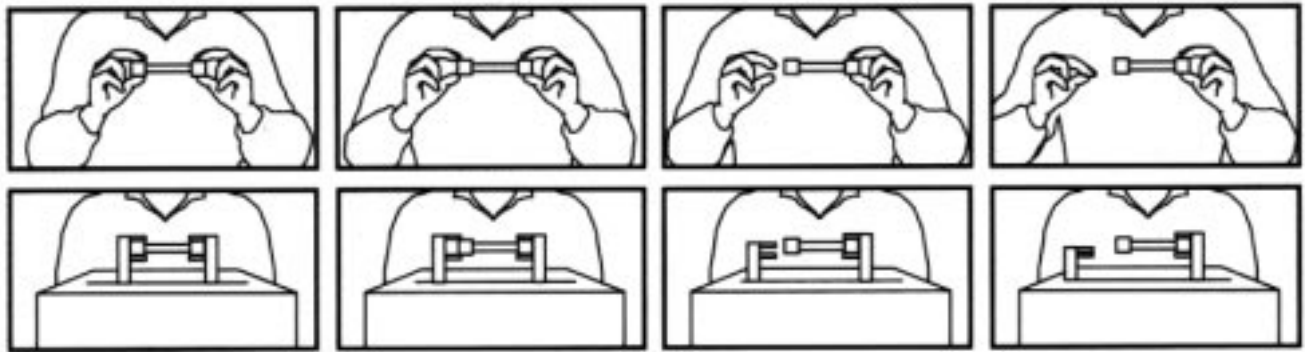
Human kind's greatest expeditions, from determining the vastness of our universe to exploring the inner workings of the atom, weren't possible until technology advanced to allow them. Now, some of the world's top scientists have convened to explore one of the most intriguing and uncharted frontiers—the human brain. Aiding them are cutting-edge technologies, some available only as recently as five years ago. With the findings they hope to increase human capacity not only to learn and retain information, but also to exhibit important traits such as empathy and compassion.

As with most important expeditions, the Santa Fe Institute Consortium's (SFIC) quest begins with the accomplished explorers involved. "We have brought together some of the world's leading developmental psychologists, cognitive neuroscientists, neurologists, and neurobiologists," says SFI President Ellen Goldberg. These scientists come from a range of top institutions in North America, including the University of Washington's Center for Mind, Brain, and Learning,

the UCLA and Harvard Schools of Medicine, Rutgers University's Center for Molecular and Behavioral Neuroscience, the University of Illinois' Beckman Institute, the California Institute of Technology, and the Montreal Neurological Institute of McGill University.

The project, titled "Increasing Human Potential," is the vision of SFI Distinguished Fellow George Cowan, who, after years of contribution to science, including work on the Manhattan Project, remains determined to apply hard-science methods to the behavioral study of the brain. "There have been a lot of studies of psychology, which is concerned with behavior," says Cowan, "but psychology deals only with externally observable behavior, not with underlying neurophysiological processes. One of the several things that make this project unique is the parallel assessment of behavioral development and the growth and maturation of many of the critical neural functions that shape behavior."

Above: Researchers measure brain function in infants using a geodesic net dense array EEG/ERP system.



Infants are sensitive to the intentionality of other humans. Andrew Meltzoff discovered that they responded differently to a human action (top panel) than they do to a similar action performed by a machine (bottom panel). This has implications for social understanding and the development of empathy and morality. (From Meltzoff, A.N. [1995]. "Understanding the intentions of others: Re-enactment of intended acts by 18-month-old children." *Developmental Psychology*, 31.)

FILLING THE GAP BETWEEN THE NEURON AND THE CHALKBOARD

Clearly, the time has come for such a project. Not only is the technology finally available to harmlessly peer into the brains of healthy humans, but also the world is poised to receive the findings. In the last four years both the Clinton and Bush administrations convened White House conferences on early childhood cognitive development. One of the SFIC team members, Patricia Kuhl, co-director of University of Washington's Center for Mind, Brain, and Learning, was a keynote speaker at both conferences, where she stressed, "There is a tremendous gap between the neuron and the chalkboard, but furthering the research on children between the ages of zero to five will revolutionize the classroom."

Ultimately the U.S. leaders and the SFIC researchers want to find out how improved learning can create a better society. This, says SFIC member Paula Tallal, co-director of the Center for Molecular and Behavioral Neuroscience at Rutgers University, leads to concern about public education, specifically in the area of teaching literacy. In a congressional briefing presented recently to the U.S. Congressional Biomedical Research Caucus, Tallal reported that, "Millions of American students who are not learning disabled, but enter school with weak English skills, are not learning to read and are ending up in special education classes with lowered expectations and dim prospects." Many of those students get frustrated and drop out of school, which leads to lower employment rates and higher adjudication rates. Statistics show that 85 percent of juvenile delinquents are learning disabled, as are 60 percent of prison inmates.

Such statistics raise many questions about when and how learning is most effective, and now, finally, the resources are available to try to answer them. "If the world is going to survive another two to three genera-

tions," stresses Cowan, "we must become better informed about the factors that shape human behavior."

WHEN AND HOW SHOULD CHILDREN LEARN?

Researchers involved in the project question why so many advances have been made with the human body, including increased longevity and reduced infant mortality, but little has been done to increase human memory, intelligence, or intellectual capacity. "We have the tools to understand how the brain is trying to learn. Why don't we use that information as a way to learn how to teach?" asks John Mazziotta, from the Departments of Neurology, Radiology, and Pharmacology at UCLA's School of Medicine and one of the key drivers of the SFIC. He's quite familiar with convening researchers to advance science. As director of the Ahmanson-Lovelace Brain Mapping Center at UCLA, he's in the process of creating an atlas of the human brain, a project involving 7,000 people spread across four continents and seven countries.

Through his work with the human brain, Mazziotta has grown to question the teaching methods employed in the U.S. "Kids start school at age six because of the industrial revolution, when it was important to send them to school at that age," he says. "It wasn't based on how the brain was trying to learn, it was based on convenience." He and the other SFIC members are remaining open to what they find about how and when the brain learns best. "The brain gets wired during development. Initially it's able to do anything, but in order to specialize, it becomes wired in certain ways," he says. In view of this, he hypothesizes, "Maybe you shouldn't teach French in the eighth grade; maybe you should teach French in the crib."

THE NEWEST TECHNOLOGY

Until only recently researchers had to speculate about how exactly the brain's wiring occurred, but with

the advent of new technology scientists are able to examine brain anatomy and physiology in new ways without adversely affecting the subjects. Some of the tools the SFIC researchers are utilizing include Magnetic Resonance Imaging (MRI) and functional Magnetic Resonance Imaging (fMRI), which use magnetic fields and radio waves to examine the anatomy and function of the brain. Use of MRI allows researchers to obtain estimates of the gray-matter and white-matter volume in different parts of the cerebral cortex, as well as to measure blood flow. Those areas of the brain that have the most blood flow are being used most during a particular task.

Optical Intrinsic (OI) Signal Imaging, processed with Diffuse Optical Tomography (DOT)—similar to CAT scans—and Near Infrared Spectroscopy (NIRS) use infrared light and its reflections from the brain's surface to produce images and to examine brain function. These techniques allow researchers to measure where and when in the brain important neuronal events are occurring while the individual is performing specific behavioral tasks.

Electroencephalography (EEG) and Event Related Potentials (ERPs) measure the electrical potentials of the human brain by recording them from the scalp using electrodes that can be worn in a cap. These measures give insight into how the brain solves problems and learns new information.

THE BLOCKBUSTER— A MOVIE OF THE CHILD'S BRAIN

In the study, healthy children ages 6 months to 5 years, and 10 to 14 years, will undergo first a period of observation, during which researchers monitor their brain function and behavior as they perform linguistic, cognitive, and social tasks. The technological instruments will help the researchers come up with a complete description of selected behaviors, anatomy, and physiology of the brain.

The scientists involved in this monitoring have distinguished themselves as leaders and pioneers within their areas of study. They will be expanding upon meth-



Imitation is natural to babies from birth. Meltzoff thinks that early imitation helps form a social bond between parents and infants. His work shows that we are role models for our infants. What we do in front of them matters. (From: Meltzoff, A.N., & Moore, M.K. [1977]. "Imitation of facial and manual gestures by human neonates." *Science*, 198.)

ods they've already developed as well as creating new ones. One SFIC member, April Benasich, a developmental neuroscientist at Rutgers University's Center for Molecular and Behavioral Neuroscience, uses the EEG/ERP system to get what's ostensibly a movie of a child's brain responses while he or she performs a particular task. "You can actually watch the processing of an event unfold in tens of milliseconds," Benasich says. "This allows you to look at processing that's important to language and to determine the sorts of strategies the child is using to learn."

Assessing response is no small task in preverbal infants. Benasich accomplishes it by measuring the children's visual and auditory discrimination behaviorally (what captures their attention) as well as by observing their brain waves using ERPs. For example, children are trained to respond to a change in the incoming information stream (e.g., a change from a "Ba" sound as compared to a "Da") by turning their heads to a reinforcing toy. ERPs allow discrimination or recognition of a new stimulus from an old stimulus without an overt response from the child. Through this research Benasich and Paula Tallal have shown that the speed with which the infant processes rapid auditory and visual information correlates with and accurately predicts the child's later language skills.

BEING A CITIZEN OF THE WORLD

Benasich and Tallal are coordinating their research with Patricia Kuhl and Andrew Meltzoff, co-directors at the Center for Mind, Brain, and Learning at the University of Washington. Kuhl has provided profound findings about how the brain learns language. She calls infants before their first birthday “citizens of the world” because they have the capacity to hear distinct sounds of any language. However, as the brain develops, it excludes certain sounds, making the baby a more “language-bound listener.” Kuhl has shown that by exposing the infant to a language such as Mandarin, it’s possible to keep the brain “open” to languages.

However, Meltzoff stresses that more is not necessarily better. As well as finding out when a child learns best, the goal of the study is to find out how much enrichment children need in order to thrive and reach their maximum potential. “Food is good for you, but more food isn’t necessarily better,” says Meltzoff. “The research should help teach us what’s the right brain food to deliver at what times.”

LEARNING BEGINS IN THE CRIB

Much of Meltzoff’s research has involved the impressionability of infants. “Babies are more proficient imitators than commonly believed,” he says. He’s worked with newborns showing that they’ve already developed the capacity to imitate. With one 42-minute-old baby, Meltzoff poked his tongue out and the baby imitated; he opened his mouth, and again the baby imitated the action. These developmental studies are complemented by brain studies done by neuroscientists who use fMRI to locate the cortical regions responsible for imitation. “Human beings have fundamental connectedness in the first years of life,” Meltzoff says. Experiments such as this and others that demonstrate that children not only imitate very early, but also remember for months an action they saw, fuel the initiative’s premise that learning begins in the crib, not, as many believe, in later years.

Meltzoff performed other experiments that showed that 18-month-old children already have the capacity to interpret beneath the surface of outer actions in order to understand another person’s goal. He had adults model an action such as pulling a tube in two, but fail at it. Even though the children didn’t see the action performed correctly, they were able to perform it themselves correctly. And yet they did not do so when a machine mis-performed the action. “Kids are beginning to treat other people as having something within that is like intention,” he says.

Further experiments link this to a sense of empathy. Meltzoff has demonstrated that a 30-month-old might



PHOTO: BENASICH LAB: CMBN, RUTGERS

A two-year-old child performs a two alternative forced choice procedure at Rutgers University.

bring a blanket to someone in pain. “Even at an early age children demonstrate a budding sense of empathy,” he says. The SFIC hopes to determine whether those who exhibit a lot of empathy early in life continue to do so at a later age, and what factors might increase that quality in an individual.

THE DISNEYLAND BRAIN EXPANSION

As the researchers illustrate that children learn early and remember what they learn, the question arises, Will an enhanced environment actually change the brain? Using animals, William Greenough, of the University of Illinois’s Beckman Institute, has shown that it does. He placed rats in what he calls a “Disneyland” environment, with lots to see and do and plenty of social interaction. Others he placed within environments deprived of sensory and social stimulus. Then he took a look at the brain development. “In a complex environment, the brain definitely grows larger,” he says.

His measurements don’t merely involve the size of the brain but also such intricacies as numbers of synapses and capillaries. He sees the brain as an adapting organ whose capacity can definitely increase. “You’re making a bet that tomorrow will be like today and the brain is fine-tuning itself to handle what happens tomorrow,” he says.

GETTING CONNECTED

The SFIC is concerned not only with the growth and development of the brain, but also how connections are made. Tomas Paus, a cognitive neuroscientist at McGill University’s Montreal Neurological Institute, will be using MRI on teenagers to examine the structural and functional maturation of the brain. Paus’s work is particularly involved with white matter and the maturation of

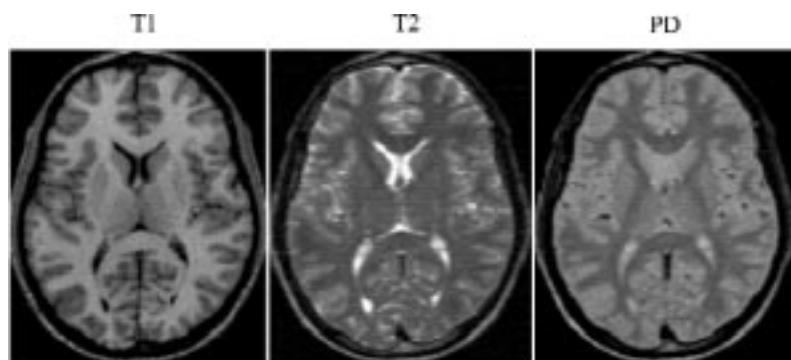


Figure 1: T1-weighted, T2-weighted, and Proton-Density (PD) images of a single brain.

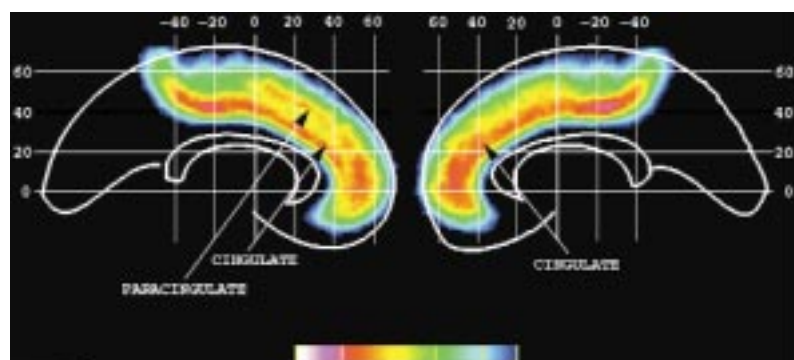


Figure 2: Probabilistic map of the human cingulate sulcus [Paus et al., 1996a].



Figure 3: Blurred grey-matter density image (right) is obtained by passing a binary grey-matter mask (center) through a low-pass filter. The mask is a product of an automatic tissue-classification based on T1 (left), T2 and PD MR images.

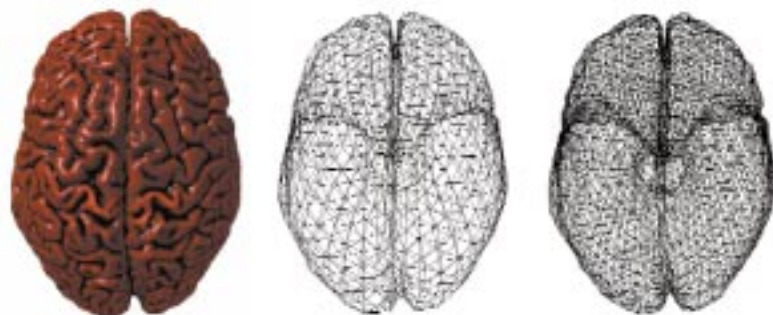


Figure 4: Surface-rendered image of the cerebral cortex (left) with two corresponding "mesh" representations of the cortical ribbon (center and right). The three-dimensional location of each node is specified by X, Y, and Z coordinates.

Computational analysis of high-resolution MRIs of the human brain provides a unique window into the details of gross morphology of the developing human brain. These analyses begin by classifying, point-by-point, the brain tissue into grey matter, white matter, and cerebrospinal fluid. An automatic classification is achieved by combining information from different types of MR images, namely T1-weighted, T2-weighted, and Proton-Density (PD) MR acquisition (Figure 1).

Subsequently, segmentation algorithms can be applied to extract, for example, only those grey-matter voxels that constitute a given "segment" of the brain, such as the frontal cortex. These algorithms typically take advantage of probabilistic information supplied in the form of probabilistic maps (Mazziotta et al., 1995; Mazziotta et al., 2001, Mazziotta et al., 2001a). Such maps are created by averaging a manually defined structure of interest over a large sample of individuals (>100). Figure 2 shows an example of such a probabilistic map, namely that of the human cingulate sulcus (Paus et al., 1996a,b).

Thus, we can obtain automatic estimates of the grey-matter volume in different parts of the cerebral cortex. The segmentation approach requires that we define arbitrary borders between regions. This can be circumvented by employing the point-by-point, or voxel-wise, analysis of images. For this purpose, all individual images are first transformed into standard stereotaxic space. The images are then blurred with a low-pass filter to average signal intensities across the neighboring voxels (Figure 3). Subsequently, statistical comparisons are carried out to identify clusters of voxels, i.e., brain regions, in which the variable of interest correlates with the underlying anatomy.

Another voxel-wise approach has been developed to quantify individual differences in the 3-D anatomy of the cortical surface. This approach begins with the generation of a 3-D mesh that fits the sheet of the cortical grey-matter (Figure 4). Once the mesh is generated, it can be unfolded and the size of the cortical surface can be measured.



A mother sits with an infant during an operantly conditioned head-turn procedure.

connectivity—how pathways get better with age in terms of the speed of transmission of impulses from one region to another—through a process termed myelination. Paus, along with Marco Iacoboni and Mirella Dapretto, who are from UCLA's Ahmanson-Lovelace Brain Mapping Center, will research mood, empathy, and imitation in teenagers, and their find-

ings will later be compared with similar studies done on infants.

In order to study mood and its effects on behavior, the team will show teenagers images of people expressing an emotion such as happiness or sadness in order to induce that mood within the teenager. Then the teens will read a sentence, while the researchers use imaging technology to follow what's happening within the brain. In this way the researchers can find out how a particular mood affects speech and which parts of the brain are active in the process. Paus clarifies that this work is not intent on examining mood per se. "We're really interested in the interaction between mood and volition, how those things go together," he says. "If you're happy, you're full of energy; if you're depressed, it's hard to get going."

Such research will help the SFIC determine the most optimal time and method for effectively and efficiently teaching school topics. The scientists stress, however, that such "topics" may not be the traditional ones we have used to categorize formal education in the past such as reading, arithmetic, history, and chemistry. Rather, they hope to identify "basic skills" that are required for the mastery of those traditional academic topics as well as other areas such as music and sports.

THE THREE-PART PLAN

The project is designed to have three phases, beginning with Phase I: Monitoring. "In this first phase," says John Mazziotta, "we track information over a number of years. We'll bring the children in and make the same measurements over and over to gauge language, thinking, and social and emotional development." This phase will also track the children's family and household environments. Initially each group will be studied every three months and then at longer intervals over a five-year period.

Once the researchers have monitored the children,

they will move onto Phase II: Outcome. "In this second phase," says Mazziotta, "we see what happens to the children, how they turned out." With the use of the information gathered in Phase I, the researchers will make both cross-sectional and longitudinal comparisons measured at four time points. Thus, they will assess an individual pattern of behavioral, anatomical, and physiological variables for each subject in both groups. In addition, the researchers will assess the brain changes between the two groups.

Lastly, the SFIC will implement Phase III: Modification and Enhancement. "In this third phase," says Mazziotta, "we take a new group of children and try to manipulate their environment so that they are better than they would have been at some of these tasks." Researchers will use the knowledge gained from the first two phases to modify the learning environments and exercises in the laboratory and the home. Like Phase I, Phase III will be a longitudinal study. It will determine whether enhancing the environment brings behavioral gains and structural and functional differences in the brain anatomy and physiology when compared to the original groups of children studied in Phases I and II.

FINDING FUNDING

Initially, the consortium is seeking private funding for the project for a few reasons. The primary one is time. With the project already underway, organizers are reluctant to lose momentum by relying on the lengthy process of securing government funding. Since all of the researchers are established in their fields, they are doing this research out of a passion for understanding rather than a need for more work or funding for their own projects. The SFIC wants to move now while the researchers have committed the energy to do so.

Another reason for seeking private funding is that, as Mazziotta says, "The project is very innovative." He explained further that the U.S. Government likes to fund already established research in an incremental fashion. Later, the consortium may seek government funding but, for now, the research is so new that it needs alternative methods.

After years on the "bandwagon" of this kind of expedition, Mazziotta is overjoyed that it is finally underway. "This can be done and we have the people who can and are willing to do it," he says. "It's the right chemistry, the right time."

Lesley S. King is a freelancer who also writes for Audubon and The New York Times.

Collaborative Workshop Brings Agent-Based Modeling to Business Professionals

An innovative five-day workshop for business professionals titled “Capturing Business Complexity with Agent-Based Modeling and Simulation (ABMS): Useful, Usable, and Used Techniques” takes place March 4 to 8 at Argonne National Laboratory. The course is jointly sponsored by Argonne, the University of Chicago, and SFI. The first half of the program will focus on ABMS concepts from the perspective of company managers and analysts. The last two and a half days of the meeting will consider ABMS implementation from the perspective of company software developers and will include extensive hands-on exercises. Depending on their interests, participants may attend the first session, the second session, or both.

Though the workshop is planned in particular for members of the Institute’s Business Network, some openings may be available to other participants. The workshop is designed for three types of profes-

sionals: strategic planning and operations department managers, analysts who design and operate models, and software developers who build models. Managers should attend at least the first session of the course. There they will learn the basics of ASMS, explore how these approaches can be useful to their businesses, and discuss the effective presentation of ABMS results to senior decision makers. Analysts—who should preferably attend the full program—will consider in addition to the above topics the fundamental features of the leading ABMS development tools and how these features affect ABMS design. The course will give software developers the basic principles of ABMS design, and show how to effectively use the leading ABMS development tools. Software developers should attend both sessions of the course.

Topics include the definition of agents, agent design and construction, agent environments, understanding ABMS results,

effective presentation of ABMS data, and applications of these core topics to specific examples. Examples include supply chain and market models which will be discussed in detail: a Mathematica supply chain ABMS, a RePast market ABMS, a RePast supply chain ABMS, and a Swarm supply chain ABMS. Participants also will be asked to provide a paragraph on the ABMS applications they are most interested in to help focus instruction on the business issues of greatest relevance to the group.

The registration fee for the full course is \$2,500 for SFI Business Network members; \$5,000 for non-members. Enrollment is limited to 40 participants for the first session of the course, and to 30 participants for the second session. Enrollment priority will be given to Business Network participants. For more complete information including course faculty, readings, and an on-line registration form, please click on <http://www.dis.anl.gov/abms/>.



A snapshot of a Swarm agent-based model showing the topology and parameterization of two companies pending merger. Several different sets of customers (or markets) are partitioned across three geographical regions. The goal of the simulation is to find organizational configurations, pricing, and management policies for the merger that decrease cost, satisfy more customers, and thereby increase profits.

Each entity in this model is an autonomous computer code that can be programmed to act as appropriate in its own environment, or simply serve as empirical placeholder agents (e.g., historical customer demand by market). In this way, operating specifics of each entity in the model can be described and tested in the full context of the other entities in the organization.

Management options can then be evaluated by experimenting with either the topology of the model (the org-chart), or by modifying the operating procedures of any entity in the organization (job descriptions).

Solid colored ellipses indicate groups within a company used for manufacturing and distribution. Customers are shown as hollow circles, with different colors indicating different product/marketing preferences. These preferences in turn dictate demand and possible pricing. Triangles represent the executive staff of each company, and squares are summary metrics for profit and loss based on the current set of customers, employees, and internal costs.

Green, orange, and red indicate the status of any relationship between two nodes. For example, a red line between a manufacturer and a distributor means that bulk shipments of a product to the distributor are not occurring as planned. A red line between a customer and a distributor means that the distributor is failing to satisfy a known market demand. A green line between management and a manufacturer means that management’s wishes are not being fulfilled.



SFI Bulletin
WORK IN PROGRESS



KEEPING IT IN THE FAMILY

SOUTHWEST VIEW OF "SEdgeLEY PARK," THE COUNTRY SEAT OF JAMES COWLES FISHER, ESQ.
BY THOMAS BIRCH, CIRCA 1819
NATIONAL MUSEUM OF AMERICAN ART, WASHINGTON DC/ART RESOURCE, NY

KEEPING IT IN THE FAMILY: DOES INHERITANCE PLAY A ROLE IN INEQUALITY?



PIONEER'S HOME
CURRIER & IVES, 19TH CENTURY
SCALA/ART RESOURCE, NY

Wealth, family connections, quality schooling—most everyone wants these assets, for themselves and for their children. And yet, in many ways they are reserved for relatively few people, a fact that many feel is unfair. Yet it's not that people resent the wealthy. In this country those who achieve success on their own are regarded highly as long as the playing field is level. It's the inheritance of what it takes to be successful that draws criticism. Researchers at SFI and elsewhere are finding that this country does indeed have a surprisingly large amount of inherited inequality. But contrary to what one might think, the inheritance of economic success isn't the result merely of families passing down wealth to their children. It involves little noted factors such as personality and health. So does that mean that the "rags to riches" notion is no more than a fantasy for America's poor children?

Through a series of SFI workshops, Samuel Bowles, professor of economics at the University of Massachusetts at Amherst and director of SFI's Economics Program, has created an interdisciplinary research network that seeks to better understand the persistence of economic and social inequality among both groups and individuals. The network also is exploring the impact of economic and social inequality on the ability of groups to cooperate in the pursuit of common objectives such as sustainable use of local environments. Another aim of the research project is to better understand the impact of global economic integration on the capacity of governments and other collective actors to alleviate poverty and economic insecurity given the constraints of global economic integration. Over the next several years, four books will result from this initiative, addressing problems



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of inequality that, while hardly new, have risen to greater prominence in recent years. Funding support for this effort comes from the Russell Sage Foundation.

One of the questions that drew Bowles, co-author Herb Gintis (an SFI External Faculty member), and his team to this research is, How level is the playing field in the U.S., and what accounts for its tilt? Also, does the transmission process between generations violate widely held norms of fairness? If so, can public policies make the attainment of economic success more equitable?

Few would argue with the statement that children of well-off parents in most cases receive more and better schooling, and inherit material, cultural, and genetic advantages. But until recently, economists believed that in the United States each generation has tended to win or lose its own success. Early research on the statistical relationship between parents' and their children's economic status after becoming adults found only a weak connection and thus seemed to confirm that America was indeed the "land of opportunity."

This conclusion seemed to confirm the widely held view that economic competition, together with liberal democratic institutions, pushes the economic fortunes of otherwise similar individuals and groups towards convergence. This presumption is captured by standard results such as Paul Samuelson's international factor price equalization theorem (global competition will equalize wages among countries) and the concept of regression to the mean in intergenerational transmission processes. Regression to the mean was originally applied to measures of physical stature over a hundred years ago by Sir Francis Galton. He found that kids of tall parents are also tall, but not as tall as their parents. The idea is now widely applied to income as well, where parental advantages are passed on, but they dissipate over the generations.

In a controversial 1972 paper, Bowles had challenged the "land of opportunity" conclusion, showing that previous estimates for high levels of intergenerational mobility were artifacts of two kinds of measurement error: mistakes in reporting income, and transitory shifts in current earnings not related to underlying permanent income. The resulting noise in the measurement of economic success artificially depressed the measures of intergenerational transmission. During the past decade new data allowed definitive estimates correcting the biases Bowles had identified. When corrected, using a variety of methods and data sources, intergenerational correlations appear to be substantial, two or three times previous estimates, and in some studies (one of them presented at SFI this past fall) even exceeding Galton's estimate of the inheritance of height.

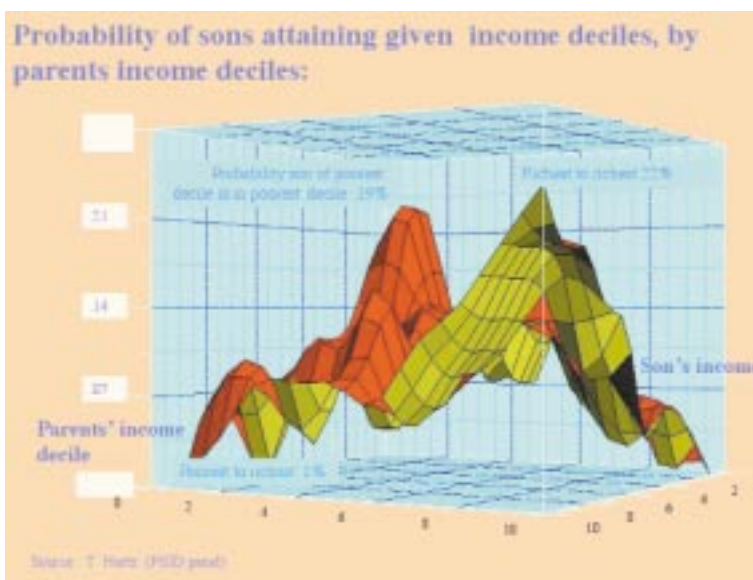
POVERTY AND AFFLUENCE TRAPS

A single correlation is not very informative about how success and poverty are passed from parents to children, however. In the figure below, parents are arranged by income decile (moving from left to right, they go from poor to rich) and with adult sons arranged by income decile along the other axis. The surface height indicates the likelihood of transitions from the parents' decile to that of the son's. Note that the underlying inter-generational correlation of incomes for this data set is a modest 0.36. However, the difference in the likely life trajectories of the children of the poor and rich are substantial. Indeed, some are stuck in poverty or affluence, as represented by the "twin peaks." In fact, as Point D shows, a person born to the top decile has better than a 1 in 5 chance to attain the top decile in adulthood. Meanwhile Point A indicates that for the son of the poorest decile, the likelihood is 1 in 100. This matrix and studies by other authors (including SFI External Faculty member Steven Durlauf) suggest that the inheritance of inequality is a heterogeneous process; it operates through distinct transmission mechanisms—wealth inheritance at the top and adverse neighborhood effects at the bottom, for example.

Bowles uses the term poverty trap to describe a situation in which the evolution of individual wealth or well-being is governed by a pathdependent process such that, depending on initial conditions, otherwise identical individuals, nations, or other groups may remain for long periods of time (if not indefinitely) "locked into" poverty (or affluence). He organized a workshop this past July on this topic and is editing a book of the papers presented. Recent evidence points to the importance of history in the inequality-generating process. One example of this involves the divergent income levels among nations where a distinct "twin peaks" pattern has been identified with upper middle income countries approaching the income levels of the rich countries, and lower middle income countries slipping downward towards the poor nations. Another example is the resilience of some income differences between whites and African American males in the U.S., despite the progressive disman-

tling of the more obvious structural determinants of inequality (such as those of educational opportunity, and de jure segregation).

In this sense poverty traps do not refer to situations in which it is simply difficult to escape low incomes. It is generally true that initial conditions matter: a country's average income level in the recent past and one's parents' wealth typically affect current outcomes, but these situations need not generate a trap. The key characteristic is that the "good" and "bad" outcomes are self-enforcing, so that small interventions may not alter the long-term outcome. By contrast, a one-time large intervention, like the GI Bill of Rights, which allowed thousands of vets to be the first in their families to graduate from college, may have long-term effects.



Poverty and affluence traps exhibit both positive feedbacks and increasing returns to scale, two concepts that have typically been eschewed by economists, but have recently received renewed attention in the context of economic complexity. Members of the SFI economics community—in particular W. Brian Arthur and Steven Durlauf—have produced ground-breaking work in this area over the past 15 years or so. A good example of positive feedback between economic actors is social conformity currently under study by Durlauf as well as by SFI External Faculty members Rob Boyd and Peyton Young. A way to explain this phenomenon is to assume that a behavioral choice by one agent makes similar choices on the part of

other agents more likely. Underlying this interpretation is a significantly different assumption about the nature of economic actors. Traditional economics assumes individual interactions are simple exchanges governed by contracts; neighborhood effects, social conformity, and positive feedbacks are absent. The alternative framework being developed sees individual actors as decision-makers whose choices depend directly on the decisions of others.

Systems with positive feedbacks, in turn, can exhibit multiple types of self-reinforced behavior at an aggregate level. An example of this comes from the economics of education: the income payoff to getting a college education may depend on whether one ends up working with other college-educated people. If one expects to wind up in a college-educated work environment, college may be worth the investment. But those whose parents' experiences, group membership, and neighborhood contacts lead them to expect not to work with highly educated people will not undertake the investment. Thus educational expectations are self-fulfilling. Complex economic environments often display instances of such positive feedbacks—in social and psychological as well as production contexts—as a result of positive feedback relationships. One of the workshop papers, for example, showed that low sense of personal efficacy contributes to economic failure, which further depresses the sense of efficacy.

A BLACK BOX

Positive feedbacks explain how the cumulation of advantage may counteract regression to the mean and thus support high levels of intergenerational transmission of economic status. It also seems clear that success is handed down via many channels, rather than just one. But we know little as yet about the how the transmission process works. Most researchers agree on these facts: Brothers' incomes tend to be much more similar than those of randomly chosen males who are the same race and age. Identical twins' incomes are much more similar than income of fraternal twins or non-twin brothers. Children of well-off parents

receive more and higher quality schooling. And, the offspring of the very rich benefit greatly from financial inheritance. One might conclude from these facts that families matter, that genes matter, that inequality in education matters, and that wealth inheritance matters. How much they matter, and how they interact is another question.

One mechanism is the genetic and cultural transmission of income-generating traits in demand by employers, such as cognitive skills and non-cognitive personality traits. Another mechanism is the inheritance of group memberships that enhance wealth and income, most notably race. Still another is the better education and health which offspring of more affluent families enjoy.

Though those mechanisms clarify some of the reasons for inequality, still the transmission of economic success across generations remains something of a black box. Research shows that such mechanisms as superior cognitive abilities and education, while important, only tell a small part of the story. Moreover, while it appears that gene transmission of income earning traits may be important, IQ appears to play little role in the process.

IQ—NOT AS IMPORTANT AS YOU WOULD THINK

The similarity of parents' and offspring's scores on cognitive tests is well documented. Correlations of IQ between parents and offspring range from 0.42 to 0.72, where the higher figure refers to measures of average parents' vs. average offspring IQ. Moreover, the contribution of cognitive functioning to earnings both directly and by way of schooling attainment has also been established in a large number of studies. Do these two facts—parent-child similarity in IQ and an important causal role for IQ in generating earnings—imply a major role for genetic inheritance of cognitive ability in the transmission of intergenerational economic status? Surprisingly, no.

To approach this puzzle, Bowles and Gintis began with the question, How much lower would the correlation of parents' and adult children's

income be if there were no genetic inheritance of IQ (that is, if the parent-offspring similarity in IQ were due entirely to cultural inheritance)? This thought experiment is hypothetical; nevertheless, it is informative. Working back from this question using a complex set of assumptions and calculations drawn from statistics, genetics, human development, and economics, the researchers ultimately estimated that the contribution of genetic inheritance of IQ to parent-offspring transmission of income is the very small 0.018, or roughly a twentieth of the observed level. Of course this does not rule out an important role for genetic transmission; it just questions whether it's IQ that's on the transmission belt.

WHAT TWINS DO AND DON'T TELL US ABOUT GENES AND THE ENVIRONMENT

The remarkable similarity in the income of identical twins suggests that genetic inheritance, or environmental components, or both, play a part in the intergenerational transmission of economic status (presumably most identical twins grow up in the same setting). Disentangling the effects is challenging empirically as well as controversial. One of the reasons why more heat than light is sometimes generated by these estimates is that many people believe that if heritability of a trait is substantial and the environmental component of its variance small, then the trait cannot be affected much by changing the environments affecting its development. In this case, it is sometimes concluded, public policy is powerless to level the playing field.

But this view is false. Consider a highly genetically heritable trait such as height. There are significant height differences among the peoples of the world. Dinka men in the Sudan average 5 feet and 11 inches—a bit taller than Norwegian and U.S. military servicemen, and a whopping 8 inches taller than the Hadza hunter-gatherers in Southern Africa. But the fact that Norwegian recruits in 1761 were shorter than today's Hadza shows that even quite heritable traits are sensitive to environments. What can be concluded from a finding that a small fraction of the variance of a trait is due to environmental variance? Policies to alter the trait through changed environments will require non-standard environments that differ from the environmental

variance on which the estimates are based.

The challenging part of the estimation of environmental and genetic effects from twin studies arises because so much depends on the precise assumptions about how the two interact, and the extent to which the environments of identical twins are more similar than the environments of fraternal twins. Bowles and Gintis, while stressing the large margin of error in the estimates, nonetheless conclude that the twin data suggest that genes may play a significant role in the transmission process. Their second conclusion is that environmental effects are significant, and that less than half of the estimated environmental effect can be accounted for by educational differences. What other mechanisms accounting for the persistence of income over generations have been ignored?

BEQUESTS—PROPERTY AND PERSONALITY BOTH COUNT

If IQ isn't the key to how inequality persists over the generations, and if schooling gives, at best, a partial account of the environmental effects, one would surely look to inheritance as a more straight-forward mechanism: the inheritance of wealth. Little research has been done in this area, however, in part because no representative data exists to measure the second generation's wealth once they've reached the age at which inheritance of wealth occurs, typically late in the life of the second generation. It has been shown that intergenerational persistence is greater for wealth than for earnings. This parent-offspring similarity in wealth may make a major contribution to the family persistence of income differences.

Still, these data tell us little about the importance of wealth inheritance or transfers during the life of the offspring, leading to some doubt about their role. The skeptics have a point: income from property provides a negligible fraction of total income for most individuals. Only among the very well-to-do is it a major source of income. Correspondingly, very few individuals receive significant inheritances. Transfers that occur during life are not captured in these figures and they may be considerable. But still it seems unlikely that for most of the population a substantial degree of eco-

conomic status is transmitted directly by the intergenerational transfer of property or financial wealth. For the upper third of the income distribution, however, Bowles and Gintis estimate that wealth inheritance plays a major role.

GROUP MEMBERSHIP AND PERSONALITY

Most economists have attempted to explain intergenerational transmission of economic status by parent-offspring similarity in either skills or wealth, namely by focusing on the things that contribute to production. But this focus on the productive contribution of individuals has not yet shed much light inside the black box. Bowles and Gintis and their co-researchers have pursued a different line of reasoning. An individual's income is affected by things that are not really productive inputs at all, such as race, first language, religion, or other aspects of group membership. One is born into such groups, and changing membership is both difficult and unusual. Thus group membership traits are persistent across generations and are arguably as important as cognitive skills in the determination of income.

Another inherited trait that is hard to square with the focus on skills and other productive inputs is physical appearance. Women who are obese, for example, tend to have low earnings; this holds even for women who were obese as teenagers but not as adults. Similarly, men who are tall tend to have high earnings. Attractiveness predicts high earnings for both men and women irrespective of whether they interact with the public.

Dispositions, such as a sense of personal worth, work ethic, honesty, or a strong orientation toward the future, provide a second example of the importance of non-cognitive traits. Though these traits are not inputs into production, they contribute to individual economic success because they increase the gains from economic transactions in situations where contracts are incomplete. Traits such as these are significant to an important class of exchanges, including the hiring of labor, borrowing and lending, or the exchange of goods of uncertain quality, particularly when it is impossible to specify all relevant aspects of the exchange in a contract enforceable by the

courts. The reason is that where contractual guarantees are impossible, it is essential that both parties can trust that a handshake is a handshake, and the personal dispositions of the parties to the exchange may determine whether this is true.

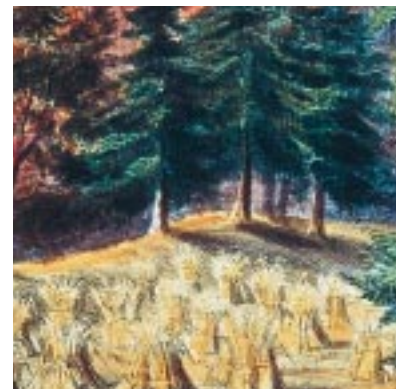
In situations where this is the case, the terms of the exchange are influenced by the degree of trust, honesty, hard work, and other dispositions of the parties to the exchange. For example, an employer interacting with an impatient employee who only thinks of the present will find it costly to provide strong incentives for the employee. The reason is that the present-oriented employee will not value the promise of continued employment in the future conditional on good work, and hence will require a higher wage to motivate hard work in the present. The problem is not that the impatient worker lacks productive skills, but that it's very expensive to induce such a worker to put his skills at the disposal of the employer through hard work. As another example, a fatalistic worker who believes that her job security is unaffected by her own actions will be costly to motivate under this type of labor contract.

A little-researched part of the transmission process concerns health. Since children of the well-to-do are much healthier than poor children, and poor health has sustained effects on incomes later in life, this factor may account for a substantial part of the intergenerational transmission process, but the necessary research has not yet been done.

CAN THE FIELD BE LEVELED?

Though America may still be considered a land of opportunity by some accounts, parental wealth and income remain strong predictors of the likely economic status of the next generation. It has become clear that economic success is transmitted from one generation to another through many channels—some only recently identified.

A policy maker concerned that intergenerational transmission of economic status gives an unfair



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MIS HERMANOS BY JESSE TREVINO, 1976
SMITHSONIAN MUSEUM OF AMERICAN ART, WASHINGTON DC/ART RESOURCE, NY

advantage to the well-to-do, might use this new knowledge to design policies to interrupt the parts of the process thought to be objectionable. But the policy maker still faces difficult questions. Does a level playing field require that there should be no correlation at all between parental and child incomes? If so, how might the pursuit of fairness be balanced against the costs of the downward mobility that would be required for the kids of the rich? And what of the competing claims of privacy and the value of family life that would have to be compromised?

A more reasonable approach, in Bowles' and Gintis's view, would be to ask which mechanisms of intergenerational transmission are unfair, and direct policies accordingly. The role of race, for example, in transmitting status, is usually deemed unfair; as is the fact that wealthier children tend to be healthier children; and many feel that the passing of massive amounts of wealth to the next generation gives the children of the rich an unfair head start. And most people favor policies to compensate

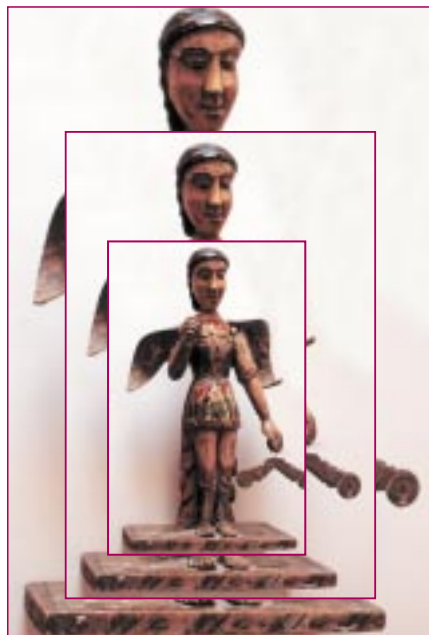
for inherited disabilities.

However, other mechanisms of persistence—the genetic inheritance of good looks, for example—strike most people as unobjectionable and not an appropriate target for policy interventions (a beauty tax?). And what about bedtime stories? They may help kids get ahead, but is it unfair that better-off parents may have more time than poor parents for reading to their children?

Addressing the policy challenge will require not only moral clarity about these difficult questions but also a better accounting of which causal mechanisms are at work in producing the substantial levels of intergenerational persistence of economic differences.

Some of this material is adapted from "Inheritance of Inequality," by Samuel Bowles and Herbert Gintis, to appear as the lead article for a symposium in the Journal of Economic Perspectives.

RESEARCH EXPERIENCES FOR UNDERGRADUATE STUDENTS AT THE SANTA FE INSTITUTE, 2002



SFI has a limited number of research openings for undergraduate interns during summer 2002. Through an NSF Research Experiences for Undergraduates Program at SFI, students can work with a faculty mentor on an individual project focusing on some aspect of the computational properties of complex systems. SFI's broad program of research is aimed at understanding both the common features of complex systems and comprehending the enormous diversity of specific examples. Projects focus on adaptive computation; physics, mathematics, information science, and computational aspects of complexity; economics as a complex, adaptive system; and the life sciences including modeling of the immune system, theoretical neurobiology, genetic data analysis, theoretical ecology, and models of protein folding.

This program is highly individualized. Each student works with one or more faculty mentors on a specific self-selected project. Participants are expected to be in residence approximately 10 weeks, from about mid-May to mid-August. Internships may be part- or full-time, although it is likely that most summer students will hold full-time positions.

Interns receive round-trip travel expenses (air or car) from their home institution and living stipends (from which housing costs are deducted) during their stay. The Institute will make appropriate, affordable, shared housing arrangements in Santa Fe for REU interns. Since this program is an educational rather than employment experience, stipends are expected to support a "no-gain/no-loss" situation for students (although previous, frugal interns have managed to save modest amounts out of their summer support).

Because Santa Fe lacks a full public transportation system, automobiles are provided to participants on a shared basis. Those interns who can bring their private transportation are urged to do so.

ELIGIBILITY

This program is open to U.S. citizens and permanent residents only. For the purposes of this program an undergraduate student is a student who is enrolled in a degree program (part-time or full-time) leading to a bachelor's degree. Students who are transferring from one institution to another and are enrolled at neither institution during the intervening summer may participate. College seniors graduating in 2002 are not eligible for this program; nor are graduating high school students who have not yet enrolled as undergraduates.

Mathematical or computational skills or experience (particularly knowledge of the rudiments of the Unix operating system and/or a programming language such as C) are favorably considered.

HOW TO APPLY

Send a current resume, transcript of grades, and a statement of your current research interests and what you intend to accomplish during your internship. Also, please have three scientists who know your abilities write letters recommending you for this program. Include your e-mail address and/or fax number. Send complete applications to:

Summer Research Opportunities for Undergraduates

MS-NG

Santa Fe Institute

1399 Hyde Park Road

Santa Fe, New Mexico 87501

Applications must be postmarked by February 15, 2002.

Women and minorities are especially encouraged to apply.

For further information, a deadline, and electronic submission details:

<http://www.santafe.edu/sfi/education/indexREUS.html>,
or contact Paul Brault, (505) 984-8800 x 235;
paul@santafe.edu.

INTERNATIONAL PROGRAM FORGES AHEAD

Now approaching its second anniversary, the SFI's International Program is flourishing. The initiative aims to spread the Institute's scientific approach to countries throughout the world. It now targets areas where funding is not readily available for interdisciplinary research activities, and/or where restrictions on the availability of financial support might preclude extensive travel opportunities for educational purposes. Focusing on participants from and activities within China, India,

examines signaling processes at the cellular level. **Beata Oborny's** permanent position is at Eötvös Loránd University in Budapest, where she is an associate professor of plant taxonomy and ecology. Her research focuses on the evolution of spatial patterns as an adaptive strategy in plants. Oborny will be participating in the 2002 Complex Systems Summer School in Budapest, and she plans a residency at SFI this spring. **Juan Pablo Paz** is a physicist; like Dawson, he is from the University of Buenos Aires. His research focuses on quantum computation, quantum coherence, and the physics of information. Both Dawson and Paz are currently in residence at SFI. E. "Som" **Somanathan** is an associate professor at the Indian Statistical Institute in New Delhi. He is pursuing research on the evolution of preferences

and consumption patterns and how they relate to environmental issues in developing countries. Somanathan will join the SFI research staff during a visit this spring. **Gareth Witten** is completing a doctorate in applied mathematics at the University of Cape Town in South Africa. His research involves models for energy partitioning in physiological and metabolic systems. Witten visited SFI in January 2002.

FELLOWS HOST WORKSHOPS IN CHINA, INDIA, AND RUSSIA

Meanwhile, the activities of the inaugural class of fellows—whose appointments extend through 2002—are well underway. **Li Wei** from the Central China Normal University in Wuhan and Han Jing from the University of Science and Technology in Hefei col-

laborated to host a five-day workshop in Beijing late last year titled, "A Workshop on Complex Problems." Senior advisory support came from Professor Cai Xu at Wuhan, and additional support came from the China Center of Advanced Science & Technology directed by Nobel laureate T. D. Lee. The event drew nearly 80 participants including professors and students from the undergraduate to postdoctoral level. The meeting covered a broad range of complexity science topics, from networks and evolution to measuring complexity. It served to not only introduce participants to the field but provided a venue for establishing new research collaborations and networks.

In January 2002, **Sitabhra Sinha** organized a workshop in Calcutta focusing on the dynamics of networks and spatially-extended systems. Co-sponsored by SFI and the Saha Institute of Nuclear Physics (SINP), the meeting followed STATPHYS-KOLKATA IV, an international meeting on statistical physics. Joining the group in India were SFI community members Homayoun Bagheri-Chaichian and Sanjay Jain.

SFI Fellow **Nelley Kovalevskaya** is planning the workshop "Studies of Socio-Natural Coevolution" to be held in the summer of 2002 in Barnaul, Siberia. The thrust of the workshop is to explore how a complexity approach might be brought to bear on specific research within the Russian Academy of Science, including work on biotic and abiotic adaptation, biospheric organization, and human/environmental co-evolution. Approximately 35 scientists from throughout Russia will likely participate.

SFI ALSO PLANS MEETINGS

In tandem with the Fellows' workshop initiatives in their home countries, SFI is actively developing a roster of



Latin America, Africa, Eastern Europe, and the Former Soviet Union (FSU), the program funds fellowships, workshops, summer schools, and expanded international participation in the Institute's wide range of research programs.

SFI APPOINTS ITS SECOND CLASS OF INTERNATIONAL FELLOWS

SFI recently selected the 2001-2003 class of International Fellows from a pool of more than 100 applicants. They are as follow: **Hao Bai-lin** is a Research Professor at the Institute of Theoretical Physics in Beijing. His work invokes linguistic, combinatorial, and graph theory approaches to model the complexity of DNA and protein sequences. Bai-lin previously visited SFI last year and will return in the autumn of 2002. **Silvina Ponce Dawson** is an assistant professor in physics at the University of Buenos Aires. Her work



international workshops. In fact, nearly all SFI meetings feature rosters including international participants. What distinguishes international workshops from these others is that they generally involve an international organizer or co-organizer and the venue is often in another country. Along with its scientific aims, an explicit goal of the workshop is to extend the Institute's multidisciplinary research approach to new constituencies.

Last May SFI External Faculty member **Juergen Jost** hosted a workshop in Leipzig at the Max Planck Institute for Mathematics entitled "Complexity: Unifying Themes for the Sciences and New Frontiers for Mathematics." Thirty-

f o u r
researchers—
from (former
East) Germany,
Hungary, Czech
Republic, India,
Poland, Romania,
Russia, and the

U. S.—participated. As a result of the meeting Beata Oborny applied for and has become an SFI International Fellow.

An international workshop titled "Interdisciplinary Applications of Ideas from Nonextensive Statistical Mechanics and Thermodynamics" will be held in



April at SFI; it is co-chaired by Distinguished Fellow **Murray Gell-Mann** and **Constantino Tsallis**, a professor at the Brazilian Center for Physical Sciences in Rio de Janeiro. During recent years, a good deal of study has been devoted to a nonextensive generalization of entropy and of Boltzmann-Gibbs statistical mechanics and standard thermo-

dynamics. That generalization has intrinsically nonlinear features and yields power laws in a natural way. The workshop—which will involve a number of speakers from Latin America—focuses on the interdisciplinary applications of these ideas, and also on various phenomena that could possibly be quantitatively describable in terms of these ideas.

Another outcome of the 2001 Leipzig meeting is an upcoming workshop in Prague. "Exploratory Workshop in Evolutionary Dynamics," scheduled May 27 to June 4, 2002, is coordinated by SFI Vice President for Academic Affairs **Tom Kepler** and **Ivan Havel**, Charles University and the Academy of Sciences of the Czech Republic. It will include researchers from Eastern Europe, India, and the U.S.

"Guidance of Complex Systems" is scheduled for October in Beijing. This meeting will focus on stochastic, distributed, and adaptive control as tools contrasted to complex natural systems in which intervention by goal-directed agents is inherent, yet not explicitly considered as a control system. Markets, social institutions, ecologies, and human-environmental interaction will be discussed. This workshop is co-chaired by **Tom Kepler** and **Lei Guo** from the Institute of Systems Science of the Chinese Academy of Sciences. Honorary chairman of the program is Jiang Zhenghua, vice chairman of the Standing Committee of the National People's Congress.

INTERNATIONAL COMPLEX SYSTEMS SUMMER SCHOOL IN BUDAPEST

Over 500 students from throughout the world competed for a combined total of 120 slots at the two 2001 Complex Systems Summer Schools in Santa Fe and Budapest. Both schools offered an intensive introduction to complex behavior in mathematical, physical, living, and social systems for graduate students

and postdoctoral fellows in science and the social sciences.

The Santa Fe school is nearly 15 years old, while the Budapest school hosted its first session in 2001. Despite its inaugural status, the Hungarian program matched its U.S. counterpart with about 250 applications. Ultimately 58 students were selected, representing Central and Eastern Europe, Russia, China, and Latin America. As part of SFI's International Program, the Budapest school particularly served students from the Program's target regions. However, both schools featured broadly international student populations.

Computer scientist **Melanie Mitchell** was a co-director for both the Santa Fe and Budapest schools. Co-director for the Budapest school was **Imre Kondor** (physics of complex systems), Eötvös Loránd University, Budapest. In addition to funding from SFI's International Program, support for the Budapest school was provided by the Central European University, with supplemental funding from the Collegium Budapest.

The Budapest summer school will again be offered in July 2002, this time on the campus of Eötvös Loránd University. Co-directors of the program are **John Pepper**, SFI postdoctoral fellow, and **Imre Kondor**. Administrative support will come from the Central European University and SFI, with the Collegium Budapest providing housing support.

For a complete program schedule and faculty roster, see <http://www.santafe.edu/csss02.html>.



Surviving in Extremes on the Tibetan Plateau: the Ancient Past as Prologue to the Present

by Nancy Zimmerman



ALL PHOTOS: JEFF BRANTINGHAM

The stark and windswept Tibetan Plateau, where a mean annual temperature below zero degrees Celsius and a marked scarcity of water render the landscape virtually uninhabitable, would seem an unlikely place to look for insights into human evolution and adaptive behavior. But to Jeff Brantingham, a postdoctoral fellow whose work in archaeology at SFI combines research in the field with computer modeling prehistoric hunter-gatherer groups, this barren expanse of tableland on the roof of the world provides an exciting, even romantic, setting for pursuing some of the basic questions of human existence.

A native of Vancouver, B.C., Brantingham began his studies in archaeology as an undergraduate at the University of British Columbia, then decamped to the Sonoran desert to pursue his M.A. and Ph.D. at Tucson's University of Arizona. It was there that he honed his interest in the larger questions about human evolution that arise in connection with archaeological research, and

it's this challenge—how to relate the ancient past to the present—that allows him to remain excited even while toiling in a bleak and inhospitable region far from the reality he seeks to understand.

“Actually, the main premise of the research is independent of the geographic location,” he explains. “The key question is, How is it that humans in their basic form as hunter-gatherers managed to colonize some of the most extreme environments on the planet? The Tibetan Plateau combines arctic desert-type conditions with high elevation and low oxygen availability, making it a good test case for investigating human biogeographic capacities.

“The next question is, How, in view of the physio-

Above: The Qinghai-Tibet Plateau is a continuous high-elevation ecosystem characterized by extremes of climate and environment. Small river and stream drainages such as the one pictured here, at 4500 m above sea level, provided focal points for early human hunter-gatherer groups eking out an existence on the Plateau more than 10,000 years ago. Right: Surface archaeological materials consisting of stone cores, flakes and tools from the Kunlun Pass (4800 m), though of unknown age, provided evidence of stone raw material procurement strategies and potential pathways of population movement within the Plateau environment.

logical and biological constraints of low resource availability, low water availability, and high energy demands, did these forager groups manage to survive in such extreme conditions? And why would they want to? Ultimately, what role do behavior and culture play in providing a successful adaptation to those extremes?”

WHAT IT TAKES TO SURVIVE

Answering these questions with present-day experiments would prove difficult since it would entail subjecting a human population to harsh conditions in order to study its ability to adapt. The Tibetan Plateau, remote and relatively untouched, thus serves as a natural laboratory for exploring these issues, its early inhabitants unwitting participants in an investigation that was to be undertaken tens of thousands of years hence.

So far, the archaeological evidence points to human habitation of the region around 25,000 to 20,000 years ago, far earlier than in other extreme environments, such as the high Arctic or the Andes, to which populations migrated only about 10,000 years ago. The lives of these early arrivals probably focused on the hunting of big game—medium ungulates the size of a gazelle, wild yaks, blue sheep, wild ass, wild goats—as well as smaller game like birds and marmots.

“Tibet is an interesting case because we can compare it with other extreme environments,” says Brantingham. “Is there a unique solution to survival at high elevations? We haven’t answered that yet, but I suspect that human behavioral adaptations, human culture, can find multiple solutions to the same problem. For example, the Tibetan and Andean populations appear to have made different physiological adaptations to high altitude; the Tibetans adapted genetically in a way that allowed their hemoglobin to carry more oxygen, whereas the Andeans compensated through increased heart and lung size to pump more oxygen. That suggests two different biological solutions.”

CULTURAL CLUES

“Of course culture is infinitely more flexible than genetic systems,” says Brantingham, “so we can find multiple cultural solutions to the problem of foraging for survival at high elevation.”

The bulk of the clues come from lithic materials—stone tools used for hunting and the remains of rock

fireplaces—that indicate a certain level of sophistication in terms of manipulating the environment to ensure survival. The stone technology includes specialized blades with lots of cutting edge, which would have been very efficient for large-game hunting as they are easily hafted into spears.

This cultural capacity to adapt to extreme environments is deeply rooted in evolutionary time. That the population was able to survive in such an inhospitable place 25–20,000 years ago is interesting in itself, since it suggests that the cultural and behavioral capacities to handle an extreme environment were already in place, and that all that was needed was a specific contextual element—drought, population packing, or some such impetus—to “flip the switch” that would activate this capacity to adapt. For example, this apparently did not happen in the Arctic prior to the Last Glacial Maximum (the last time the planet experienced full glaciation of the continents), not because the populations in the Siberian sub-Arctic were without those capacities, but because the ecological and historical context did not exist to spur a push northwards as it may have on the Tibetan Plateau.



MIGRATIONAL CLUES

Figuring out the context that caused populations to move onto the Plateau is part of the whole behavioral reconstruction process. “There really are two issues,” says Brantingham, “reconstruction of exact behavioral strategies that hunter-gatherers used on the Tibetan Plateau, which is a difficult task in itself, but then also placing those strategies and the timing of colonization in much broader regional context. For example, we can look at the migration patterns in greater Northeast Asia,



Top: The Kunlun Pass is the primary conduit for movement of contemporary pastoralist populations between the desert basins in northern Qinghai Province distributed between 3000-4000 m and the high-elevation Plateau above 4000 m. Archaeological evidence from the Kunlun Pass suggests that it may also have served as a major artery of movement during the later portions of the Paleolithic.

Bottom: A large hearth, or roasting pit (viewed from above) from the site of Heimahe near Qinghai Lake (3100 m) provides evidence of a hunter-gatherer occupation lasting several weeks. This hearth, dated to 11,400 radiocarbon years ago, is one of at least five large features, each 1 m in diameter, and suggests that multiple family groups were operating together as an integrated social and economic unit. Multi-family foraging organization may have provided one solution to the challenges presented by life on the Plateau.

about which we know a bit more, as a general model for what may have happened to push the populations onto the Plateau.”

The Plateau has, until now, seen little exploration, making the task of answering the above questions that much more difficult. Brantingham and his colleagues, Professor Ma Haizhou, of Qinghai Normal University in China, and Gao Xing, from the Institute of Vertebrate Paleontology and Paleoanthropology of the Chinese Academy of Sciences, have had to start from scratch, surveying the landscape and collecting artifacts essentially for the first time ever. In the two field seasons (2000–2001) of the pilot project, they were able to identify archaeological sites ranging in elevation from around 3,000 meters (9,840 feet) to as high as 4,800 meters (15,744 feet) above sea level.

“There’s an awe-inspiring vastness to the terrain,” says Brantingham, who finds working on the Tibetan Plateau a lonely but strangely satisfying undertaking. “With nothing but desert steppe as far as the eye can see, you get a mixed feeling out there because the landscape is unquestionably barren and harsh, but working there breeds a kind of connection to the questions that arise in the course of the research.”

In examining the geographic distribution of these sites, a question arises: Are they the same sort of places, or do they occur in different environmental settings? “Most of these sites are associated with some kind of water—river terraces, lake beaches, standing water of some kind, and in a few circumstances they’re related to high mountain passes where populations would generally pass from one lake basin into another,” continues Brantingham. “That tells us already what was constraining hunter-gatherer groups on the Plateau. It’s not par-

ticularly surprising, but in future research, if we find sites that are outside of that particular location, we can then ask, ‘What’s different? What’s going on here?’”

He sees it as a hierarchy of forms of evidence. “You have site distributions in space and time in a broad sense. Then you can ask what environmental situations the sites are associated with. The next level of inquiry would be, ‘What types of things are we finding at these sites that indicate specific behavioral strategies, and how do they fit into other behavioral strategies at other places?’ Then you can look at individual artifacts and ask what inferences can be made about them specifically.”

ARTIFACTS TELL A STORY

“We’ve found two types of sites here,” he continues. “First there are the surface sites consisting of scatters of stone tools that we believe are some of the earliest. Then there are the geologically stratified sites where we’ve found bone fragments of small to medium ungulates, like gazelles.”

Stone technology is the primary evidence, of course, but Brantingham cautions that primary evidence is not necessarily the most important evidence. Because stone survives the ravages of geological time, archaeologists have invested thousands of pages of text on how to analyze stone tools and make inferences from them. But it’s not necessarily the most important information, he points out.

Other evidence, such as faunal (animal) remains, tells a great deal more about how humans were hunting and what they were eating, as well as saying something about the local environment. Faunal remains thus provide a very important window into the organization of prehistoric adaptations, but bone is a mineral material and doesn’t survive very well in most geological contexts. Similarly, human fossils, while important in some respects, are not as important to understanding humans as one would think: When you find a human fossil, it’s only one individual presumably from a larger breeding group, which doesn’t tell you much about biological variability within that population.

MODELING TO PREDICT BEHAVIOR

To both formulate the right questions about these early foragers and to make logical inferences from the answers, computer modeling plays a key role. “The SFI philosophy is important,” says Brantingham, “since modeling for theory-driven research is best done in a formal sense to provide specific qualitative and quantitative predictions. In the context of the Tibetan Plateau, given what we know about hunter-gatherer behavior, we try to develop models to predict what combinations of interac-

tions would drive colonization. If you take the methodological approach of SFI, you can look at how complex cultural innovations evolve in response to specific situations. The models are an integral part of problem-oriented research and provide an opportunity for bringing innovative methods to archaeology.

“For example, our models have been quite informative in indicating that the earliest colonization of the Plateau may have proceeded much like a random walk. The Plateau environment prior to the Last Glacial Maximum was a very uniform resource “mega-patch” (a large piece of land containing a relatively uniform distribution of resources), and models suggest it could have been successfully exploited using random movement rules. This leads us to very interesting predictions about where we might find archaeological sites and what we might find there.”

The persistence of hunter-gatherer strategies in today’s world underscores the notion that the cultural capacity to adapt is deeply rooted in evolutionary time, Brantingham points out. “Understanding how hunter-gatherers operated in the past informs us about how we interact today by leading us to an understanding of the fundamental features of human behavior. A modern example would be in how we approach problems such as controlling crime. If we look at a bunch of teenagers out to steal a car, we see that they’re actually employing basic foraging strategies, usually in an environment they know well, one that is rich in resources, say a parking lot, and they use a variety of tactics to find, steal, strip, and dump them.” With this understanding of their behavior, he explains, we’re better able to devise a crime-fighting method to address it. “Overall, when you look at modern behavior as a collection of hunter-gatherer strategies, you can see where archaeology is really a theoretical discipline that provides general principles for describing the human condition that help inform us about our lives. In that way, we’re not so different from those early hunter-gatherers on the Plateau.”

Nancy Zimmerman is a freelance writer, editor, and translator based in Tesuque, New Mexico.



At present, the high-elevation Qinghai-Tibet Plateau is occupied only by nomadic pastoralists. The archaeological evidence thus far recovered suggests that pastoral adaptations, which emerged only after 6000 years ago, were not necessary to successfully meet the challenges of the Plateau environment. Hunter-gatherers were present on the high Plateau by 12,000 years ago and possibly as early as 25-23,000 years ago.

Recognition

SFI Trustee and Science Board member **Robert McCormick Adams** (U. California, San Diego) received the Archaeological Institute of America's Gold Medal at its annual meeting in Philadelphia in January. This award is given annually in recognition of a scholar who has made distinguished contributions to archaeology through his or her fieldwork, publications, and/or teaching.

The Italian daily *La Nazione* characterized External Faculty member **Sam Bowles** (U. Mass., Amherst) November 2001 inaugural lecture for the University of Siena's Center for the Study of Complexity as one of the "best lectures of the past 20 years," ("le piu belle lezioni degli ultimi 20 anni"). Entitled "Fugitive Resources: the Weightless Economy and the Invisible Hand," the talk presented a model and an agent-based simulation of the evolution of the new information-based economy.

Two new trade books by **John Casti** have been published: *Goedel: A Life of Logic* (co-authored with De Pauli), from Perseus Books and *Mathematical Mountaintops: The Greatest Problems of All Time*, from Oxford University Press.

At an August 2001 meeting of the Ecological Society for America (ESA), former SFI Postdoctoral Fellow **Brian Enquist** (U. Arizona) received that organization's George Mercer Award for the year's best paper by a first-time author under 40. The paper, "Allometric Scaling of Production and Life-History Variation in Vascular Plants," had

appeared in *Nature*. (Co-authors of this paper are Geoff West, E.L. Charnov, and Jim Brown.) At the same ESA meeting External Faculty member **James H. Brown** (U. New Mexico) received the Eugene Odum Award for "Excellence in Ecology Education."

Michelle Girvan (Cornell U.) has been named an SFI/NSF Physics Graduate Fellow. Girvan has been working with Mark Newman exploring the statistical properties of networks, and developing generalized measures to characterize them. Their recent work on network structure has focused on a few properties common to many networks: the small-world property, power-law degree distributions, and network transitivity.

Science Board member **Juris Hartmannis** (Cornell U.) has been awarded the Grand Medal of the Latvian Academy of Science for his research contributions to computer science. The award was made in August 2001 in conjunction with the Second World Congress of Latvian Scientists in Riga, Latvia.

SFI Postdoctoral Fellow **Peter Hrabar** has been invited as a keynote speaker at the 3rd Conference of the International Society for Ecological Informatics (ISEI) to be held in Rome in August 2002.

External Faculty member **Tim Kohler** (Washington State) has been awarded a three-year grant for "Coupled Human/Ecosystems over Long Periods: Mesa Verde Region Prehispanic Ecodynamics," through NSF's Biocomplexity Program. The project

seeks to understand the long-term interaction of humans, their culture, and their environment in southwestern Colorado from A.D. 600-1300. The research will use agent-based simulation to examine various models for how farmers locate themselves and use resources on this landscape.

In January 2002, SFI Postdoctoral Fellow **Michael Lachmann** joined the research staff of the Max Planck Institute for Mathematics in the Sciences in Leipzig.

SFI/NSF Physics Graduate Fellow **Eric Lee** (Columbia U.) has completed a project with Jim Crutchfield modeling the effects of specialization on community assembly. He will spend three additional months at SFI collaborating with Walter Fontana to develop a simplified genotype-phenotype map.

Science Board member **Simon Levin** has won the 2001 Okubo Award sponsored by the Japanese Association for Mathematical Biology and the Society for Mathematical Biology. The Okubo Award is given every other year to honor (in even years) a distinguished work by a junior scientist and (in odd years) lifetime achievement by a senior scientist. This is the second Okubo Award, and the first lifetime achievement Okubo Award.

SFI Postdoctoral Fellow **John Pepper** has accepted a position as an assistant professor in the Department of Ecology and Evolutionary Biology at the University of Arizona in Tucson. The post will start August 2002.

HARTWELL 2001 NOBEL LAUREATE

SFI postdoctoral researcher **Spyros Skouras**'s paper "Decisionmetrics" received the second prize in the Crowell Memorial Prize Paper Competition. The prize is awarded annually by Panagora Asset Management to academic papers relevant to asset management.

SFI External Faculty member and Director of the Center on Organizational Innovation at Columbia University, **David Stark** in December 2001 hosted at Columbia the Gitelson Roundtable entitled "From Infrastructure to Interface: Socio-technical Networks in Crisis and Recovery." Representatives from companies including Merrill Lynch, Deutsche Bank, Sun Microsystems, and Cantor Fitzgerald comprised the meeting. Stark is also the recipient of a three-year grant from NSF's Program on Innovation and Organizational Change for work on "Organizational Innovation and Interactive Media among NGOs in Postsocialist Eastern Europe." He is also organizing a conference to be held in May 2002 on "Social Studies of Finance" funded by the Social Science Research Council.

Dowman Varn, an SFI/NSF Physics Graduate Fellow from the University of Tennessee, received his Ph.D. in condensed matter physics in December 2001. He will continue his residency at SFI for six additional months as a postdoctoral researcher working with Jim Crutchfield on inferring probabilistic dynamical models from spectra data.

Last October, SFI Distinguished Fellow **George Cowan** received the 2001 Alumni Distinguished Achievement Award from Carnegie Mellon University (CMU). The award, presented by CMU President Jared Cohon, recognized Cowan's lifetime career achievements.

Leland Hartwell, along with R. Timothy Hunt and Paul Nurse, share the 2001 Nobel Prize in Physiology or Medicine for their discoveries of key regulators of the cell cycle. Hartwell is president of the Human Biology Division at the Fred Hutchinson Cancer Research Center. He is an advisor to SFI's Evolutionary Dynamics program and a former member of the SFI Science Board.

Hartwell and his co-recipients have identified key molecules that regulate the cell cycle in all eukaryotic organisms, including yeasts, plants, animals, and humans. These fundamental discoveries have a great impact on all aspects of cell growth. Defects in cell cycle control may lead to the type of chromosome alterations seen in cancer cells. The research may, in the long term, open new possibilities for cancer treatment.

Hartwell is awarded for his discoveries of a specific class of genes that control the cell cycle. One of these genes called "start" was found to have a central role in controlling the first step of the cell cycle. Hartwell also introduced the concept, "checkpoint," a valuable aid to understanding the cell cycle.



PHOTO: FRED HUTCHINSON, CANCER RESEARCH CENTER

August Course Fosters Cross-Talk and Collaborations

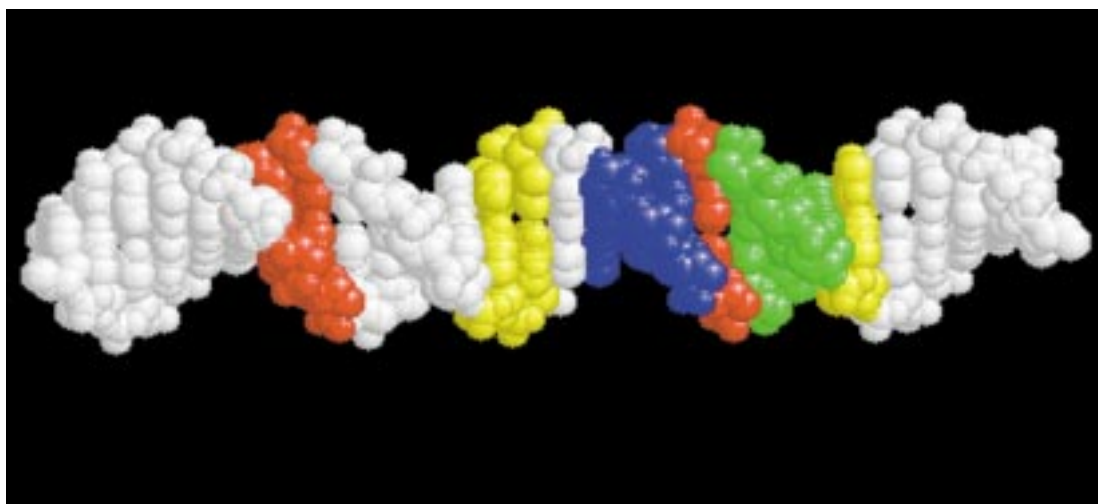
The August 2001 workshop “Mathematical Models in Molecular and Cellular Biology” succeeded resoundingly. The goal of the event was to provide concrete examples of how mathematical modeling can improve biological understanding. An immediate outcome was several potential follow-on collaborations between theorists and experimentalists—just what organizers had set out to achieve.

Bringing together theorists and experimental biologists requires an understanding of each of the different cultures as well as an appreciation of how each community of practice can facilitate the others’ research activities. Routinely, experimentalists settle into a niche in a specific area of biology and find it risky to begin interacting with theorists. Through short courses like the August meeting, the cultures are beginning to understand each other’s languages.

The August workshop is part of a series of related activities at SFI under the umbrella award “Mathematical Tools and Modeling for Biologists,” funded by the National Institute of General Medicine (part of the NIH). The broad purpose of this initiative is to involve junior and mid-career scientists in cross-talk

with the ultimate result that they will become involved in further seminar series, courses, and workshops within their own universities and institutes.

At the August meeting, 16 faculty joined program leader Lee Segel. Thirty students (ranging from doctoral students through mid-career researchers) were selected from an applicant pool about three times that number. The first week of the course included lectures in mathematical modeling in molecular and cellular biology and a mathematics refresher, including an introduction to topics in differential equations. The second part of the workshop focused on actual research problems to demonstrate how theory and mathematical modeling can be used to gain a deeper understanding of biological problems and their complexities, and eventually be used to facilitate experimental design in a laboratory setting. Topics of the lectures included biochemical kinetics, ligand binding and cell signaling, cell cycles, oscillations and bursts in cellular neurobiology, making inferences from biological data, matching models and experiments in immunology, patterns in *Drosophila* developmental biology, gene regulation, and nematode-plant interactions.



Two representations of a mathematical model for the DNA recognition site for the recombination actuation proteins (RAG-1,2) which play a key role in the development of the immune system. Colors in the left figure show which DNA bases are correlated with each other. The additional colors on the second figure show the bases shown by biochemical studies to be important.

Proposals for three follow-on collaborations are pending. The first proposal would convene a workshop at SFI on “Stochastic Simulation of Immunological and Neuronal Synapse: Novel Mathematical Framework.” It is designed to bring together experimentalists and modelers with the intent of establishing working groups that will attempt to gain insight into the mechanism underlying T-cell differentiation and neuronal signal transduction using stochastic modeling approaches. The second proposal comes from a workshop alumni attending from Budapest. His interest is in modeling morphogenesis in fission yeast concerning microtubule and actin movements. The third proposal is to establish a collaborative project with SFI Postdoctoral Fellow Lauren Ancel to develop computer simulations of the evolution of nucleic acids related to the experimental evolution of nucleic acids.

Next August’s workshop “Modeling and Simulating Biocomplexity for Mathematicians and Physicists” reverses the 2001 approach. Participants will be graduate students, postdoctoral fellows, and junior faculty members in mathematics, and physicists who are interested in applying their knowledge in the biological sciences. Lee Segel will again act as workshop coordinator. Faculty and topics lined up for this course are Leah

Edelstein (U. British Columbia) on actin dynamics and the cytoskeleton; James Keener (U. Utah) on modeling heart physiology and cardiac arrhythmias as excitable media; Bette Korber (Los Alamos National Laboratory) on bioinformatics and AIDS; Henry Markram (Weizmann Institute) on “liquid computing” by brain microcircuits; Michael Laessig (U. Cologne) on the physics of biological information: sequence similarity; James Murray (U. Washington) on the growth and control of brain tumors; Luca Peliti (U. Naples) on evolution; and James Sneyd (Massey U.) on cell sodium and calcium: oscillations, waves, and cell volume control.

Additional activities as part of this initiative are a 2002 workshop on cellular control networks planned by Michael Lachmann (Max Planck Institute, former SFI postdoctoral fellow) and SFI Research Professor Walter Fontana. Also planned is a series of biology lectures to be presented by SFI Science Board members who work at the interface of theory and experiment. The lecturers include Harold Morowitz, Alan Perelson, Frances Arnold, Deborah Gordon, Laura Landweber, Marc Feldman, Geoff West, Richard Lewontin, Charles Stevens, George Oster, Simon Levin, William Greenough, Peter Heilbrun, Don Glaser, Nancy Kopell, and Lord (Robert) May.



Figures from Cowell, L.G., M. Davila, T.B. Kepler and G. Kelsoe. “An Analytical Representation of Recombination Signal Sequences that Predicts Recombination Efficiencies,” in preparation.

April 24**Making Sense of Life**

Evelyn Fox Keller, History and Philosophy of Science, Massachusetts Institute of Technology; author of many reviews and 10 books including, most recently, *The Century of the Gene*, which traces the history of genetics.

No one doubts the extraordinary advances made over the course of the 20th century in our understanding of vital processes. "In fact, so dramatic have been these achievements," notes Evelyn Fox Keller, "that today . . . biology may well be outflanking physics as the leading natural science. Yet I would argue that, despite such indubitable success, biology is scarcely any closer now than it was a hundred years ago to a unified understanding (or theory) of the nature of life. The models, analogies, and metaphors that have contributed so much to our understanding remain partial." Keller will discuss this "mosaic structure" of the project of making sense of life.

May 13**Ending Civil Conflicts: Durable Settlements or Wars Without End**

Elisabeth Jean Wood, Politics, New York University, and Visiting Professor at the Santa Fe Institute. Wood is the author of *Forging Democracy from Below* and the forthcoming *Insurgent Collective Action and Civil War*.

The specter haunting contemporary civilization is no longer total war but civil war. The number of civil wars taking place in the 1990s was about seven times the number during the 1950s. The average duration of civil wars has also increased. In El Salvador and South Africa, long-standing and bitter civil conflicts were durably resolved by negotiation. But the ongoing conflagrations in Colombia and Angola proved resistant to settlement. What explains the difference? Some possible variables—the end of the Cold War, third-party intervention, and ethnic identity—do not appear to resolve this puzzle. Wood draws on several case studies to explore the conditions that foster enduring settlements and those that tend to undermine them.

June 19**Predicting Climate Change in a Complex Biosphere: A Daunting Challenge**

John Harte, Energy and Resources Group, University of California, Berkeley

Harte presents evidence from ice-core studies and other investigations suggesting that there is strong feedback between Earth's climate and terrestrial ecosystems. A consequence of such feedback is that current climate models may be greatly underestimating the magnitude of impending global warming. Quantifying ecosystem-climate interactions is a daunting task, however, confounded by the limited spatial and temporal scale of empirical research in ecology. New approaches and new insights from current research on climate-ecosystem linkages will be presented and implications for climate policy discussed.

July 24**The Scientist in the Crib—How Children Learn and What They Tell Us about the Mind**

Alison Gopnik, Psychology, University of California, Berkeley

For centuries, psychologists and philosophers agreed that babies were the opposite of adults. They were emotional and passive, dominated by perception and incapable of rational thought. Today, scientists have only recently begun to appreciate just how much even the youngest babies know—and how much and how quickly they can learn. There are three elements to this new picture. First, that children know a great deal, literally from the moment they are born. Second, that they are born with extremely powerful learning abilities, more powerful than the most sophisticated computer. And, finally, that grown-ups appear to be "programmed" to unconsciously teach babies and young children just the things they need to know.

September 24, 25, and 26

**Ninth Annual Stanislaw Ulam Memorial Lectures
Propagation and Purpose: Parables from
Complex Systems and Their Possible Meanings
for Our Lives.**

J. Doyne Farmer, McKinsey Professor, Santa Fe
Institute

In 1950 John von Neumann said that “science and technology will shift from a past emphasis on motion, force, and energy to communication, organization, programming, and control.” He was right. This has happened in almost every field of science and engineering, and has had a huge effect on the way we communicate, do business, and even entertain ourselves. But at a more fundamental level, we are slowly gaining a better (if still fragmentary) understanding of how the material properties of the world give rise to its informational properties. While the universe becomes in one sense more random, in another sense it becomes more orderly. Patterns spontaneously emerge, grab energy, rearrange, compete, and perform complex tasks such as prediction of their environments, for the purpose of better propagating themselves through time. People and their societies are just one example. Farmer will argue that viewing ourselves in the context of the broader organizational process of which we are a part can shed a little light on our beliefs and institutions, and our relation to the universe.

October 23

**Rice Paddies, Coral Reefs,
and the Goddess of the Lake**

Steven Lansing,
Anthropology,
University of Arizona



Centralized planning has not been good for Indonesia’s rainforests, rice paddies, and coral reefs. Thirty years of “Five Year Plans” has left a trail of environmental devastation. Paradoxically, some of the world’s most successful systems of resource management are found on Indonesian islands such as Bali, where for centuries farmers have cooperated in the management of whole watersheds. Computer simulations of Balinese water temple networks show that they are

well adapted to managing a complex ecosystem from the bottom up. But such methods of control are nearly invisible to planners accustomed to a top-down approach. Current models for resource management have been a dismal failure, and there is clearly much to be learned from systems like the Balinese water temples. Ironically, they may vanish just as we are beginning to comprehend them.

November 20

Einstein’s Clocks, Poincaré’s Maps

Peter Galison, Mallinckrodt Professor of History of
Science and Physics, Harvard; MacArthur Fellow

In the standard picture of the history of special relativity, Albert Einstein’s reformulation of simultaneity is considered a quasi-philosophical intervention, a move made possible by his *dis*-connection from the standard physics and technology of the day. Einstein’s job at the patent office is generally viewed as a lowly day job, offering him some technical training but little relevance to his work on relativity. Galison argues that, on the contrary, Einstein’s patent work located him squarely in the middle of a wealth of cultural discussions and important patents surrounding the coordination of clocks along railway lines and throughout the cities of central Europe. A similar *dis*-connect has been seen in the work of French physicist Jules Henri Poincaré. However, far from being lost exclusively in the far reaches of mathematics as many believe, Poincaré was at the same time profoundly involved with the use of coordinated clocks for longitude determination. By understanding the history of coordinated clocks, Einstein’s and Poincaré’s work in relativistic physics shines in a very different light.

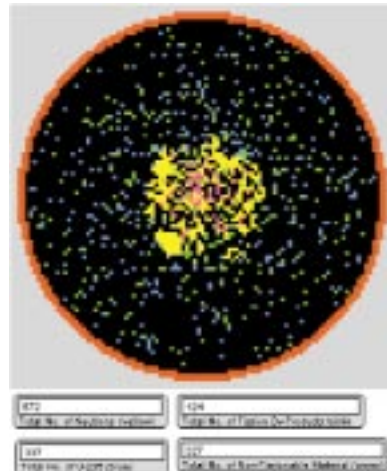
Talks take place on Wednesday evenings at 7:30 p.m., at the James A. Little Theater on the campus of the New Mexico School for the Deaf, 1060 Cerrillos Road, Santa Fe. There is no admission charge and no reservations are necessary, but seating is limited.

Please contact the Santa Fe Institute to arrange for sign language interpretation if necessary.

Exploring the World through Computer Models

A FREE SUMMER WORKSHOP FOR SANTA FE AREA HIGH SCHOOL STUDENTS

JUNE 17-28, 2002, AT THE SANTA FE INSTITUTE

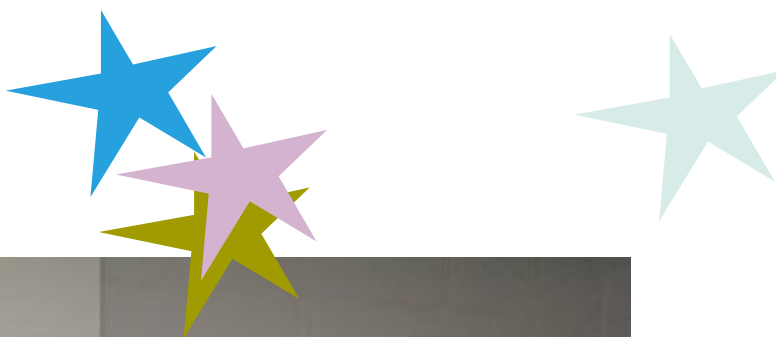


SFI invites selected students from Santa Fe's public and private high schools to spend 10 days at the Institute using Starlogo software to develop computer models of decentralized systems such as traffic jams, ecosystems, economies, and ant colonies.



Starlogo is software developed at the Massachusetts Institute of Technology Media Lab. It is an excellent teaching tool because users can begin modeling their ideas without first having to learn a programming language, and then develop the models with programming. Starlogo encourages users to break out of conventional models of thinking about complex phenomena.

Summer students will meet with workshop staff and Santa Fe Institute researchers. Included in the program will be Starlogo instruction, tutorials on complex system phenomena, informal project discussions, and plenty of one-on-one project time with staff. A fully equipped computer lab will be available to the workshop participants. It will be business as usual at SFI during the workshop, so participants will have a chance to interact with on-site researchers. Guest lecturers to the workshop will showcase some of the cutting-edge work in progress at the Institute, from research on the formation of ancient cities to the workings of the human immune system.



The workshop faculty is led by James Taylor, head of the Computer Science and Technology Department at Santa Fe Preparatory School. Taylor coordinates and teaches Starlogo modeling at Santa Fe Prep, and has co-directed Starlogo workshops for teachers and students throughout the United States and in Mexico.



ENROLLMENT IS LIMITED AND IS BY APPLICATION.

To apply, see

<http://www.santafe.edu/sfi/education/sssc/summer02/>
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