Social, Behavioral and Economic Research in the Federal Context

National Science and Technology Council
Subcommitee on Social, Behavioral and Economic Sciences

January 2009

About the National Science and Technology Council

The National Science and Technology Council (NSTC) was established by Executive Order on November 23, 1993. This Cabinet-level Council is the principal means within the executive branch to coordinate science and technology policy across the diverse entities that make up the Federal research and development enterprise. Chaired by the President, the membership of the NSTC is made up of the Vice President, the Director of the Office of Science and Technology Policy, Cabinet Secretaries and Agency Heads with significant science and technology responsibilities, and other White House officials.

A primary objective of the NSTC is the establishment of clear national goals for Federal science and technology investments in a broad array of areas spanning virtually all the mission areas of the executive branch. The Council prepares research and development strategies that are coordinated across Federal agencies to form investment packages aimed at accomplishing multiple national goals. The work of the NSTC is organized under four primary committees: Science, Technology, Environment and Natural Resources, and Homeland and National Security. Each of these committees oversees subcommittees and working groups focused on different aspects of science and technology and working to coordinate across the Federal Government.

For more information visit: www.ostp.gov/cs/nstc

About the Office of Science and Technology Policy

The Office of Science and Technology Policy (OSTP) advises the President on the effects of science and technology on domestic and international affairs. The office serves as a source of scientific and technological analysis and judgment for the President with respect to major policies, plans and programs of the Federal Government. OSTP leads an interagency effort to develop and implement sound science and technology policies and budgets. The office works with the private sector to ensure Federal investments in science and technology contribute to economic prosperity, environmental quality and national security.

For more information visit: www.ostp.gov

About the Social, Behavioral and Economic Sciences Subcommittee

The purpose of the Subcommittee on Social, Behavioral and Economic Sciences (SBE) is to advise and assist the Committee on Science and the NSTC on US social, behavioral and economic science policies, procedures, and plans that relate basic and applied research and development (R&D) efforts to national priority areas and the use of SBE research knowledge for the benefit of all Americans.

COVER IMAGES CLOCKWISE FROM TOP RIGHT: MICHAEL WELIN; ANNE YODER, DUKE LEMUR CENTER; PAUL TORRENS, ASU; JEFFERY HEATH, DEPARTMENT OF EDUCATION; NATIONAL EYE INSTITUTE, NIH; SEBASTIAN KAULITZKI/NATIONAL HUMAN GENOME RESEARCH INSTITUTE

Social, Behavioral and Economic Research in the Federal Context

Report of the
National Science and Technology Council
Subcommittee on Social, Behavioral and Economic Sciences
January 2009

EXECUTIVE OFFICE OF THE PRESIDENT

NATIONAL SCIENCE AND TECHNOLOGY COUNCIL

WASHINGTON, D.C. 20502

January 13, 2009

Dear Colleagues:

I am pleased to forward this report, "Social, Behavioral and Economic Research in the Federal Context,"developed by the National Science and Technology Council.

The social, behavioral and economic (SBE) sciences are focused on human behavior and the actions of groups and organizations at every level. Research information provided by the SBE sciences can provide policymakers with evidence and information that may help address many current challenge areas in society, including education, health care, the mitigation of terrorism, the prevention of crime, the response to natural disasters, and a better understanding of our rapidly changing global economy. This is a particularly important time to reassess the role and opportunities for the SBE sciences in all of these areas. Recent advances in genomics, neuroscience, computing, imaging and other areas have combined to provide revolutionary new tools for SBE scientific study.

The report is a distillation of the most pressing scientific challenges in the SBE sciences and their policy implications for Federal agencies. It outlines the specific tools, methodology and infrastructure that are changing our understanding of how these challenges in the social and behavioral arenas may be addressed. In doing so, it strikes a balance between scientific and policy agendas and identifies new areas of SBE science that can inform policy decisions.

Sincerely,

John H. Marburger, III

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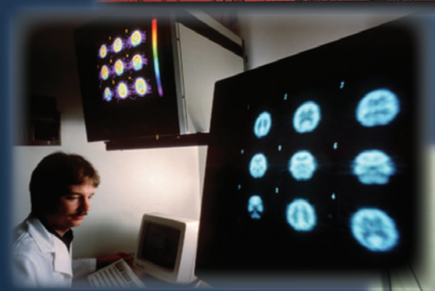
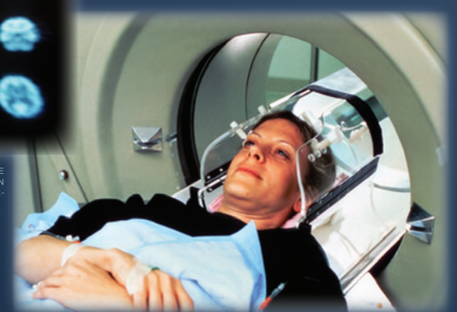
Executive Summary





FROM TOP: DAVID SHARP, U.S. ARMY; KISHORE NAGARIGARI; SCOTT BAUER, USDA; WARREN GRANT MAGNUSON CLINCAL CENTER, NIH; WARREN GRANT MAGNUSON CLINCAL CENTER, NIH

Recent advances in genomics, neuroscience, computing, imaging and other areas have combined to provide revolutionary tools for the social, behavioral and economic (SBE) sciences. In order to identify priority research areas and ensure that these new tools are best applied, the National Science and Technology Council established the Subcommittee on Social, Behavioral and Economic Sciences. This interagency collaborative group identified the crosscutting research opportunities and priorities articulated in detail in this report. The areas identified primarily lie within the broad areas of Education, Health, Cooperation/Conflict, Societal Resilience/Response to Threats, Creativity/Innovation and Energy/Environment.

The SBE sciences are focused on human activity at every level—from an individual's brain, to behavior, to the actions of groups and organizations. The SBE sciences provide policymakers with evidence and information that help address many of today's most pressing challenges, including providing high quality education, providing all citizens with healthcare, fighting terrorism, preventing crime, and preparing for and responding to natural disasters. SBE scientists from a broad array of fields are performing interdisciplinary research that takes advantage of a new set of tools and holds the promise of providing insights and solution not otherwise available.

The SBE sciences are supported by several Federal agencies, and examples of scientific progress policy applications are numerous. In education, SBE research findings have been translated into policy in the form of literacy assistance programs run by retired adults. With respect to health, SBE scientists have discovered how relatively small behavioral changes can have immense benefit in terms of lifespan and quality of life. In the area of cooperation and conflict, SBE research has made strides toward understanding the cultural bases of conflict and identifying peaceful means of resolution. Concerning societal resilience and response to threat, a major achievement has been to better understand how humans behave in the face of disasters and to use this information to develop better preparedness systems. In the area of creativity and innovation, SBE scientists are studying how science policy is formulated based on scientific findings. With respect to human roles in energy and the environment, the SBE sciences are pursuing strategies to ensure the adoption of varied forms of energy, and are working toward more effective means of reducing the adverse impacts of human activity on the environment.

Progress in addressing these challenges depends not only on the application of new tools but also on continued investment in foundational SBE research—the research that provides a theoretical basis for these interdisciplinary or crosscutting themes.

The first such broad theme identified by the Subcommittee is that of understanding the structure and function of the brain and how consciousness, behavior and emotions arise and are regulated. Understanding how the brain governs speech, reasoning, learning and related activities through research and human performance modeling provides insight into individual behaviors.

Research on the complexity of human societies and activities is the second foundational theme. SBE scientists can now capture the webs of interpersonal and interorganizational ties within and across populations using new techniques, such as network modeling.

Lastly, research focused on how the genetic and environmental origins of human identity and diversity informs our understanding of the nature of humanity. Origins research also provides insights into the evolution of the human brain.

CURTIS MAREAN, ASU

New archaeological evidence suggests that the first modern humans evolved between 100,000 and 200,000 years ago along the southern coast of Africa. At the site pictured here, researchers have discovered the earliest dependence on shellfish, as well as the earliest use of pigment, both of which help us understand the origins of human society.

Interagency coordination will enable progress in Federal SBE research on the challenges described here and other challenges as they arise. This report identifies four key priority research focus areas for Federal agencies to leverage in addressing these important priorities and enhancing foundational research for SBE. These include developing specific tools and technologies for SBE studies, improving methods for collecting and managing data, building more integrated systems to allow for sharing across data sets, and focusing on scientific questions with immediate policy implications to ensure that policies generate evidence of their efficacy. Addressing these challenges will require sustained investment and ongoing dialog among Federal agencies, academic and private sector researchers, and policymakers.

FROM TOP: PEGGY GREB, USDA; KAREN WYNN, YALE UNIVERSITY; THOMAS PLUMMER, SUNY; MICHAEL GALKOVSKY; NATIONAL HUMAN GENOME RESEARCH INSTITUTE

I. Introduction

The social, behavioral and economic (SBE) sciences comprise a number of different disciplines focused on the common goal of developing a deeper understanding of human beings at every level, from brains, to individual behavior, to societies. For this reason, the SBE sciences are often simply referred to as the human sciences.

This quest is one of the most difficult and wide-ranging that science has undertaken. Among the participants are anthropologists, archaeologists, neuroscientists, psychologists, linguists, economists, sociologists and political scientists. These scientists study a wide range of questions, such as the origins of language, culture and abstract thought; the inner workings of mind and brain; the neural basis of language; the rise and fall of past civilizations; the mechanisms underlying diverse economic systems; and drivers of social movements and social change. Appendix A lists and defines these sciences and presents some of the relevant scientific questions posed by each.

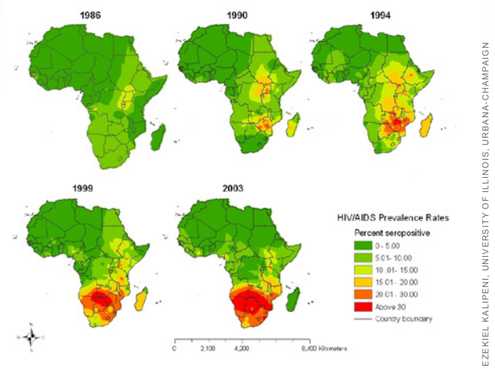
Many of the questions posed by the SBE sciences are best answered using tools and methods of several of these disciplines; indeed, many research projects cut across traditional academic boundaries. One example is the emerging area of neuroeconomics, in which researchers use the tools of neuroscience to investigate how people make economic and ecological decisions. Another example is the field of brain-based educational research, in which investigators combine functional MRI scans with more traditional tools to study how children learn (e.g., learning how to read) in order to design early interventions for children who encounter problems. Still another example is that of SBE scientists combining tools from biology and epidemiology with those of behavioral science and social network modeling to gain new insights into the social dynamics underlying the spread of HIV, permitting the development of specifically targeted intervention messages and strategies.

The quest for deeper understanding of humans is key to managing society's most critical challenges. It was with this understanding that the Subcommittee on Social, Behavioral and Economic Sciences identified those challenges that could most benefit from Federal investment and focused SBE research. In the broad areas of Education, Health, Cooperation/Conflict, Societal Resilience/Response to Threats, Creativity/Innovation, and Energy/Environment the subcommittee determined specific needs. Some of these challenges include:

- Developing more effective education programs
- Developing better health care programs
- Understanding violence, suicide, abuse, neglect, addiction and mental illness
- Mitigating fanaticism, extremism and terrorism
- Protecting confidentiality and privacy
- Fostering societal resilience in the face of both natural and human-made disasters
- Fostering a culture of creativity and innovation and maintaining America's competitiveness in an era of rapid globalization
- Addressing the long-term sustainability of civilization within Earth's ecosystems

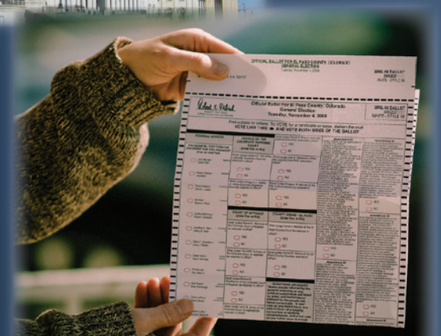
These challenges all share a human element, which makes them resistant to untested interventions or technological solutions, and makes evidence-based policymaking difficult. After a half-century of progress, however, the SBE sciences can offer more rigorous, evidence-based strategies to address this human element. This progress has been spurred by the introduction of new tools such as grid computing, functional MRI scans of the brain, geographic information systems and DNA analysis. These new technologies, some of which are described in Appendices B–D, have transformed the work of the human sciences and can provide new insights into these issues.

This report makes recommendations on the role Federal science agencies can play in these areas. It provides a context for SBE research currently supported by Federal agencies and identifies future opportunities for Federal focus. The report also reiterates the foundational themes upon which the SBE sciences are based and how continued research within these fundamental areas will continue to support agency goals. Finally, the report describes new tools that increase the reach of SBE sciences. By leveraging these tools, Federal agencies may increase their effectiveness in making progress toward their individual missions and national priorities.



Using sophistcated new geographic methods, researchers have mapped the spread and prevelance of HIV/AIDS in Africa over time.

II. Federal Context



FROM TOP: PHIL ROMANS; CHRIS COLEMAN; JEFFREY RODAMER, DEPARTMENT OF EDUCATION; SCOTT BAUER, USDA; WALTER MATTHEWS, U.S. NAVY

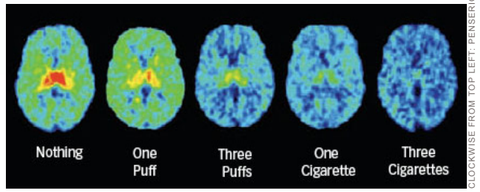
The human sciences are concerned with human actions, whether individually or in groups, whether productive or destructive, whether conscious or unconscious in motivation and—in all cases—over various time scales. The Federal government, because of its historical interest in securing the welfare of its citizens and institutions, takes an active interest in understanding the causes and effects of human activity. Without the data, research, and analyses that SBE scientists can provide, there is a greater likelihood of engaging in ineffective or counterproductive policies. Well-intentioned, "common sense" solutions too often lead to undesired outcomes.

It may be noted that not all the SBE sciences require or are even appropriate for government support. For example, consumer behavior and the successes and failures of commercial marketing campaigns are major targets of SBE research but are well funded through industry support. What, then, is the role of the Federal Government in support of the human sciences? What does and should it support, and what are the potential benefits of this support to citizens and institutions?

There are human dimensions to every policy matter, and today's societal challenges demand that Federal agencies utilize the human sciences for insights to achieve their missions efficiently and effectively. National defense, for example, may be secured through technologies such as early warning systems, advanced weaponry and increasingly powerful software. This technology can be made more effective, however, when combined with an understanding of factors controlling radicalization and human conflict.

Similarly, pharmaceuticals and medical technologies can help reduce the pain and suffering associated with disease; however, some disease risk factors are largely behavioral—smoking is just one example. Human attitudes and decisions about natural resources and land management have significant impact on climate change and are central to Federal management of the environment. These are just some examples of areas in which the Federal government may utilize the SBE sciences to better fulfill their missions.

Currently, Federal agencies fund basic research within the SBE sciences that spans the broad range of disciplines and questions listed in Appendix A. This research includes studies of human learning and development, health, education and response to natural disasters, among others. In addition, Federal agencies are increasingly working in partnership with one another to identify research opportunities for collaboration.



CLOCKWISE FROM TOP LEFT: PENSERIO; JERRY CHARLOTTE; NIH NATIONAL INSTITUTE ON DRUG ABUSE

A functional magnetic resonance imaging (fMRI) study shows how nicotine receptors in the brain respond when a subject is smoking a cigarette. An understanding of smokers' need to maintain receptor saturation can be used to better understand some of the behaviors that characterize nicotine addiction and can be used to develop treatments for smokers who wish to quit.

Research in the human sciences relies heavily on the generation of high-quality longitudinal data gathered in surveys. Federal agencies play an integral role in assuring the proper accumulation, utilization, interpretation and stewardship of these data. Data obtained through these surveys can reveal previously undetected patterns in demographics, attitudes, and long- and short-term trends in economic, political, health and social behavior. Surveys have been called the telescopes of social science; they are the instruments that provide the clearest view of what people think and do and how well policies and programs work. A few of the most important surveys that have been collecting data on a massive scale over the course of decades are described below.

The **Panel Study of Income Dynamics (PSID)** focuses on the economic well-being of American families. The PSID is a systematic effort to follow a nationally representative set of U.S. families over several generations. The survey started with 4,800 families in 1968 and by 2001 had expanded to 7,000 families as children grew up and started families. This longitudinal database provides a variety of information on American families over time; it tracks incomes, financial success of families and what makes particular families successful, how wealth and earning capacity are transmitted over generations, why people move and how they acquire job skills. The results often confound conventional wisdom and have implications for issues such as bankruptcy policy or understanding credit card debt.

Early Application of Federal SBE Research

Prior to World War II, Federal agencies were only minimally involved, if at all, with basic research in the SBE sciences. In the years during and immediately following the war, the Federal government began to take a more active role in understanding the causes and effects of human activity. One of the earliest applications of Federal social science research was in human factors studies—i.e., the science of making technology fit the users instead of vice versa. Human factors research emerged as a distinct discipline in World War II, when modern machines and weaponry began to impose demands on their operators' capacity for attention, decision making and hand-eye coordination. One of the landmark studies in human factors research was carried out in 1943 by psychologist Alphonse Chapanis, a lieutenant in the U.S. Army. At that point in the war, pilot error in military aircraft had become an urgent issue; fully functional aircraft, despite being flown by well-trained pilots, were crashing, and ground accidents occurred at an appalling rate. Chapanis showed that these problems could be greatly reduced by considering the human factor. Instead of confronting pilots with a confusing array of dials and levers, designers simply had to create a cockpit where the controls were easy to distinguish and logically arranged. In the decades since the war, human factors studies have continued to improve aircraft cockpits and have contributed to the design of NASA space suits, the touch-tone telephone keypad, power plant control rooms, air traffic management tools, and a host of other technologies, including software user interfaces.

CLOCKWISE FROM TOP: US AIR FORCE, KATHRYN HEDGES, NASA

Human factors research originally conducted to improve the design of WWII fighter plane cockpit controls has had far reaching implications, informing the design of many other devices from NASA space suits to telephone keypads.

The **American National Election Studies (ANES)**, collected every two years since 1948, is a series of surveys on presidential and congressional elections, focusing on the linkages among the public, political parties and their candidates. Analyses of ANES data have examined such topics as the supposed divisions among the American public on economic and social issues and the role of campaign financing, name recognition, competition and strategy in national elections.

In the realm of education, the **High School Longitudinal Studies** have been conducted by the National Center for Educational Statistics every decade since the 1970s, allowing researchers to track factors affecting teaching, learning, school completion rates and students' transition to higher education and/or the workplace. More recently, the Early Childhood Longitudinal Studies have provided invaluable data on the factors that lead to early trajectories of academic success and failure.

The National Assessment of Educational Progress has likewise served as "the nation's report card" since 1969. The information it provides on student achievement has had an increasingly important role in informing policy and improving practice in America's schools.

The **Health and Retirement Study (HRS)** interviews 22,000 Americans, aged 50 and over, every two years about their health, housing, assets, pensions, employment and cognitive and physical functioning. Specific data are collected such as Social Security earnings and Medicare data as well as blood and DNA samples. The HRS has spawned over 25 coordinated studies spread across the world, and has yielded a wealth of scientific information about normal aging, retirement, physical, mental and economic health and well-being.

The **General Social Survey (GSS)** has been exploring people's views about a wide variety of topics since 1972, such as computer and Internet usage, civil liberties, crime and violence, morality, psychological well-being and priorities for national spending. The survey has been conducted biennially since 1994, and 3,000 people participate in each survey. The GSS also collects cross-national data as part of the International Social Survey Program (ISSP), which now includes 39 nations and is the largest program of cross-national research in the social sciences. Some of the topics covered by recent annual ISSP modules include work orientation, religion, social inequality, the environment, social support and networks, women, work and family, national identity and citizenship.

CLOCKWISE FROM LEFT: PAMELA ENTZEL, CAROLINA POPULATION CENTER, UNIVERSITY OF NORTH CAROLINA; PACIFIC NORTHWEST LABORATORY

Historically surveys have typically involved personal interviews with respondents to obtain both qualitative and quantitative data, but an increasing number of surveys now incorporate biological markers of health and disease. These biomarkers, when combined with interview data, allow for integrative research on the relationships between social processes and health.

Survey data can also provide useful metrics for judging the effectiveness of policies or existing programs, which can then be adjusted in light of rigorously developed scientific findings. Some well-intentioned, "common sense" programs may lead to undesired outcomes once implemented. Listed below are examples of policies and programs that were modified or overturned after scientific analyses.

BLEND IMAGES

New social psychology studies of implicit attitudes on women in the workplace provide scientific evidence that, contrary to "common-sense" policy, assertiveness training programs do not meaningfully address the problem of wage discrepancy along gender lines.

In the **D.A.R.E. (Drug Abuse Resistance Education)** program, participating schools invite police officers to talk to students about the risks of substance abuse. Despite its widespread use and popularity with parents, schools and police, researchers found that early versions of the program did not decrease drug abuse. Indeed, there was some evidence that it may have led to increased student experimentation with drugs. This research has been used to redesign the program to increase its effectiveness.

The **Scared Straight** program, also tremendously popular, was designed to deter children and young adults from criminal activity by exposing them to the realities of prison life. But rigorous studies showed that the program increased rather than reduced the likelihood that the child would subsequently get into trouble with the law.

Grade-level retention programs, where students are kept in a grade if they do not reach certain performance measures, are popular in many states. However, retention practices have not been found to improve student performance. Timely interventions targeted to each child's particular needs are more effective than grade-level retention programs. Moreover, if a child is held back in grade more than twice during K–12, it greatly increases their likelihood of drop out by high school.

Federal agencies also have an important role to play in the economic component of the SBE sciences because they have the potential to generate revenue or result in other significant benefits to the public. One example of this is the use of spectrum auctions by the Federal Communication Commission (FCC), which is described below. Spectrum auctions have resulted in revenues of more than $40 billion to the U.S. Treasury and worldwide revenues in excess of $200 billion.

In all of these areas, through the use of surveys and other tools, the Federal Government has made, and can continue to make, important contributions to improve the lives of citizens through the use of the SBE sciences. Following is a set of policy challenges that should inform areas of future focus for government agencies.

The Simultaneous Ascending Auction

Prior to 1994, the FCC awarded bands of the electromagnetic spectrum (for broadcast, wireless services and other uses) to businesses through either comparative hearings or lotteries. Both methods were time consuming and resource intensive. A congressional act in 1993 authorized the FCC to award bandwidth through auctions and competitive bidding.

FROM LEFT: DOT; HHS; DOT

Cell phones and personal digital assistants are examples of widely used technologies that rely on the electromagnetic spectrum. SBE scientists have developed auction mechanisms for ensuring that the spectrum can be used fairly and efficiently.

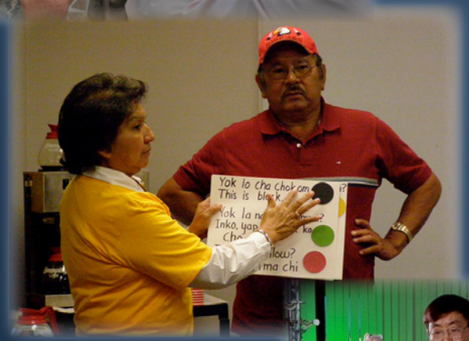
The FCC and Congress needed the best auction design: it had to be efficient, flexible, capable of handling large numbers of bidders, and transparent (where all bidders know what others are bidding) while also maximizing the likelihood that the license would go to the firm who would use the spectrum most efficiently. The FCC assigned this challenge to a working group of social scientists. Their solution was the simultaneous ascending auction, which works by making multiple interrelated licenses available at the same time. During any bidding round, the bidders have flexibility in that they can shift to a different license package that represents a better value, which may change from round to round. The availability of multiple licenses typically results in a more efficient use of bandwidth.

III. Policy Revelance

This chapter discusses several of society's fundamental challenges, how SBE scientists are addressing them, and their implications for policy.

These challenges fall into six broad areas:

- Education
- Health
- Cooperation and Conflict
- Societal Resilience and Response to Threats
- Creativity and Innovation
- Energy, Environment and Human Dynamics



FROM TOP: SCOTT BAUER, USDA; NATIONAL SCIENCE FOUNDATION; TODD FRANTOM, U.S. NAVY; LINDA LANGLEY; NATIONAL SCIENCE FOUNDATION

Education

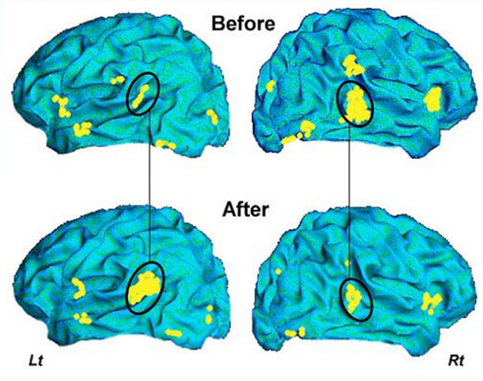
Challenges:

- How can society be best equipped for learning?
- How does the brain learn throughout development?
- How do the brains of people with learning disabilities function?

Implications for policy:

- Improved education programs and curricula
- More accurate testing paradigms
- Better training for teachers

A sound educational system is fundamental to a nation's success in an increasingly globalized world. It is the fundamental infrastructure of a successful society and a key to improving health, fostering innovation and protecting democracy. However, there are grave concerns with the current state of the U.S. educational system. The scores of American students on achievement tests are often lower than those of their peers in other nations, many American students never complete high school, and U.S. colleges and universities now graduate a smaller proportion of students than universities in several other advanced nations.



P.G. SIMOS, UNIVERSITY OF TEXAS-HOUSTON HEALTH SCIENCE CENTER

Research is showing that some functional learning differences that originate in the brain can be reversed or mitigated with early intervention. The image above shows activation maps from a dyslexic child before and after intensive remedial instruction. After two months of instruction, researchers noted significant improvement in reading skills and increased activity in the region of the brain associated with these tasks. (Lt = Left Hemisphere, Rt = Right Hemisphere)

SBE research is helping to address these problems. For example, studies of dyslexic children have led to careful measurements of how the brain functions, which in turn allows researchers to design more effective instructional strategies for all students. Other scientists have demonstrated the importance of early life developments for effective learning and the power of investment in early education for improving later educational outcomes. Researchers working at the intersection of cognitive science and information science have helped design better educational technology and other learning tools, which can make good teachers better and increase student learning. These tools are increasingly incorporating real-time assessments of how well students are learning, where their problems might lie, and where teachers, schools and parents can

most effectively target their resources. In short, better instructional design and information technology are making it increasingly possible for students of all ages and abilities to learn what they need, when they need it.

Meanwhile, there is potentially good news regarding the connection between the learning sciences and how schools operate in the real world. Too often, potentially useful ideas are never tried—or if tried, never rigorously evaluated and improved. Now, however, evidence-based education studies are beginning to improve teaching and learning with the same kind of research tools that have transformed medicine. The goal is to replace instruction based on tradition, educational fads, or anecdotal information with rigorous research to identify and improve what works. Those research findings, in turn, are moving us to smart schools and learning systems tailored to each child. Two landmarks in this move from anecdotes to evidence are the No Child Left Behind Act and the Educational Sciences Reform Act, both of which require that Federal resources focus on support of effective instruction based on scientific research.

This learning revolution will not be quick or easy, but rigorous social and behavioral research is helping us better understand the learning process.

Involving Older Americans in Education Leads to Smarter Students and Healthier Seniors

A set of innovative educational programs that place retired people in classrooms to assist in literacy and other educational efforts are proving to have benefit not only for the students but for the seniors as well. The first wave of baby boomers turns 65 in 2010, meaning a rapid increase in the total percentage of the U.S. population in retirement. Aside from some of the more obvious economic implications of this population shift, there are potentially grave consequences for our nation's productivity with a drastic cut in the workforce. SBE research has shown that a majority of older adults wish to remain productive and continue contributing to society in their retirement years. These findings spurred the development of these innovative programs, where volunteers aged 55 and over are placed into classrooms at the K–12 levels.

EXPERIENCE CORPS

Programs in which retirement-aged individuals are placed in classrooms to assist with K – 12 education are gaining popularity as they have proven effective. The Experience Corps program is one such effort that has found that benefits extend not only to the students but to the senior volunteers.

These programs, including the Experience Corps program in Baltimore, are cost-effective and have clearly benefited both the students and the older Americans. Baltimore students in Experience Corps classes showed significantly higher scores on standardized tests and a 50% reduction in classroom misbehavior. The volunteers spent more hours in mentally stimulating activities and increased their social networks, both of which are known to help maintain mental and physical health in late adulthood.

Health

Challenges:

- How can a healthier society be fostered?
- What are the underlying causes of violence, suicide, abuse, neglect, addiction and mental illness?
- How does individual behavior contribute to risk and prevalence of disease?

Implications for policy:

- More efficient and responsive health care systems
- Better strategies for modifying behaviors and optimizing patient self-care
- Integrated approaches to improving health in at-risk populations

Modern medical research continues to make remarkable advances. Unfortunately, the goal of improving health and preventing disease broadly in the human population is still elusive. Achieving that goal requires consideration of a host of social, behavioral and economic issues.

Up to 80% of all the premature deaths in modern industrial societies as well as a substantial fraction of chronic diseases such as obesity and diabetes are related to "voluntary" behavioral factors such as tobacco and alcohol use, poor diet, lack of physical activity and risky sexual behaviors. Moreover, this is compounded by human factors in the health care system itself, such as medical error, lack of health literacy, or poor access to care.

TOP: NATIONAL INSTITUTES OF HEALTH; BOTTOM: BILL BRANSON, NIH

SBE research provides both reliable statistics about health in the U.S. and abroad, and informs successful strategies for healthy lifestyle change.

Psychological Stress Increases Susceptibility to Respiratory Illness

NATIONAL INSTITUTES OF HEALTH

Studies show that stress can increase the risk of potentially fatal diseases like influenza and pneumnoia.

Respiratory infections such as influenza and pneumonia are the seventh leading cause of death in the U.S., and are responsible for more than 50 million missed days of work each year and more than $1 billion in lost productivity. SBE researchers are attempting to determine what fraction of these illnesses is attributable to psychological stress, which is known to adversely affect the immune system. Although it is largely unclear why only certain people get sick, we do know that psychological stress is a trigger for behavioral and physiological changes placing people at greater risk. Stress suppresses the body's ability to respond to infectious agents and causes more severe symptoms.

Interpersonal stressors (such as social conflicts at work, home or with friends) are potent risk factors for disease. Being out of work or having a job that is not commensurate with one's abilities and training also appear to increase one's susceptibility to illness. SBE investigators have discovered that having supportive social relationships reduces the risk of infection by reducing levels of stress; similarly, having a challenging and fulfilling job appears to mitigate stress levels in most people. This work suggests that many health problems may be profitably addressed through social and behavioral avenues, in addition to pharmaceutical interventions.

SBE research on behavioral approaches to lifestyle change has been instrumental in improving human health. For example, programs for decreasing tobacco use and preventing HIV-AIDS transmission have contributed to impressive declines in heart disease, lung cancer and the incidence of HIV infections in the U.S. in recent decades. The impact can be surprisingly large: moderate lifestyle interventions can reduce the contingent risk of diabetes by 58%—a higher success rate than obtained with frequently prescribed drugs.

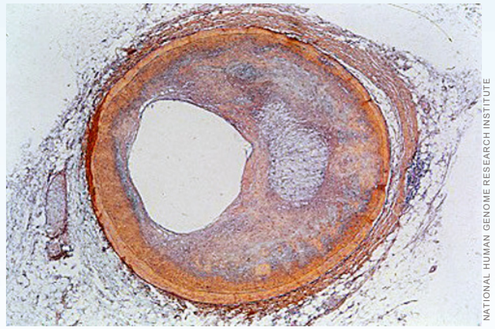
The SBE sciences are providing new evidence that health and health behaviors are strongly influenced by the contexts within which people live, work and attend school. These contexts include networks of families and friends that are in tur influenced by neighborhood, community and national and global socioeconomic systems and policies. This research is informing the development of integrated strategies for improving health that target individual behavior change within these contexts. In the case of obesity, for example, the larger context would include changes in the environment, such as the offerings of local grocery stores. An approach to obesity could also target culturally based dietary traditions as well as individuals' eating and exercise behaviors. In the case of stress, which impacts individuals' susceptibility to infectious diseases, this means training people in better ways to identify and minimize potential stressors.

Inequalities in health are a major concern. In the U.S., life expectancy is substantially lower for African Americans and the poor, and these groups experience higher rates of cancer, birth defects, infant mortality, asthma, diabetes and cardiovascular disease. SBE scientists have been at the forefront of research on the environmental, behavioral, psychological and physiological factors that are responsible for this inequality, and are developing large-scale, multilevel models to study it and identify innovative intervention strategies.

Finally, health care is facing major changes within the next decade or two. An evolving knowledge of genomics (see Appendix C) is likely to lead to pharmaceuticals that target the broken cellular machinery precisely in individual patients. Rising health care costs and declining access to insurance coverage are prompting calls for universal health coverage and reimbursement policies based on the effectiveness of treatments. These changes will have broad systemic effects and could have unanticipated consequences for health and health disparities. SBE research is elucidating these effects and informing the evolution of new policies and practices.

In cases such as smoking cessation, HIV transmission, or the management of diabetes, where the effectiveness of behavioral and social interventions has already been demonstrated, researchers are investigating better ways to disseminate and integrate such sucessful mechanisms into standard medical practice, community programs and health policy.

STEPHEN AUSMUS



NATIONAL HUMAN GENOME RESEARCH INSTITUTE

Top: A dietary psychologist technician works with a patient on nutrient recall. These data are used in field studies that evaluate the impact of dietary intake as it relates to nutrition and health. Bottom: a coronary artery with plaque built up, a condition that restricts blood flow to the heart and muscles.

Cooperation and Conflict

Challenges:

- How can cooperation be fostered?
- How can violence, conflict and terrorism be mitigated?
- What underlies the actions of extremist and terrorist groups?

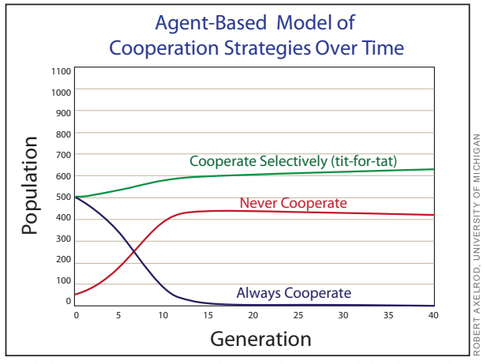
Implication for policy:

- Better methods for identifying and mitigating terrorist groups and terrorist activities
- Reduction in instances of person-on-person crime and abuse
- Better management of the effects of globalization

Human history provides countless examples of both violent conflict as well as remarkable cooperation and altruism. It is not fully understood why humans sometimes engage in battle to achieve their goals, while at other times opt to work cooperatively. SBE scientists have used game theory and computer simulations to explore this question. While cheaters can prosper in the short run by preying on their more trusting brethren, social experiments, computer simulations and game-theoretic analyses all suggest that over the long run, cooperative strategies allow participants to do far better as a group than the cheaters do alone. This observation is not purely a matter of academic interest. Human capacity for trust and social cohesion is the basis of family, community, political stability, the ability to function in large organizations and, arguably, supports the ability to sustain a complex, modern economy.

The impetus for cooperation is not universal. Violence persists in the form of bullying, assault, murder, war and terrorism. Experience suggests that the human capacity for violence and aggression is not a problem that has a solution. It appears to be an integral part of the human personality, inextricably tied to other personality qualities such as drive, ambition, the urge to explore, and the hunger for recognition. This suggests that violence is a reality that has to be managed.

SBE scientists have put significant effort into studying how violent behavior can best be managed. In the process, they have accumulated large bodies of research on forms of violence such as spousal abuse, organized crime, gang warfare and ethnic cleansing. SBE scientists have likewise done extensive work on the nature of disputes such as divorce and classroom disruption and



ROBERT AXELROD, UNIVERSITY OF MICHIGAN

Work by social scientists with agent-based models shows that cooperation over time will usually benefit participants more than either cheating or behaving altruistically.

their resolutions. They have also examined national and international conflicts, such as environmental standoffs. This work has had some tangible benefits, such as:

- Effective school-based interventions that reduce violent behaviors by elementary, middle school and high school youth largely by changing social norms about the use of violence and by teaching conflict-resolution skills
- Empirical confirmation that environmental disputes can be resolved more quickly and more satisfactorily through informal social contacts or other cooperative solutions between citizens, regulators, scientists and industries, rather than by traditional regulatory processes alone
- Newly developed "cognitive agent" simulations that allow soldiers to practice effective communication in diverse cultural contexts with individuals and groups whose behaviors are unfamiliar

SCOTT ATRAN

The Spirit of Mahatma Gandhi, for whom "values become your destiny," on the wall at the Kalandiya checkpoint separating the West Bank from Israel. Research on both sides of the wall reveals similar patterns of moral reasoning on trade-offs for peace.

Nonetheless, many questions remain. For example, in trying to broker peace in any of the world's many civil wars, are there ways to end fighting without sowing the seeds for subsequent conflict? Can terrorists be detected and deterred before they strike? How can the roots of terrorism be addressed? What are the best means of communication with those from very different cultures?

FROM LEFT: SANDIA NATIONAL LABORATORIES; TODD FRANTOM, U.S. NAVY

Left: New "cognitive agent" simulations designed by social scientists help train U.S. personnel in adaptive thinking, negotiation, conflict resolution and leadership within cross-cultural settings. Right: A U.S. Army Sergeant puts such training into practice as he checks an Iraqi child's swollen thumb in Hadar, a community in Southern Baghdad, Iraq.

Evidence of White-Collar Crimes Can Aid in Terrorist Detection

The social sciences have given us a better understanding how "white-collar" criminals operate. White-collar crimes are usually nonviolent in nature and include, but are not limited to activities such as: credit card fraud, insurance fraud, identity theft, money laundering, immigration fraud and tax evasion. Psychology has provided a better understanding of the nature of deception and how the criminal mind operates, and sociology has provided an improved understanding of the organizational structure of criminal networks. These scientists have discovered that certain features of white-collar crimes—especially the need for anonymity during the planning stages—are characteristic of terrorist groups.

THE WIDE WIDE WORLD

SBE research has shown that white collar crimes, such as credit card fraud and identity theft, can give us important insights into larger-scale and more violent crimes, including terrorist actions.

Since the terrorist attack of September 11, 2001, law enforcement officials are increasingly focused on white-collar crimes as a means of detecting terrorism plotters. In a recent study of 100 Federal criminal terrorism cases, all included charges of document fraud or financial deception.

Terrorist organizations are typically not hierarchical, where field cells are supported by a central cell, but instead tend to be composed of semi-independent cells that develop their own plans with little financial or strategic support from other cells. Therefore, individual terrorist cells need to raise their own funds for travel, training, shelter, weapons and food. More often than not, this is done through white-collar crimes. In fact, investigators have recently turned up training materials for both al Qaeda and Jamaat Ul Fuqra, a terrorist group that operates in both Pakistan and the United States, that include tutorials on forging, counterfeiting and other deceptive practices.

Societal Resilience and Response to Threats

Challenges:

- How can society become resilient in the face of both natural and human-made disasters?
- What are the human behavioral contributions to environmental change?
- How can confidentiality and privacy be protected?

Implications for policy:

- Development of policies for disaster responses that are efficient and effective
- Discovery of ways in which to mitigate harmful by-products of human society's activities within the ecosystem
- Implementation of methods for sharing data without compromising security

Our society not only faces natural disasters such as hurricanes, tsunamis, earthquakes and health threats such as pandemic diseases, but now there are additional threats, such as weapons of mass destruction, global economic crises and global climate change. In an increasingly crowded and interconnected world, questions about disaster are not a matter of "if" but "when."

Enhancing resiliency is often a social, behavioral and economic challenge. SBE scientists have given high priority to this challenge—perhaps most dramatically in the form of rapid-response research teams that traveled to the Gulf Coast area in the aftermath of hurricanes Katrina and Ike, where they studied topics ranging from interagency coordination to the reasons why some communities were able to recover so much more rapidly than others. Similar teams went to the field in the aftermath of the 9/11 terrorist attacks in 2001 and the Indian Ocean tsunami in 2004 to collect time-sensitive data.

SBE researchers are exploring how people and organizations behave during a disaster and how they make decisions in the face of uncertainty, time pressure and chaos. Do they panic or respond rationally?

NATIONAL OCEANIC AND ATMOSPHERIC ADMINISTRATION

In "Tornado Alley," a region that passes through South Dakota, Nebraska, Kansas, Oklahoma, and Texas and has on average 1,200 tornadoes a year, social psychologists are conducting survey research to better understand how people prepare for and respond to natural disasters. This type of research is vital for implementing effective policy for official warnings, general preparedness and emergency response.

Preparedness and Warnings—The Importance of Understanding Human and Social Behavior

JOE FRIEND

DAVE MYERS

Human sciences yield important insights on how societies respond to emergencies, be they human-induced, such as the World Trade Center attacks (top) or natural disasters such as the 2004 tsunami in South and Southeast Asia. Below, a survivor of the tsunami holds pictures of his missing wife and two children.

Recent disasters—both human-made (attacks on the World Trade Center and Pentagon) and natural (hurricanes Katrina and Ike and the earthquake and tsunami that devastated many coastal communities in South and Southeast Asia)—have made it clear that there is a need for improved emergency preparedness and warning systems. Disaster researchers draw upon many sources of information to better understand, detect, communicate and respond to all manner of hazards. To be effective, the pieces must come together in a coordinated fashion. For example, tsunami detection and warning systems must be linked to accurate modeling procedures that account for physical data, population data and the shoreline geography.

Researchers are developing a tsunami preparedness model to be used by state emergency managers in the U.S. to disseminate warnings. In addition to improving the accuracy of warning systems by drawing on information from the natural world, this model also takes into account the fact that a number of social and psychological variables play into whether or not people actually react to emergency warnings. Some preliminary findings show that people's first response to an emergency is not necessarily to evacuate but to ask questions: What is happening? Do we really need to evacuate? What are my neighbors going to do? An understanding of how communities interpret and use warning information is critical to help communities be better prepared for both natural and human-made disasters.

If it is the latter—as the evidence suggests—is there a tipping point beyond which people will panic? Other important considerations include whether or not responses include mob rule, violence, or community spirit and altruism—and what factors determine this.

Researchers are investigating how to improve land use decisions to reduce vulnerability and risk to natural and environmental hazards. Others are looking at effective strategies for disaster mitigation. What factors determine why some communities recover more easily than others and how can we measure those factors? Studies like these inform the determination of which actions a community can take prior to a disaster to minimize and contain the damage, or how the choice of recovery steps enhances resiliency for the next incident.

SBE scientists are also exploring the behavior of critical infrastructures during disasters, i.e., both engineered infrastructures that provide us with communication, water, power, transport and the social/political/economic infrastructures that provide fire and police protection, medical care, finance and food delivery. These researchers are attempting to identify the failure modes in such systems and how failures propagate from one system to the next, given that they are often tightly coupled.

JOSHUA LEE KELSEY, U.S. NAVY

Behavioral studies about people's response to crisis situations, such as Hurricane Katrina, can help government agencies and other organizations improve their aid and relief efforts.

The role of communications during a disaster, at both the technological and social level, is a key component of this research. What kinds of information do members of the public want and need during a crisis? Studies in the area of disaster communication can inform how officials frame warnings and other public messages when events are still uncertain, and determine the best features and delivery mode (traditional media, or blogs and podcasting) for ensuring the most effective communication.

Creativity and Innovation

Challenges:

- How is creativity and innovation stimulated?
- How can America's competitiveness be maintained in an era of rapid globalization?
- How are discoveries translated into inventions and useful knowledge?

Implications for policy:

- Improved ability to develop policies that stimulate U.S. competitiveness
- Enhanced growth and stability in the U.S. economy
- Improved methods for maintaining a skilled workforce

THE SCHOOL OF ATHENS, RAPHAEL

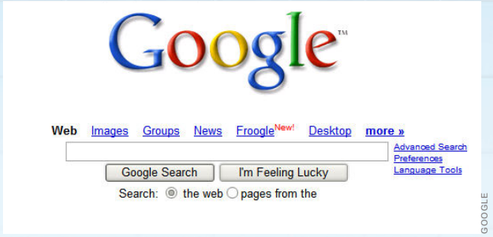
The Italian Renaissance was a period of remarkable scientific and artistic innovation, as characterized in this iconic fresco by Raphael Sanzio, *The School of Athens*. Social scientists today are working toward understanding how and why innovation occurs, and how it might better be fostered and encouraged in modern societies.

As critical as innovation is for progress, the actual process of innovation is still a mystery. Some individuals are highly creative while others are not, even when they are equally gifted. What permits groups and nations to achieve intellectual and creative heights—as in, for example, the Italian Renaissance—and how can these periods be sustained?

SBE scientists are working toward understanding what innovation is, how innovation helps the U.S. remain competitive and continue to thrive in an ever-changing global marketplace, and how innovation may be nurtured. Methods for measuring and tracking innovation are in development. Innovation does not begin and end in the laboratory, which makes its study more complex.

The purely technical work of research scientists and engineers is embedded in a rich, complex ecosystem of innovation that encompasses:

- Long- and short-term research and development (R&D) investments made by government agencies, corporations, venture capitalists and others
- Webs of communication and collaboration linking individual investigators, research groups and research fields—allowing moments of unexpected connection and insights that make real innovation possible
- The many advances needed to bring a product to market after it emerges from the laboratory, including innovations in manufacturing, marketing, and business and organizational practices
- Long-term investments in cultivating talent, including the myriad institutions for educating, training and developing skills of researchers
- The physical infrastructure for information storage and sharing, transportation, energy, health care delivery, public safety and emergency response
- The legal and regulatory infrastructure for public policy, intellectual property rights and standard-setting
- The financial infrastructure for banking, investments and venture capital
- A culture that includes a willingness to collaborate for mutual advantage



GOOGLE

The development of the Google search engine is an example of innovation that has had tremendous impact on daily life.

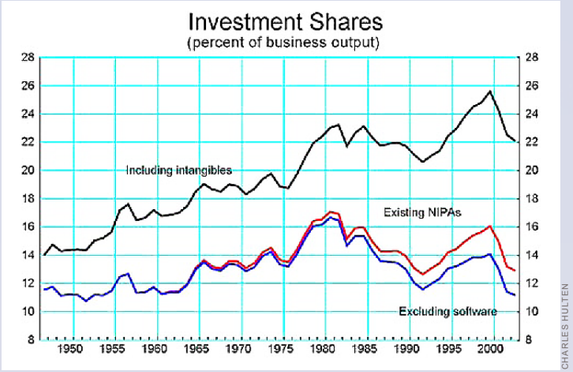
Efforts to unravel the ecosystem are essential for understanding how innovation systems work. These efforts lead to better monitoring of educational outcomes, financial returns to R&D and the innovation life cycle, as well as better ways of monitoring and evaluating the outcomes of our nation's public and private R&D efforts. One component of this effort is the development of an interagency "science of science policy" task group that has issued a roadmap on this emerging science, with a focus on innovation.

Innovative organizations encourage independent-minded individuals to "think outside the box" while simultaneously encouraging work toward a common goal. SBE scientists studying organizational processes are trying to understand how to achieve this balance, as well as how to create organizations that can effectively take advantage of new ideas and technologies, allowing them to detect and respond quickly to changing conditions and seize new opportunities as they arise.

Working Toward a Better Measure of Economic Growth and the Role of R&D Investments

It is well known that R&D investments have a positive impact on our nation's economy. However, recent work supported by the Bureau of Economic Analysis and the National Science Foundation's Division of Science Resources Statistics suggests that current methods of assessing the impact of R&D investments may actually underestimate the importance of the role of R&D expenditures in economic growth.

Current measures of gross domestic product (GDP) consider R&D expenditures as an intermediate expense (similar to salaries). However, if R&D is reclassified as a business investment—a category that includes buildings, structures, equipment and tools—it is calculated as 11 % higher (a total of $178 billion) in the measure of GDP for 2002. This work shows that R&D investments have contributed more than twice as much to the growth in GDP as other capital investments between 1959 and 2002. Moreover, the relative contribution is on the rise—using this new measure, R&D accounted for 4.5 % of growth in GDP between 1959 and 2002, and for the period between 1995 and 2002, it increased to 6.7 %.



Economic theory strongly favors treating R&D as investment. However, historical calculations of GDP have treated R&D as an expense. Here, U.S. investment shares are represented comparatively with R&D calculated as expense (Existing NIPAs line) and as investment (Including intangibles line). The marked increase in these calculations underlines the importance of investing in ideas and innovation.

Energy, Environment and Human Dynamics

Challenges:

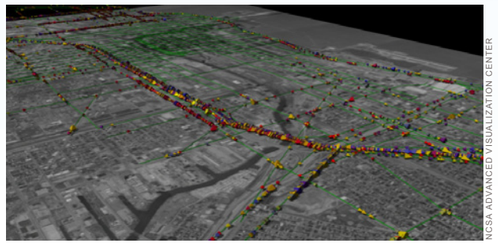
- How will changing patterns of human activity alter energy consumption and interaction with the natural environment?
- What influences how people perceive, value and use energy and the natural environment?
- How do incentives and restrictions alter the behavior of individual humans as well as groups and organizations with respect to energy and the environment?

Implications for policy:

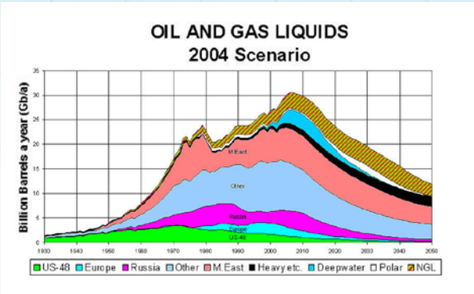
- Enhanced predictive capabilities regarding future energy consumption and environmental impacts
- Better tools for analyzing the efficacy of different policy alternatives
- Improved understanding of human–environmental dynamics by policymakers and citizens

Humans have always interacted with the natural environment in ways that shaped both their own development and the surrounding natural systems. The impact of people on the climate, oceans and ecosystems of the world has become more pronounced, partly due to increases in the human population. The industrial revolution, growing reliance on fossil fuels, economic development of the most populous countries and improved health care have led to dramatic increases in population in recent decades, thus affecting energy consumption, land use and emission of greenhouse gases and other compounds.

SBE research on the fundamental dynamics of human activity can address demographic and economic shifts that are dramatically altering patterns of population growth, consumption and use of land, energy and other resources. SBE research can yield a deeper understanding of the processes through which land-use changes affect transportation patterns and energy use and how land-use and transportation patterns are affected by changing energy prices. Studies may include the effects of global energy markets on international trade and American competitiveness, and comparisons of the efficacy of feasible strategies to increase the use of renewable energy sources.



Social scientists at the Argonne National Laboratory's Transportation Research and Analysis Computing Center are developing advanced agent-based models of downtown Chicago to create high-performance simulations that break down traffic patterns and test emergency evacuation scenarios.



ASSOCIATION FOR THE STUDY OF PEAK OIL AND GAS

The human sciences deal with important research questions that are highly relevant to policy, such as how individuals and groups will respond and adapt to declining supplies of fossil fuel energy in the coming decades.

SBE research is needed to assess the cognitive aspects of human activity regarding their environment, including perceptions, awareness, values, attitudes and beliefs of individuals, groups and organizations. Because human beings affect the environment in many ways, there are important research questions that will inform policy: understanding the ways people perceive gradual climate change in contrast with sudden, cataclysmic changes; how economics affects individual attitudes and behavior regarding energy use; and how large corporations differ from local environmental organizations. It will also be important to assess the best approaches for teaching children about energy and the environment in classroom, households and other settings.

Research also provides basic knowledge that has direct societal significance regarding human social structure and organization, the contexts and arrangements through which people operate individually in informal and formal groups. SBE science examines the effects of different regulatory mechanisms on energy production and the impacts of mechanisms such as "cap and trade" designed to reduce greenhouse gas emissions on markets as well as the behavior of businesses and households. It provides valuable insights into the impact of voluntary versus mandatory standards on organizational behavior, and it examines the efficacy of life cycle versus balanced scorecard-type accounting schemes for monitoring environmental impacts.

Research in these areas can help the U.S. and other nations develop and implement strategies that will enable modern society to live sustainably on the Earth by aiding society's adoption of varied forms of energy and developing means for reducing the adverse impacts of human activity on the environment. The ultimate achievement of these goals will improve our economic well-being and overall quality of life.

Research on Shared Resources Demonstrates Enforcement Is Critical

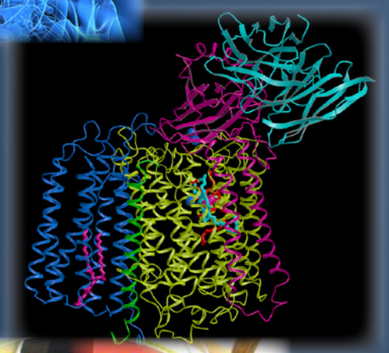
Since the publication of Garrett Hardin's "The Tragedy of the Commons" in 1968, environmental researchers have been aware of the fundamental challenges of trying to understand how individual humans operate in settings where resources are held in common. Because the consequences of their actions do not immediately affect them, individuals presumably operate in different ways than they would when they are directly impacted.

SBE researchers examined different strategies for managing forests in the more than 60 sites in the Western Hemisphere, Asia and Africa. Using a common framework for performing analyses at multiple scales, they identified key biophysical and human behavioral variables associated with differences in rates of forest regeneration. They found that no simple association exists between forest conditions and any single type of property rights regime. Instead, they found that enforcement explained most of the variance found in forest conditions. Their conclusions demonstrate that forests can be effectively managed for enhancement of ecosystem quality regardless of whether the property is privately owned, managed cooperatively, or publicly managed.

Research on marine protected reserves designed to protect marine ecosystems while ensuring the livelihoods of local people has had similar results. A variety of approaches have proved successful, provided that the local residents are part of the process of developing both strategies to manage the reserves and enforceable rules to which all parties have agreed.

FROM TOP: GODESTA; BRYAN GOSTIN

SBE research helps us to understand and predict human behavior, which is essential for developing successful strategies to preserve natural habitats, including forests and marine ecosystems.



IV. Foundational Research Themes

To address the many challenges outlined in the preceding section, it is essential to continue the foundational research that provides a theoretical basis for these interdisciplinary questions. This research may be broadly grouped into three foundational themes:

1) Understanding the Structure and Function of the Brain

2) Understanding the Complexity of Human Societies and Activities

3) Understanding Human Origins and Diversity

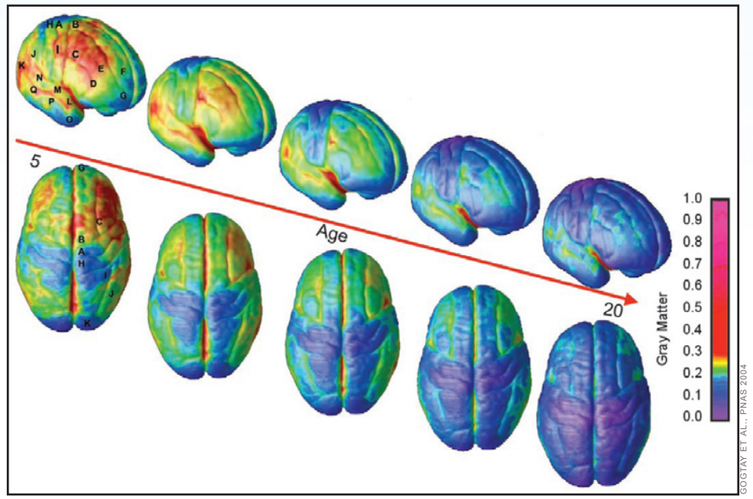
Basic research in each of these themes has been transformed over the last generation by the new technologies described in Appendices B–D.

FROM TOP: SEBASTIAN KAULITZKI; CURTIS NEVEU; FREDERICK BONATO, ST. PETER'S COLLEGE; MONIQUE BORGERHOFF MULDER, UC DAVIS; GIL CLARY, COLLEGE OF ST. CATHERINE

Theme 1:

Understanding the Structure and Function of the Brain

At the core of the human sciences are questions about individual behavior: Why do people think, feel and act the way they do? At the heart of that mystery is the central nervous system, where the brain is the main element. The brain provides the ability to speak, reason, learn, form relationships, and create families, communities and societies. We need to understand how these abilities are created. How does the mind arise from the brain in response to environmental stimuli? And how does behavior then arise from the interaction of mind, brain, and social, economic and built environments?



Developmental neuroscientists have discovered that as the human brain ages and matures through adolescence, its structure changes to include relatively more white matter to grey matter, meaning that the connectivity between areas increases dramatically as children grow.

LOU BUENO

By the time a human infant is born, the visual cortex is already functional to the point that neurons start forming connections with each other at dramatic rates as babies look at new objects and faces.

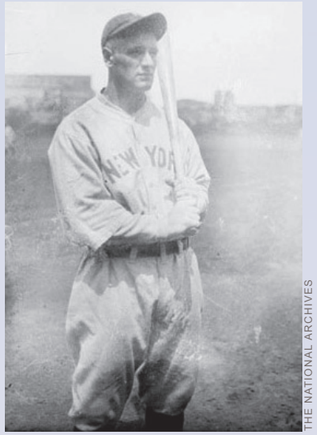
What makes this so challenging is that the brain is exceedingly complicated. It contains roughly 100 billion neurons with approximately ten times that many glial cells and an exponential number of connections between those cells. Until very recently the only way to study this intricate network was indirectly, through psychological and anatomical experiments, examination of the effects of traumatic head injuries or brain surgery, abnormal behavior and mental illness, or observation of the faint electrical fields produced by brain activity deep inside the skull.

Within the past two decades, however, new experimental methods have produced an explosion of new knowledge and understanding about the brain. As the Nobel Prize–winning neuroscientist Eric Kandel wrote in his 2006 book *In Search of Memory*, "[B]ehavioral psychology, cognitive psychology, neuroscience and molecular biology have merged into a new science of mind … [whose findings] provide meaningful and nuanced insights into mental functioning—from perception, thought, emotion and memory to schizophrenia, depression and age-related memory loss. These windows into the mind also open the way to more effective healing." SBE researchers are just now capturing these complex brain functions in mathematical models of individual and group behavior.

This new science of mind has informed the contentious debate over nature versus nurture: Are humans primarily shaped by their inborn genes (nature) or by personal experiences (nurture)? It appears now that nature and nurture are not either-or choices but are intertwined. A classic example is vision. By the time a newborn baby's eyes first open, genes have already instructed the neurons in the visual cortex to start forming connections with one another at a prodigious rate—far more connections than needed, in fact. As the baby shifts gaze from one object to the next, the signals coming from the retina begin a Darwinian contest for survival. The more frequently used connections are strengthened while the less frequently used connections are pruned. In effect, world experience begins to sculpt the baby's brain. Without that sculpting—without the right kind of visual input during those critical first months of life—the visual cortex will remain poorly organized and the baby will never see properly. With this sculpting, the baby's visual circuitry becomes exquisitely fine-tuned to seeing the world.

This same proliferation-plus-pruning motif occurs frequently during the course of development. Another example is the remarkable ease with which very young children extract words and grammatical structures from the conversational babble around them—a facility that peaks at roughly the same time as the formation of specific neural connections. Children appear to have some temporal and perhaps genetic "programming" for language because they acquire it easily and effortlessly at young ages. This programming is shaped by experience, since they develop fluency in whichever specific language(s) they hear, whether Japanese, or French, or Arabic. Moreover, if they are exposed to no language at all during those critical early years, they are crippled in their ability to develop either speech or comprehension, even if they are exposed to language later.

The Brain Waves of Thought



THE NATIONAL ARCHIVES

New understanding of brain waves may soon allow us to communicate with patients who suffer from "locked-in syndrome," which occurs with Lou Gehrig's Disease.

The complex patterns of human brain activity produced during mental events like thinking and remembering are beginning to make sense to scientists. When a person imagines saying different vowels, distinctive neural patterns linked to actual movements of the mouth, jaw, and lips can be identified. Neural patterns involved in memory are also being decoded, again with a strong link between thinking and doing. The same cells that respond when a person simply thinks about, or remembers, a movie also respond while the person actually watches the movie.

Significant hurdles exist to the widespread use of these discoveries (the recognition algorithms must be trained to recognize each individual's unique neural "fingerprint," subjects must be trained to "think loudly" so the brain activity is enhanced, and so on). Nevertheless, the ultimate implications may be profound. Thought vowels are currently made audible by using the neural patterns to drive a speech synthesizer. Someday patients with "locked-in syndrome," which can occur with diseases such as severe amyotrophic lateral sclerosis (ALS), or Lou Gehrig's Disease, may be able to communicate merely by thinking, and people with Alzheimer's disease and other forms of dementia may have help maintaining memories.

The interplay between nature and nurture, genes and experience, continues to be a rich field of study. Recently researchers have found compelling evidence that one particular gene is associated with behavioral problems and violent crime in men, but only if subject to abuse in childhood. Without such abuse, the gene alone does not result in these antisocial behaviors.

More generally, as this example suggests, scientists' rapidly accumulating insights into the brain-behavior-society connection have begun to have significant impact on critical national issues. Among the current and near-term applications of brain and behavioral sciences:

- Better treatments for alcohol, tobacco and drug dependency, based on a clearer understanding of addiction.
- Better diagnosis and treatment for schizophrenia, depression, autism and other forms of mental illness as well as better teaching methods for autistic children, based on a deeper understanding of how the brain interacts with the environment.
- Improved understanding of how the brain and mental and physical illness are linked, with special attention to the influence of socio-economic environments and policies on our brains, bodies and overall well-being.
- Better insight into the effects of stress at various times of life—especially during sensitive developmental periods such as early childhood, or even in utero. Early life stress, deprivation and trauma can have devastating effects on the course of physical and mental illness, disability and suffering.
- Lower medical costs to care for aging baby boomers, based on research that demonstrates how physical and mental exercise can improve memory, cognition and independent living throughout aging.
- Greater understanding of how factors such as depression or lack of social support can increase death rates and reduce quality of life in people with chronic medical conditions like cancer and heart disease.
- Measures to improve the accuracy of eyewitness testimony, based on research into the fundamental mechanisms of memory.
- Improved education practices, based on research into the fundamental mechanisms of learning.

The list is growing rapidly as the SBE sciences continue to use the equally rapid advances in genetics, neural imaging and bioinformatics (Appendix D). In the not-too-distant future, an increasingly integrated "systems view" of the brain may be taken, in which interdisciplinary teams from the biomedical, physical, mathematical, computer and SBE sciences develop new brain imaging techniques that reveal how the various parts of the brain work together and how they give rise to the complexities of mind and behavior.

Theme 2:
Understanding the Complexity of Human Societies and Activities

Human societies have often been compared to complex ecosystems. The flow of energy and nutrients through an ecosystem is strikingly similar to the flow of money, goods and services through a modern economy. Likewise the intricate food chains, the web of symbiotic relationships, and the dominant role of climate and geography all have parallels in human societies.

Yet there are critical differences. Unlike other living organisms, humans shape their surroundings and create interactions for purposes that go beyond survival within an ecosystem. In addition to dealing with one another through kinship bonds and face-to-face interactions, humans create interest groups, clubs, corporations, armies, churches, universities, city-states, nation-states and transnational alliances.

LORI LEONARD, JOHNS HOPKINS UNIVERSITY

A scientist in Chad teaches locals about methods for testing for soil fertility. Farmers in this region have lost arable soil due to construction of a large pipeline as part of the development of Chad's oil industry.

Modern society also relies on a far-flung "system of systems" for emergency response, law enforcement, health care, food, education, finance, insurance, communication, entertainment, transportation and a host of other services. Society has experimented with organizing principles such as socialism, capitalism and democracy—and in the process, has had to face issues arising from economic globalization, technological innovation, mass migration, environmental degradation, global warming, religious zealotry and other forces for change, none of which have ever before operated on such a worldwide scale.

Meeting this challenge is daunting because it demands a comprehensive systems approach that integrates data and analyses over the whole range of human sciences, from neuroscience and psychology to political science, economics, geography, anthropology, archaeology, linguistics and sociology. Fortunately innovations in SBE methodology and theory are helping pave the way for systems SBE research. For example, advances in network modeling have enabled visualization of the webs of interpersonal

and inter-organizational ties that foster the spread of information, ideas and microbes within and across populations; advances in multilevel modeling have led to analysis of the impact of community change on individual outcomes; and advances in simulation modeling are permitting the integration of knowledge from a multitude of studies on specific behavioral, social and biological mechanisms into working models of the entire ecosystem.

As these efforts mature, the results could be similar to those being produced in the field of systems biology, which is a similarly comprehensive, cross-disciplinary view of biological interactions. Just as systems biology points the way toward new forms of personalized medicine, systems SBE science could lead to new kinds of "personalized social interventions." Future work could focus on collecting data such as health, infrastructure and social-support systems from neighborhoods and communities across the U.S., These data, in turn, would help identify the pockets of highest vulnerability to economic dislocation, natural disasters and other societal problems. Planners could use these profiles to devise proactive interventions to help communities become more resilient, and to empower individuals, families, groups and neighborhoods to take action on their own behalf.

Social Interaction Can Change Gene Expression

MICHAEL GURVEN

Cultural anthropologists are working with Tsimane families in the Bolivian Amazon to better understand how patterns of social grouping, economic production, sharing and intergenerational support have contributed to their particularly long life span, and the broader implications about how social networks and diet relate to health and longevity.

While scientists have concentrated on the mechanisms by which genes affect behavior, it is recognized that the reverse is equally important. Animal studies have documented that differences in maternal care very early in life can affect the expression of a gene in an area of the brain that is involved in reactions to stressful events. This is the first evidence that positive parental behavior early after birth can alter gene function in offspring and can "program" behavioral and neuroendocrine responses to stress in adulthood.

Early negative experience with aggression can also alter gene expression in the brain. In a study of mice that are "bullied" by a larger mouse, researchers demonstrated that repeated social aggression alters gene expression irreversibly in a neural circuit in the brain that may underlie a long-lasting aversion to social contact. This research provides insights into understanding the long-term effects of war trauma, natural catastrophes, racial and ethnic discrimination, poverty, child abuse and violence—and why different people can react to similar events in very different ways. Work that combines animal and human research in the SBE sciences may eventually lead to better screening measures to predict and to protect those who are prone to posttraumatic stress disorders and depression and help develop better treatment and prevention strategies.

Theme 3:
Understanding Human Origins and Diversity

People are fascinated by origins. This fascination drives many types of scientific research; for example, physicists seek to reconstruct aspects of the Big Bang in the Large Hadron Collider, and biologists have studied the origin of species for 150 years. In addition to biological and physical theories of origins, human sciences seek to understand how human behaviors in the past have shaped the present.

A fundamental and compelling challenge for the SBE sciences is to understand the nature of humans. Where and how did humanity originate, and how did we acquire the capacity for language, culture and abstract thought? What is the basis for human diversity? Until recently such questions were the domain of field anthropologists and archaeologists. Today field work remains critical, but is being substantially augmented by new tools and techniques to learn about our ancestry and relationships.

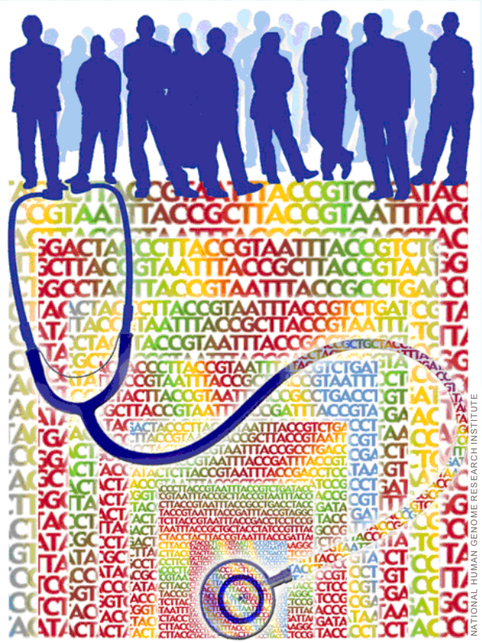
An understanding of how human anatomy and genetics vary across populations is essential for investigators in many disciplines, from forensic scientists trying to identify skeletal remains to physicians working on global public health issues. SBE scientists seek to understand, for example, why certain populations are disproportionately affected by diseases, and how different populations experience systemic health changes caused by their unique combination of genetic, behavioral, social and economic factors.

Scientists are applying increasingly sophisticated modes of analysis to the physical remains—fossils and artifacts—of early humans and their behavior. These analyses show us how ancient peoples looked, what they were capable of manufacturing, the raw materials they used, their food sources and where they lived, hunted and foraged—all of which provide significant insights into human behavior over the last 50,000 or more years.

RICK POTTS, SMITHSONIAN NMNH

Children at the Smithsonian Institute National Museum of Natural History learn from physical anthropologists about the science of human origins.

SBE scientists can now investigate the diets of ancient humans and other human ancestors by examining chemical isotopes, which transfer from soil to food and eventually leave distinct traces on fossilized teeth and bones. By linking this information to geographic regions, they can also recreate ancient migration patterns in unprecedented detail. Moreover, because that same skeletal material allows them to determine the sex of an individual, they can even determine the conditions under which men and women migrated differently.



The Human Genome Project made remarkable strides toward understanding the influence of genetics on behavior and health. Scientists are now discovering the importance of variation between different individuals.

Scientists are using genomic approaches to trace the peopling of the globe as our earliest ancestors moved out of east Africa and populated the rest of the African continent, then Asia and Europe and finally the New World. They are also using imaging techniques borrowed from medical settings, such as CT scanning, to visualize the inner structure of fossils without destroying them. This generates data on early ancestors; one recent example is an understanding of the degree to which early ancestors relied on the sense of vision by determining the relative and absolute size of the visual cortex.

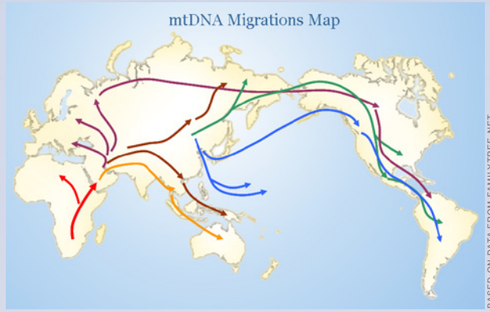
Work such as this provides clues to how the brain has evolved and with it the human capacity for language, social relationships and vision. The larger brain size requires that birth occurs earlier in development to enable the skull to pass through the birth canal; this in turn leads to lengthened infant dependency, which affects the organization of all human societies.

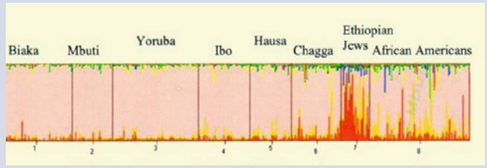
As discussed under Theme 1, important questions include how and when the remarkably sophisticated brain human developed. What drove its evolution, and how did its alterations affect other aspects of human anatomy and behavior? Using the techniques of genomic analysis, scientists are studying the incorporation of genetic and molecular changes that control energy regulation in the brain. The structure of these molecules, when compared in mice, monkeys, apes and humans, have changed coincident with the appearance of the higher primates. Did this boost in the energy-generating capacity of our ancestors' brains affect our ability to learn languages, innovate and conduct social interactions?

Determining Human Settlement Patterns Using Multiple Sources of Data

Scientists can now use multiple lines of evidence to trace human settlement patterns. In addition to archaeological and fossil remains, genetic and linguistic data can be used to determine where and when settlements were created. By pooling data from these different methods, new information is produced. For example, for many years the prevailing theory of the peopling of Indonesia was that Austronesian-speaking peoples from Southern China and Taiwan moved into Indonesia around 4,000 years ago—and largely displaced the people already living there.

Now recent research using both genetic and linguistic data points to an indigenous appearance of Austronesian languages in Indonesia without the radical replacement of the population as suggested by earlier models. SBE investigators are also using these methods to determine whether the different languages currently spoken in the region originated with the same patterns.





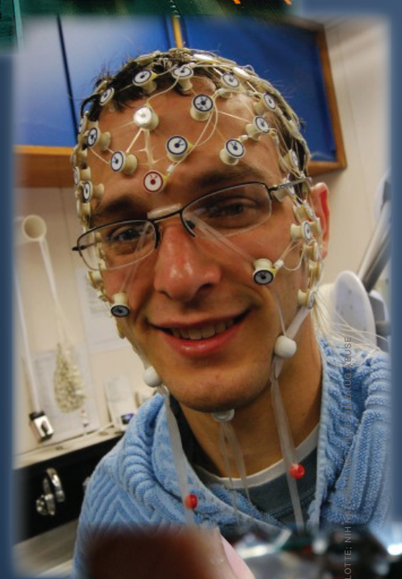
Using new techniques, scientists are able to use DNA to reconstruct migration maps of the spread of humans across the globe. This information is also useful when paired with linguistic data to shed light on the development of languages and their relation to one another.

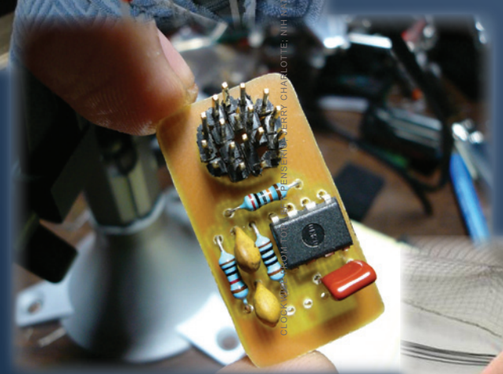
V. Priority Research Focus Areas

The interdisciplinary nature of SBE science makes it vital that agencies and departments set complementary research priorities, collaborate on interdisciplinary efforts and share results. Recent growth in sensors, information technologies and other tools that have broad applicability further demands that breakthroughs and new approaches be shared.

Discussed below are the four areas the Subcommittee identified as priority research focus areas:

- New Tools and Technologies
- Data Gathering and Management
- Systems Integration
- Evidence and Policymaking

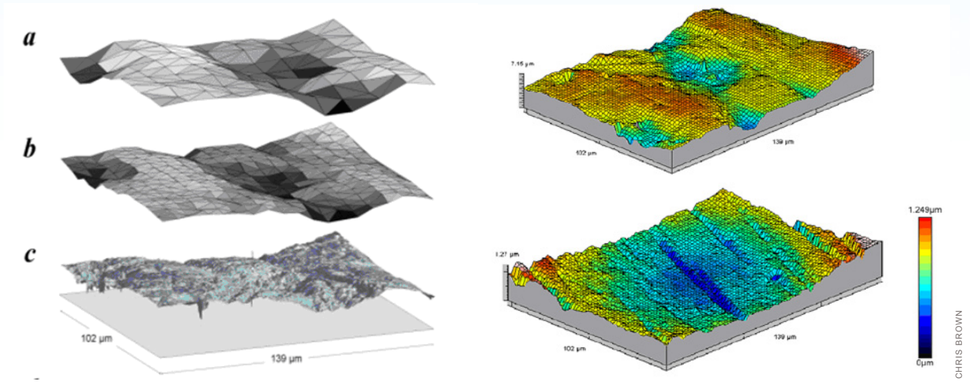




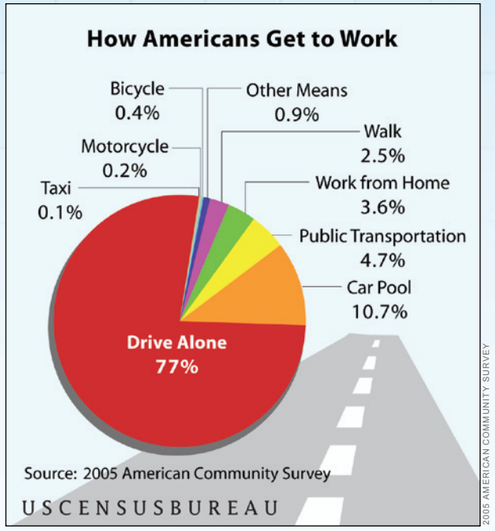
FROM TOP: PATRICK BOURY; JUSTIN WYNE; COLIN MEL; BRET FAJEN, RIT

New Tools and Technologies

The SBE sciences are being transformed through new tools that permit better data analysis, integration and simulation. SBE scientists are now able to collect and share data in new ways and at unprecedented scales. These tools include cyberinfrastructure (Appendix B), genomics (Appendix C), functional brain imaging (Appendix D), human performance modeling and advanced survey techniques. The continued development of these new tools and their novel application to important problems is a principal goal for Federal research. Agencies should continue to develop new tools and techniques for research and ensure the broadest dissemination possible for those tools. Brain imaging, for example, will become even more powerful when high-resolution neural data are gathered from participants moving freely and interacting in natural ways. Extracting patterns and meaningful information from free-form data such as text, audio and video requires advances in natural language processing, image understanding and other forms of artificial intelligence. These studies require the collaborative efforts of SBE scientists with chemists, biologists and computer scientists. Advances in cyberinfrastructure (Appendix B) are occurring at an ever-increasing rate, and continued advancements in cyberinfrastructure ensure that large amounts of data can be securely stored and combined with other data sets to identify interrelationships and patterns that were previously undiscoverable.



Innovative collaborations between disciplines can apply new technology to long-standing questions. Here topographical maps of fossilized teeth are available in unprecedented detail when analyzed with technology designed by mechanical engineers. Tooth-wear is of critical importance in anthropology because it relates to diet and behavior, and this tool opens up new possibilities for future research.



Many surveys provide longitudinal data that offer reliable information to enable informed policy decisions. For instance, the American Community Survey offers information about commuting behaviors and other aspects of American life relevant to energy use and climage change.

Well-established tools such as surveys also offer fertile ground for the application of new technologies. Although surveys are a uniquely valuable tool for scientists and policymakers, in the past they have tended to be slow and expensive to conduct. Potential survey volunteers increasingly balk at the time and trouble required to participate. This makes it imperative that surveys be redesigned to take advantage of emerging technologies to collect more timely information and reduce the burden on participants. One example of such an innovation is the American Community Survey (ACS), which is the key component of the U.S. Census Bureau's re-engineering of the 10-year census count. Modern information technology has allowed this streamlined version to replace the traditional census long form, which was sent out once a decade. Instead, the ACS is sent out to a sample of households annually, producing a national snapshot once every year.

Data Gathering and Management

Decision makers need the most complete information for addressing real-world problems such as natural disasters, geopolitical crises, or other situations. The transformational tools being developed enhance SBE scientists' ability to collect data and provide evidence in a timely way and specifically applicable to the problem at hand. These new tools also allow the use of analytical methods that would not otherwise be practical. Their development should be a priority.

Support long-term "baseline" studies, the foundation for SBE science and knowledge

The classic example of systematic data-gathering is the U.S. Census, which has been conducted once per decade for more than two centuries. Other examples include the large-scale "gold standard" surveys discussed in chapter two. These surveys have followed individuals and families over generations and grow steadily more valuable as time goes on. They provide an increasingly detailed picture of society. Similarly, efforts should be made to include geographic information in SBE data. The technology for exploiting such information has been enhanced enormously through the development of Geographic Information Systems (GIS). As studies of poverty, segregation, conflict and communications have documented, understanding where an event is occurring is often critical to understanding how and why.

Collect short-lived data in the wake of disasters and other unexpected events

It would be extremely valuable to have an SBE research infrastructure prepared to study what happens during and after natural and human-made catastrophes. Information gathered by SBE first responders would be particularly important for giving decision makers a good situational awareness during a crisis as well as for monitoring how personal and social impacts unfold in the aftermath. Including SBE scientists among the first responders to extreme events such as earthquakes, hurricanes, tsunamis and terrorist attacks allows them to assess a wide range of issues, including the needs of small businesses, the ecology of emerging infectious diseases, and the reasons people ignore or heed warnings to evacuate. This would best be organized on an interagency basis and developed in conjunction with natural disaster physical scientists and engineers who would similarly benefit from being able to assess a disaster's implications as soon as rescue operations allowed.

KEVIN ROFIDAL, U.S. COAST GUARD

SBE scientists collect data in the wake of natural or human-made disasters, which is then useful for training first responders, planning emergency procedures, and anticipating future catastrophes.

Encourage accessible and widely shared data collections while guaranteeing privacy and security

Information is rarely useful in isolation. When data sets are shared, combined and processed to reveal significant relationships, disparate information becomes more meaningful in a wider context. Unfortunately, many of the databases that would provide benefit if combined are not easy to integrate. They may be controlled by different organizations, stored or collected in incompatible formats or contain sensitive information.

The challenge is to share and integrate the data despite these obstacles. Some technical approaches to this problem already exist, notably the "federated database" concept widely used in the private sector. Such a system responds to a single query from the user by automatically searching through multiple distributed data stores on the network, while respecting the privacy and security restrictions set up by the owners of each database.

INTERNATIONAL PUBLIC USE MICRODATA SERIES

The International Public Use Microdata Series is the largest public-use population database in the world, archiving and making available census data from countries all over the world. In many cases this means transferring data from outdated or poorly stored devices, such as these magnetic tapes, to more accessible and durable formats.

This technology can facilitate the sharing process, but in order for the shared data to be useful, the users must collaborate across disciplines and institutions to share insights and hypotheses.

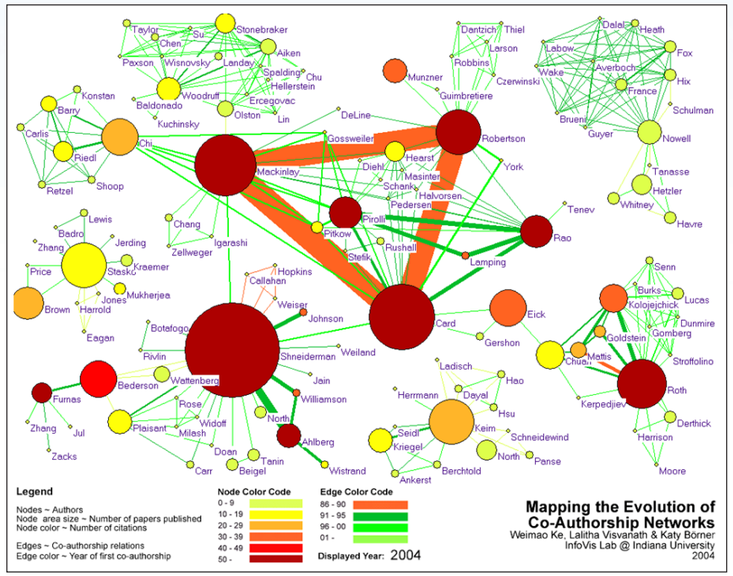
Such cooperative efforts are most likely to yield broadly useful results and should be encouraged. For example, better international collaboration on data collection will not only help avoid gaps and wasteful duplication of data storage and curation but will also facilitate comparative work. Some coordination exists—for example, the U.S.-based Inter-University Consortium for Political and Social Research (ICPSR) and the E.U.-based European Consortium for Political Research (ECPR), which compare results of the U.S. General Social Survey with the European Social Survey. Additional desirable collaborations would include partners in Latin America, Asia, Africa and the Middle East.

Meanwhile, public trust remains a sensitive issue, given the power of modern data systems to collect and diffuse information on a large scale. Without reliable safeguards, the public may refuse participation in important studies. Creating and maintaining safeguards that ensure that data are not only of high quality but also secure and confidential must continue to be a top priority for researchers, systems designers and policymakers.

Systems Integration

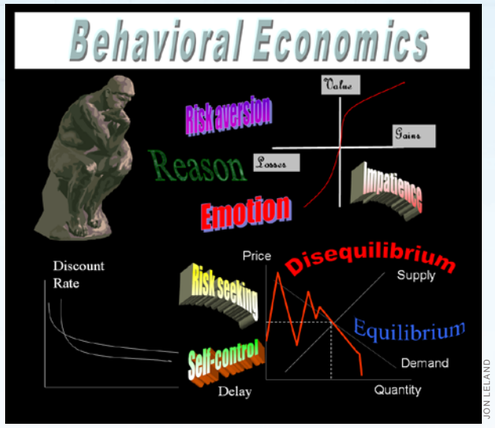
A specific opportunity for Federal effort is the integration of multiple forms of knowledge and visualizing the relationships between them. Individuals and larger societal and organizational groups are so complex that no single discipline or point of view will suffice to explain them. Thus, SBE "systems science" is emerging, and is intended to integrate as many diverse data sets as possible. Despite the size or completeness of a data collection, it does not become useful knowledge until it is determined how the data fit together to produce meaningful insights. Systems integration in SBE sciences will yield transformative advances in basic science and in its application.

While systems integration is important for scientific discovery, it is even more critical for decision making. The most pressing problems facing society are complex and involve multiple causes. For example, improvements in health care require integration of the biomedical and natural sciences with the behavioral, social, economic and public health sciences.



New SBE techniques are helping scientists understand the nature of complex systems, such as this representation of co-authorship networks among scientific publications. This type of analysis can provide a wide range of information about how sciences are related to each other, what new relationships are developing, and how Federal agencies can support and encourage future interdisciplinary discovery.

This integration of disciplines is one of the greatest intellectual and practical challenges of the 21st century, but a successful synthesis will produce more dynamic models of multilevel causal networks.



JON LELAND

An important interdisciplinary field that has arisen through collaborative research is that of behavioral economics, which introduces psychological theory and methods into economic models of human behavior. The outcome of this work over the past two decades is a vastly enriched toolkit that helps inform economic policy.

For the SBE sciences, multiscale integration is central to emerging interdisciplinary fields such as social neuroscience. This field has begun to clarify how fundamental genetic, hormonal, and physiological mechanisms in the brain shape, and are shaped by, high-level behavior such as self-discipline, empathy, risk-taking, decision making, and substance abuse. Multi-scale integration is also essential for understanding the many examples of emergence, in which purely local interactions among individual agents give rise to large-scale, collective behavior.

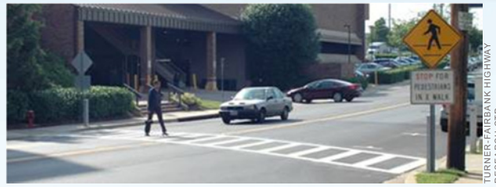
Some key elements to this opportunity are:

Incentives and Barriers: Federal funding agencies have an important role in promoting interdisciplinary research, first by working with the research community to identify the most promising new areas for interdisciplinary (and interagency) work, and then by organizing and funding that work. One often-mentioned institutional barrier to interdisciplinary research of particular concern to young researchers is the need to publish in their own discipline's journals to gain recognition in the field and tenure at their institution.

Dialog: Interdisciplinary collaborations can function only when the participants collaborate fully—when they talk together, work together, and actively try to understand cultural differences between their respective disciplines. This kind of cross-cultural communication is hard enough within the SBE sciences, since the disciplines have different origins, different histories, different theories and concepts, different research methods and different problems they are trying to solve. It is harder still when collaborations extend to biomedical scientists, geophysicists, or mathematicians, for example. But communicating is essential. One way the funding agencies can help foster such communication is by establishing formal, interdisciplinary research centers on specific problems, such as health disparities, counter-terrorism, or the science of learning. At their best, such organizations can provide a venue where multiple perspectives on a problem lead to richer insights. A prime example is disaster research, which demands strong collaborations among SBE scientists, engineers, and researchers from many other disciplines. Another example is the cross-agency science of science and innovation policy initiative that puts SBE researchers in close collaboration with natural scientists and engineers.

Evidence and Policymaking

The evidence provided by science, including the human sciences, can and does inform policymaking on a wide range of issues. Likewise, public programs and policy initiatives, properly constructed, instrumented and applied, can provide unique opportunities for scientists to advance the understanding of humankind.



TURNER-FAIRBANK HIGHWAY RESEARCH CTR.

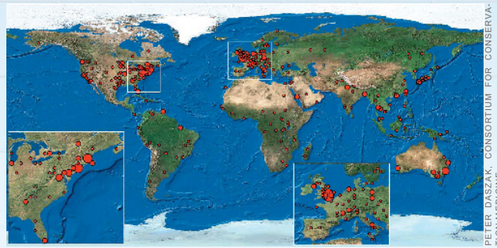
Research led by traffic engineers as well as human factors and experimental psychologists is useful to policymakers responsible for ensuring the safety of pedestrians and bicyclists.

Opportunities include:

Implementing evidence-led public policy in ways that are also evidence-generating

State, local, and Federal government agencies are increasingly turning to the SBE sciences to learn what does and does not work, and **evidence-led** policy initiatives are fast becoming a hallmark in education, health care, criminal justice and other fields. One good example is the Education Department's What Works project, the goal of which is the creation of an evidence base for education policy by gathering systematic data on the effectiveness of various teaching practices. Another example is the internationally funded Campbell Collaboration in Washington, DC, the goal of which is to foster evidence-based social policy by collecting information about the effects of interventions in a wide range of social, behavioral and educational arenas.

In the health care setting, research on the comparative effectiveness of alternative treatments is creating an information base that can be combined with SBE science on decision making to develop effective incentive structures for patients and physicians. These efforts can lead to more efficient allocation of health care funding and slow the dramatic increases in health care spending without undermining the nation's health. Still another example is the effort being made by several Federal agencies to create a science of science policy program to evaluate public research and R&D investments. The goal is twofold: First, to achieve a much deeper understanding of how innovation works at every level, from the moment of discovery in an individual brain, to the brainstorming of ideas in small groups of innovators, to the culture of innovation at the national level. And second, to devise better ways to evaluate private and public investments in innovation and their effect on the nation's prosperity and global competitiveness.



PETER DASZAK, CONSORTIUM FOR CONSERVATION MEDICINE

New technologies have enabled SBE researchers to better track the emergence and spread of infectious disease. Combining epidemiological data with geographic data enables researchers to identify "hot-spots"–those regions where new diseases are most likely to appear.

Whenever possible, policymakers should ensure that new public initiatives are not only evidence-led but **evidence-generating,** with built-in mechanisms to gather real-time data about the initiative's effectiveness and outcomes. Evidence-generating mechanisms provide understanding of how well decisions have worked in the past, how effective current actions are, and how well solutions are working now. Scientists recognize policymakers' need for timely feedback and strive to provide evidence that they can reliably use to adjust their course now, not a year or two in the future.

Understanding the Spread of Infectious Disease

Understanding the transmission of infectious disease in a population is one area where agent-based modeling may have significant impact. In studying disease spread, the number of possible agents can range into the millions, making calculations impossible without the aid of computers.

SBE scientists are working alongside epidemiologists and mathematicians to develop models both to better understand disease spread and to test ways to mitigate the spread of disease. This work takes into account the fact that human social action can be just as important as biology, as we now know from studying the spread of plague in Europe starting in the 14th century, annual influenza outbreaks, or the link between drug abuse and the spread of HIV/AIDS.

MASAKO FUJITA, MICHIGAN STATE UNIVERSITY

A nurse in Kenya talks to mothers of young children about the importance of vitamin A for maternal and child health. Anthropologists have discovered that, contrary to long-standing health policy, vitamin A suppliments early on in life can reduce mother-to-child transmission of HIV.

Many human actions contribute to the threat of global pandemics. The speed with which people move around the world, the close association of humans and livestock in parts of Asia and elsewhere, poverty, and lack of access to health care systems and education all interact to make the appearance of new epidemic diseases a consequence not just of the evolution of the pathogens but also of the complex social systems of the 21st century world.

One place where public health education efforts targeting social behaviors have started to pay off is in Kenya, where 20 to 25% of deaths can be attributed to malaria. Here programs to teach people the proper use of low-cost, insecticide-treated mosquito nets and making the nets available in attractive packaging have dramatically increased their use. These efforts are credited with saving thousands of lives, demonstrating that employing disease prevention and mitigation strategies that include social and behavioral factors can diminish a disease's impact.

Develop more sophisticated simulations

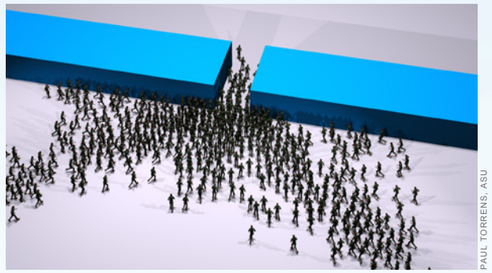
As discussed earlier, SBE scientists have made great strides in testing and refining analyses of real human systems through "agent-based" models and other simulation methods (Appendix B). But there is a clear need for simulations that are large enough and reliable enough for decision makers to use in setting public policy. Some models have begun to reach that level—one example being a simulation of epidemic disease developed at the National Institutes of Health.

Encouraging dialog between researchers and real-world practitioners

The views of practitioners such as classroom teachers, first responders, business executives, or governmental policymakers are critical input to SBE scientists as they design experiments and data collection opportunities designed to impact the day-to-day work of these people. The goal is for scientists to learn the challenges faced by real-world practitioners, design research to address these challenges, and provide answers most useful to practitioners. Indeed, the benefits flow both ways, as the late social scientist Donald Stokes argued in his 1997 book, *Pasteur's Quadrant*. Many of the most important discoveries in science occur in precisely this kind of environment, when the researchers are straddling the interface between "pure" and "applied" research.

Fostering better communication between SBE scientists and the public.

A research finding, regardless of how compelling, is of no practical societal value until it is known and understood. Encouraging dialog between scientists and the public translates into a more scientifically informed citizenry that is better able to evaluate new information and make sound decisions.



PAUL TORRENS, ASU

AL JAZEER A ENGLISH

Advanced agent-based models of crowd behavior designed by SBE scientists contribute to effective crowd management. For instance, each year millions of Islamic pilgrims make the Hajj to Mecca, and these models have helped officials predict crowd behavior and prevent dangerous stampedes.

Appendices

A: List of Social, Behavioral and Economic Sciences

B: Cyberinfrastructure—Coming to Grips with Complexity

C: Genomics—A New Window onto Culture, History and Behavior

D: Functional Neuroimaging—Opening the Black Box of the Brain

Appendix A

List of Social, Behavioral and Economic Sciences

The SBE sciences can be divided into three broad areas—human behavior, human groups and societies and human origins—with an understanding that the three have considerable overlap and cross-fertilization. For each discipline, a definition is provided, as well as a series of questions asked by researchers in that area.

Human Behavior

Research in this area is focused on understanding why humans think, feel and act the way they do and how their thoughts and feelings are represented in language. Among the disciplines that investigate human behavior are linguistics, neuroscience and psychology.

Linguistics:

The study of the human language capacity including its genetic basis; its representation in the brain and the way it is shaped by the environment; how language is used for various purposes; the range of sounds; structures and meanings of the languages of the world and the way languages change over time.

- What is the genetically encoded information that permits children to acquire their language?
- How do children produce non-adult linguistic structures and how do they subsequently outgrow them?
- What are the linguistic effects of damage to different parts of the brain?
- What are the structural elements that make the variety of the world's languages?
- How do languages change over time?

Neuroscience:

The study of the brain and mind, how humans perceive and interact with the external world and how experience and biology influence each other. Neuroscience and psychology have considerable overlap, but the former focuses primarily on underlying biological or neural processes while the latter looks at the interaction of mental functions and behavior on a systemic level.

- How are memories stored and retrieved?
- To what extent can the onset of Alzheimer's disease be prevented or delayed?
- What is the role of "mirror neurons" in the emergence of individual behavior?
- What are the bases of schizophrenia, autism, addiction and other forms of mental illness?
- How are personalities shaped by the interaction of biology and environment?

Psychology:

The study of human behavior and mental processes. It is multi-faceted, including the biological, developmental, social and cultural influences on human behavior. Psychology includes areas such as cognition, learning, memory, emotion, perception and development.

- How do humans take information in through the senses and combine it with prior knowledge to drive behavior?
- What is the "cognitive machinery" that supports complex mental activities such as reading and mathematics?
- What factors promote interpersonal and intergroup cooperation as opposed to competition, conflict, violence, crime and abuse?
- What is the basis of mental health, and how do early socialization experiences influence adult adjustments to stress in everyday life?
- How is decision making affected by gender and age? What is the social epidemiology of risk-taking behaviors?

Appendix A

Human Groups and Societies

Research in this area encompasses the study of interpersonal behavior from small groups like families to national and global forces (political campaigns, technological change, migration patterns and the rise and fall of civilizations). Among the disciplines that investigate human societies are cultural anthropology, economics, geography, political science, sociology and criminiology.

Cultural Anthropology:

The holistic study of humanity—all peoples of the world—throughout time and space. It differs from other SBE disciplines in its emphasis on cultural relativism—the principle that an individual human's beliefs and activities should be interpreted in terms of his or her own culture.

- What subsistence systems do different people, living under different ecological and demographic constraints, develop and why?
- How do different peoples of the world cope with disease and dying?
- What are the similarities and differences in religious beliefs from one group to the next?

Economics:

The study of the production, investment, distribution and consumption of goods and services and related economic policies. Economics is typically divided into microeconomics—the study of decision making at the level of the individual, household, or firm—and macroeconomics—the study of how these individual economic decisions together impact the economy of a nation or state using measures such as Gross Domestic Product. In the twentieth century, the methods of economics were applied to education, health, law, marriage, crime, war and even religion—any situation in which people have to make judgments and choices among alternatives.

- How does increasing global integration affect competitiveness, trade, financial markets, foreign investment, innovation, economic growth and development?
- What explains, predicts and affects economic growth, business fluctuations, inflation and unemployment in the global economy?
- What are the costs and benefits of alternative policies to address environmental concerns and natural resource scarcity, such as those related to water availability and quality, toxic substances, solid waste, fossil-fuel supply and climate change?

Geography:

The study of the Earth's features and how these impact the distribution of life on Earth, including human life and the effects of human activity.

- How do differences in topography, climate and rainfall impact land use?
- How does the value of the "services" provided by the ecosystem vary by location?
- What factors influence urban growth and how does the landscape affect and limit growth?
- In what ways does the "built environment" impact peoples' physical activity and overall health?
- How does land use and land cover affect the likelihood of human and economic losses from natural and environmental hazards?

Political Science:

The study of how states, groups and individuals develop institutions, rules and norms to govern their cooperative/non-cooperative activities.

- How do people organize themselves to provide public goods?
- Why do certain political institutions lead to political instability while others yield stability?
- What leads certain nations to have problems with ethnic violence while others do not?
- How are scientific research priorities determined, and what measures are used to determine the consequences of research?
- What institutional structures are most likely to promote democratic societies?

Sociology:

The study of the social rules and processes that organize people in society as individuals and as members of associations, groups and institutions, as well as how these rules and processes develop.

- How do groups and organizations form—and why do some thrive while others fail?
- What do terrorist cells have in common with other criminal networks, and how are they different?
- How can we better understand the devastating cycles of poverty, inequity, unemployment and disparities in health care that are carried across generations in some communities but not others?
- How can we maximize and harness the protective features of the social environment in order to reduce the prevalence and impact of substance abuse and addiction?

Criminology:

The scientific study of crime as an individual and social phenomenon. Criminological research areas include the incidence and forms of crime as well as its causes and consequences. They also include social and governmental regulations and reactions to crime. Criminology draws especially on the research of sociologists and psychologists as well as on writings in law.

- How do societal and governmental interventions deter (or increase) criminal activity in a population?
- Is matching the severity of punishment to the perceived severity of a criminal act an effective approach to deterring crime?
- What socioeconomic measures are correlated with criminal behavior?
- How can we better implement validated addiction treatments to achieving successful rehabilitation in the criminal justice system while reducing recidivism?

Human Origins

This research focuses on human origins, how we relate to the rest of the natural world and how we came to possess our unique abilities for language, music, culture and abstract thought. Timescales range from tens of thousands of years to millions of years. Among the disciplines that investigate human origins are archaeology and physical anthropology.

Archaeology:

The study of human behavior and the changes that behavior has undergone over millions of years, with a particular emphasis on material remains and environmental data. Practitioners examine both long-term trends and shorter term behavioral adaptations. In the U.S., archeology is typically considered a subfield of anthropology, although archaeologists may work within classical, historical or anthropological traditions.

- What gave rise to modern human behavior?
- What are the evolutionary roots of language and music?
- How, over long spans of time, did humans adapt to and change the natural environment?
- How did complex societies arise from more egalitarian hunter-gatherer forms?

Physical Anthropology:

The study of human evolution, adaptability and variation with an aim toward understanding what makes humans different from other species and how and when these differences arose.

- What genetic changes define human evolution?
- What do the human fossil record and comparisons with living primates tell us about the development of uniquely human traits?
- How have modern humans adapted to live in environments that range from tropical to polar?

Appendix B

Cyberinfrastructure—Coming to Grips with Complexity

The development of the Internet and the explosive growth of high-performance computing and broadband connectivity have given SBE researchers the power to collect and analyze information on a scale that was once unimaginable—and to do so in real time. Among these data:

- Biographical, legal, financial, or medical information existing in the form of documents, transactions, or database records;
- Behavioral patterns associated with spending, movement, or travel;
- Behavior captured in real-time video monitoring; and
- New modes of online social interaction, such as the virtual collaboration of Wikipedia, multi-player online gaming and social networking sites.

Scientists are now pioneering a global cyberinfrastructure that will allow users to link not just computers and documents but also databases, simulation packages, visualization tools, remote instrumentation and the power of the computers themselves. Cyberinfrastructure can give SBE researchers the ability to connect to individual's home and office machines, transforming the way SBE research is done.

In attempting to comprehend the full complexity of human affairs, SBE researchers have become heavy users of cyberinfrastructure and are posing challenges that drive the technology itself. For example:

- SBE researchers today can record myriad forms of data, ranging from subjects' videotaped reactions to their eye movements, heart rates, electroencephalogram results and answers to written surveys. But to reach a full understanding of human behavior, researchers also have to find coherent patterns among these data—a task that can be daunting, especially when the information has been collected at different times and places.

  Cyberinfrastructure has the potential to make that task considerably easier. And indeed, a multidisciplinary team of scientists is doing just that by creating the Social Informatics Data (SID) Grid. The SID Grid poses a significant computational challenge; gathering simultaneous, high-throughput data from, say, eye trackers and EEG machines is far from trivial. But when the SID Grid is complete, psychologists, sociologists, anthropologists, economists and neuroscientists around the world will easily be able to share notes, and to synthesize numerous forms of streaming data at once.

- One of the great advances that SBE researchers are taking advantage of is the development of Geographic Information Systems (GIS). By allowing users to see spatial data integrated with many other forms of information, ranging from soil type and hydrology to census data and crime statistics, GIS can reveal correlations that would not otherwise be apparent. Moreover, it can do so over multiple scales of space and time. Originally developed by geographers in the mid

1960s, GIS underwent rapid growth in the 1980s and 1990s with the advent of personal computers and Unix workstations. It is now used by practitioners in a wide range of fields. In September 2005, for example, shortly after Hurricane Katrina hit the U.S. Gulf Coast, an interactive web-based portal using GIS was established that integrated spatial data with data on the status of roads and power plants, census data, and data on possible sources of contaminants. This portal was used by local and state health officials as part of an effort to minimize people's exposure to contaminants and other dangers.

GIS continues to evolve. Among the current research topics: integrating GIS with simulations for better decision support; representing qualitative information and uncertainty; and designing easier, more intuitive interfaces for crisis managers, who often work in teams and make decisions under stress.

- Meanwhile, the ready availability of powerful computers has allowed SBE scientists to develop and explore increasingly powerful simulations of social systems. One particularly effective technique is agent-based modeling. A typical agent-based model resembles a laboratory experiment with each of the human subjects replaced by an "agent": a little software module that simulates his or her behavior. For example, each module might consist of a set of rules: "If this is the situation, then do that." The difference is that the computer can simulate many different kinds of agents. Depending on the needs of the model, some of them may indeed represent individuals—for example, consumers, producers, or family members. But other agents may represent social groupings (for example, families, firms, communities, government agencies), institutions (markets, regulatory systems), biological entities (crops, livestock, forests), or even physical entities (infrastructure, weather and geographical regions). The agents likewise vary in their abilities, ranging from active, data-gathering decision makers with sophisticated learning capabilities to passive entities with no cognitive function. And, of course, agents can be composed of other agents, which permits the simulation of complex hierarchies.

  The idea is straightforward: put these software agents together in the computer so that they can respond and adapt to one another in much the same way that the real agents do, then watch what happens. This approach has several advantages over conventional simulations. First, the agent-based models tend to be much easier to understand, since the agents and their behaviors correspond to the way that most people actually think about a problem. Second, instead of simply tweaking a parameter, as one might do with an equation, the effects of giving agents new strategies can be tested. Third, agent-based modeling lets researchers watch as collective behavior emerges from individual actions—typically with no single agent in charge. Examples of such "emergent" behavior include standing ovations, trade networks, decentralized market economies, mutual cooperation based on reciprocity, social norms, among others. And finally, agent-based modeling lets researchers follow as these emergent phenomena feed back and influence individual behavior.

Appendix C

Genomics—A New Window onto Culture, History and Behavior

Modern genomic science has been advancing at a breakneck pace over the past decade, most famously by providing the complete DNA sequences of *Homo sapiens* and an expanding list of other creatures. And SBE researchers have been quick to take advantage of that progress.

By looking at similarities and differences among the sequences, for example, they have begun to compile a richly detailed account of how humans emerged—an account that is independent of, and complementary to, the evidence of the fossil record. Particularly revealing was the 2005 publication of the chimpanzee genome, which showed that humans have many more regions of duplicated DNA. Since chimps are our closest living relatives, these duplications connect to how and why we developed the features that make us uniquely human, including our upright posture, our capacity for complex language and thought and our large brains. Indeed, it may be that the duplications simply gave us more raw genetic material for evolutionary experimentation. They may also help explain why some diseases, including Alzheimer's, are found only in humans.

By comparing the DNA variations among human populations, SBE scientists have begun to trace prehistoric migrations with unprecedented clarity—an account that is likewise independent of, and complementary to, the evidence of the archeological record. One especially useful tool is the Allele Frequency Database (ALFRED), an open, Web-accessible compilation of genetic, cultural and linguistic information about more than 500 populations around the world.

Finally, by comparing the DNA variations among individual humans, SBE scientists have begun to untangle the intertwining roles of genetics and experience in shaping language, personality, beliefs, abilities and habits. In addition, social scientists have begun to incorporate biomarkers into their field surveys to increase the precision of measurements of subjects' fertility, health, aging, predisposition to disease and ancestry. Such efforts will only increase and improve through the rapid development of automated gene-sequencing technology—which could give rise to portable, affordable devices able to sequence any individual's personal genome.

Appendix D

Functional Neuroimaging—Opening the Black Box of the Brain

Some of the most fundamental advances in neuroscience have come through the development of functional neuroimaging: a set of technologies that show researchers exactly what parts of the brain get activated during this or that specific task, and how those active regions vary from person to person.

Positron Emission Tomography (PET) came into routine use in the early 1980s, both for neuroimaging and medical diagnosis. The basic idea is to inject a radioactively labeled tracer compound into the subject's bloodstream and then measure the emissions as the compound accumulates in the brain. By choosing the right tracer, researchers can map the regions of the brain with the highest blood flow, oxygen use, or glucose metabolism—all of which reflect the intensity of neural activity in that region.

Functional Magnetic Resonance Imaging (fMRI) shot to prominence in the early 1990s when researchers realized that standard hospital MRI scanners could also map brain activity. The scanners turned out to be sensitive to the concentration of oxygen in the blood, which tends to be highest in regions where the brain is working hardest. Functional MRI quickly superseded PET for most neuroimaging research, since it involves no radioactivity at all, and it is still one of the primary tools. Researchers have used it to study the neural basis of language, movement, decision making, empathy and a host of other cognitive activities.

Magnetoencephalography (MEG) has been in development since the 1970s but has been greatly aided by recent advances in computing algorithms and hardware. The technique is expensive and complicated. (The subject's head is surrounded by a web of ultra-sensitive superconducting detectors known as SQUIDs, which measure the faint magnetic fields produced by electrical activity in the brain). But MEG's strengths complement fMRI's very nicely. For one thing, it measures the brain's neural activity directly, instead of via a proxy such as blood flow. For another, it can monitor how the activity changes on much shorter timescales—better than 1 millisecond, versus about 5 seconds.

Electroencephalography (EEG) was developed during the 1920s. Electrodes affixed to the scalp record the electrical activity of the brain. The temporal resolution of EEG is extremely fine (on the order of milliseconds), although its spatial resolution lags behind other methods, such as MEG. EEG is an effective tool for cognitive neuroscience because hardware and operating costs are significantly lower than other brain imaging methods. EEG is relatively simple to use and causes little if any subject discomfort. Current EEG systems use a dense array of electrodes that can be adjusted for children or adults. More recent advances include computational methods that estimate the sources of the EEG signals in the brain, the development of non-magnetic EEG systems that can be used in conjunction with other brain imaging technologies, and the development of mobile EEG devices.

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