Session Chairs
L. Louis Hegedus (Program Committee)
Kenneth J. Rothman (Megatrends)
Charles Rodes (Grand Challenges)
Carla M. Bann (Research Horizons)
James A. Trainham (Conclusions and Recommendations, Lead Fellow)
RTI Research Futures

RTI Fellow Program, July 2012

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Abstract

The RTI International Fellow Program conducted an exercise that looked beyond a 10-year research horizon to determine how the Institute may stimulate new, longer-term research (and growth) opportunities for the company in the future. The exercise consisted of a one-and-a-half-day retreat in September 2011 and subsequent analysis and inspection of national and global megatrends and grand challenges relevant to RTI’s activities and interests.

For RTI’s purposes, megatrends are defined as major, long-term developments, and grand challenges are defined as the challenges and opportunities in responding to megatrends. The Fellows considered the following megatrends: population growth; global connectivity and globalization; health and health care; and a sustainable planet. The grand challenges considered were the role of nuclear energy; global poverty and democracy; non-communicable diseases and global health; clean water supply; and global climate change and quality of life.

Having developed an understanding of key megatrends and grand challenges, the RTI Fellows analyzed research horizons in social sciences, statistics, and economics; engineering and technology; biology and biochemistry; and health and health care.
L’Aiguille du Midi, 3842 m, Chamonix, France, July 2011.
The path to the future is not necessarily a straight one.
1. Introduction

What Do We Mean By “The Future?”

The 2011 retreat of the RTI International Fellow Program was dedicated to the future of RTI’s research. For the purposes of the retreat discussions, “the future” was defined as events occurring more than 10 years from today. Shorter time horizons typically imply more structured activities, such as scheduling, planning, business development, and forecasting. Beyond these shorter horizons lie macroscopic events and related opportunities or threats that influence, or even determine, the long-range success and viability of organizations.

Turning On the “Long Headlight” In a Research Enterprise

The future is perceived as a composite of deterministic (i.e., foreseeable, and actionable) and stochastic (i.e., probabilistic) outcomes. The farther into the future we focus our analysis, the more significant is the stochastic content. While it is hard to plan for probabilistic events, they are often amenable to anticipation, foresight, and scenario analysis. By its very nature, research is aimed at the future; therefore, the Fellows undertook this exercise with the belief that turning on a long-range headlight will reveal important insights about RTI’s direction, and that these insights will trigger thoughts and actions that will better prepare the Institute for future research opportunities and challenges.

Methodology and Structure of This Analysis

The 2011 retreat began with a half-day session devoted to today’s megatrends. This session was chaired by RTI’s Kenneth Rothman and began with a plenary lecture from Michael Rogers, a former “futurist in residence” at the New York Times. This lecture was followed by breakout sessions on megatrends selected for their relevance to RTI’s scientific future. The content of the breakout session discussions was then summarized and presented to the assembly at large.

The megatrends session was followed by a half-day session on the “grand challenges”, that is, on the challenges and opportunities associated with megatrends. The session was chaired by RTI’s Charles Rodes and featured another plenary lecture by Michael Rogers. Following the plenary lecture, the assembly participated in breakout sessions to discuss grand challenges selected for their relevance to RTI’s scientific future. The grand challenges session ended with a summary presentation of the breakout session discussions to the assembled Fellows.

The third half-day session was dedicated to RTI’s longer-term research horizons. This session was chaired by RTI’s Carla Ban and was moderated by RTI Lead Fellow, James Trainham. After a plenary lecture by RTI Distinguished Fellow, Ivy Carroll, breakout sessions were held to discuss the five key scientific dimensions of RTI’s research. Again, the breakout sessions were followed by summary presentations to the assembly of retreat participants.

The RTI Fellows have decided to base this work product on a combination of the retreat proceedings and subsequent thoughts that were stimulated by the retreat. It is believed that the resulting analysis of RTI’s research futures will be of value to RTI management and staff alike.

The following sections of this report present an overview of the retreat sessions and research discussions and a summary of the subsequent analysis. The report concludes with specific recommendations for RTI in the above areas of science.
2. **Megatrends**

*Definition and Significance of Megatrends*

As discussed above, megatrends are long-range, major developments—some that extend existing trends from the past into the future, and others that are expected to originate in the future from seeds in the past and present. Matthias Horx of Credit Suisse offers a working definition of megatrends as expected to continue for an average of at least 30 years; must affect all aspects of life, including everyday living, politics, culture, and the economy; are truly global; and are powerful enough to survive setbacks. Because RTI’s interests are global, this analysis follows Horx’s definition and focuses on megatrends of mostly global significance.

*Tools and Techniques to Detect and Analyze Megatrends*

During the tutorial part of his plenary lecture Michael Rogers introduced several techniques for detecting and analyzing megatrends, including Delphi panels, in which experts exchange and analyze their views (often face-to-face); scenario building; trend forecasting; computer simulations; mathematical modeling; integrative or intuitive anticipation; and “black swans.” Black swans are rare and largely unanticipated developments that have an important impact, either positive or negative. Other techniques for addressing the future of megatrends may include morphological analysis (i.e., non-quantitative modeling, considering and ranking all possible outcomes); heuristics (i.e., “common sense” outcomes); technology forecasting; strategic foresight; and self-fulfilling or self-defeating prophecies. Most of these techniques have a significant literature and followership.

*Megatrends Today*

Michael Rogers reviewed some of the generally accepted megatrends of today, including population growth; the aging population; the new middle class (Asia-Pacific); frugal design; climate change; health care as a human right; diseases of affluence (e.g., obesity; stress; diabetes; environmentally induced cancer; Alzheimer’s); diseases of poverty (e.g., measles, infant diarrhea, river blindness, malaria); global connectivity; smart objects (e.g., the electronics-laden BMW); telepresence; and “nothing under the radar” (i.e., pervasive surveillance, accessibility, and detectability). Michael Rogers stated that if there is any debate about these megatrends, it is only about their timing and extent.

Demographic megatrends dominate the thinking of the previously quoted Matthias Horx. Horx’s megatrends include the increased human lifespan and its implications for health care, work, and leisure; the growth of unemployment and its implications for the pension systems in developed countries; the emergence of Asia (e.g., market power, aesthetics, philosophies, demography); and the global emergence of the educated woman, with implications for marriage, family, motherhood, and birth rate.

We have synthesized the above trends into the following structure for use in our subsequent analysis:

- Population
  - Population growth
    Some societies tend to be stagnant or shrinking, while others grow at a high rate, with implications to energy consumption, employment, education, welfare, crime rate, and security
  - Increasing human lifespan
    Demography shifts with implications to business, social services, and health
– **Health care as a human right**
  Organization and funding

– **Urbanization is accelerating**
  Implications to infrastructure, crime rate, transportation, and security

– **Education’s increasing importance in a modern economy**
  The sustainability of the high and rapidly increasing U.S. tuition rates

– **Increasing unemployment in the developed world**
  Social services under stress

– **Increasing mobility**
  Impact on business practices and leisure time

– **Society’s increasing diversity**
  How to make best use of societal diversity as an advantage

  ▪ **Globalization**
    – **Manufacturing and commerce are globalized at a breathtaking pace**
      Business and societal consequences; is there an optimum between national and global?
    – **Wealth in developed countries, poverty in underdeveloped countries, and the increasing gap between the two**
    – **Natural resource allocation across the globe is an increasing economic, political, security, and defense issue**
    – **The emergence of Asia (economic, cultural, political)**

  ▪ **Sustainability**
    – **Food and clean water resources become more scarce**
    – **The environmental impact of rapid industrialization (China, India)**
    – **Competition for oil between the developed and developing worlds**
    – **Increasing concerns about the globe’s ecology and future climate**
    – **Reassessment of global oil and gas reserves due to new technologies of extraction**

  ▪ **Technology Development**
    – **Information and entertainment change at a dramatic pace**
    – **Diminishing privacy (i.e., pervasive accessibility and detectability)**
    – **Electronic connectivity and communication change how we live and work**
    – **Health and health care are becoming increasingly more sophisticated, more effective, and more expensive**
    – **Materials and energy technologies evolve at a rapid pace, impacting our infrastructure, transportation, and energy consumption and use**
    – **Automation and robotics continue to eliminate manufacturing jobs, but at the same time, create the need for a sophisticated work force**
Retreat Discussions on Selected Megatrends

Population Growth

Moderator: Lee Mobley
Rapporteur: Don Bailey

Population trends are not homogeneous. In some parts of the world (e.g., Europe), the population is shrinking; in other parts (e.g., Africa, India, the Middle East), the population is growing exponentially, whereas in China, the growth of population is tightly controlled. Population growth, which affects wealth and poverty, depends on the role and education of women in society, on mortality rates, and on birth rates. Political instability and epidemics also have a significant influence on population growth.

Questions focused on populations trends include the following:

- Is there a limit to the Earth’s human population?
- Is that limit controlled by future resources after all, as originally suggested by Malthus?
- Is there an optimal size of the Earth’s population, or an optimal rate of population growth?
- Can population growth be controlled?

No definite conclusions can be reached about these questions. In a democracy, population growth cannot be controlled; however, the education and empowerment of women, along with the elimination of poverty, has strong indirect effect on population trends in developing countries.

Global Connectivity and Globalization

Moderator: John Newman
Rapporteur: Suzanne West

Global connectivity is both a powerful tool and a source of major social disruption, with a net positive effect in driving progress. There are well-known upsides and often unrealized downsides of global connectivity, and these have implications for RTI’s involvement in the information revolution.

Upsides include business and manufacturing efficiency, better communications between people and between countries, improved disaster relief, and a better-informed public on critical issues.

The negatives of global connectivity include the increasing isolation of those who are not part of the modern communications networks; the reduction of personal contact to virtual interactions; the emergence of privacy, surveillance, and cyber-security issues; some potentially negative cultural effects (e.g., the disappearance of conventional record and book stores); and information overload. Global connectivity contributes not only to increasing global cultural homogeneity but also to increasing cultural, religious, and political fragmentation and segregation.

While massive amounts of information are being stored, the quality of the information may be questionable. In addition, the use of ever-changing, increasingly sophisticated, and powerful storage systems means that information stored in outdated media and data formats is increasingly likely to become perishable.

The effect of the information revolution on RTI is pervasive, with ramifications for surveys, training, technical services, health care, the social sciences, and technical research in defense, electronics, and energy. Web publishing has speed and accessibility advantages, but its quality is often suspect or at least unknown.
Health and Health Care

*Moderator: Derick Brinkerhoff*
*Rapporteur: Kenneth LaBresh*

On a global scale, human health issues have transitioned from communicable diseases, such as tuberculosis, to non-communicable diseases, such as cardiovascular disease, as the main causes of death. U.S. health care trends include increasing costs and reducing cost effectiveness: the United States is a leader in per-person health care costs, but 39th and 42nd in mortality rates (female and male, respectively), with an estimated 50 million people uninsured. Public health care policy, or the lack of it, also is a critical factor.

Technology has been a key driver of progress. Promising future trends include increasing efforts for prevention (e.g., utilizing the promises of personalized medicine), telemedicine (e.g., remote monitoring, diagnosis, and treatment), lifestyle modifications, and the therapeutic applications of personalized medicine. Another focus is the meaning and future feasibility of health care as a human right.

Sustainable Planet

*Moderator: Paul Biemer*
*Rapporteur: Kenneth Rothman*

It is difficult to define a unique concept of sustainability for the Institute: are we trying to sustain the condition of nature, the human race, or some compromise between the two? Perhaps the best definition of sustainability is a set of actions that eliminates the need to “borrow from” or harm future generations.

Among the major trends of sustainability are the rapidly increasing human consumption of materials and food and the concomitant growing need to conserve, reuse, and recycle. Earth, including its atmosphere, has a nearly closed mass balance, but an open energy balance. Little mass is added to or subtracted from the “terrarium” which we live in, but we produce hazardous chemicals, pollute the atmosphere and water, which may alter the Earth’s energy balance by changing the composition of the atmosphere and thus its transmittance and reflectivity of thermal radiation.

The key elements of sustainability appear to be clean air, clean drinking water, sufficient arable land, natural forests, clean and fish-laden rivers and oceans, and the conservative use of natural resources, including primary energy sources and minerals. Macroscopic trends show continued accumulation of air pollutants from rapidly growing developmental economies, an increase of water salinity owing to agricultural activities, and increasing global deforestation stemming largely from rapid population growth. On the other hand, there appear to be abundant global sources of energy. Coal, natural gas, shale oil, and uranium all have been projected to last for many decades. However, this abundance comes at the expense of significant externalities (societal costs not reflected in energy prices).

Sustainability has significant socio-political and economic dimensions as well. Public policy has played a critical role in balancing economic sustainability with the sustainability of the ecology and the environment.
3. Grand Challenges

Definition and Significance of Grand Challenges

Grand challenges are defined as significant problems or opportunities that affect the entire humanity, or one or more nations; usually transcend the boundaries of scientific disciplines and political interests; and are often perceived to require significant efforts to surmount or harness, but are considered possible and worth the effort.

How Do Megatrends and Grand Challenges Connect?

Megatrends present the macroscopic trends of phenomena, activities, or societal behaviors, while grand challenges define the resulting technological, economic, or societal challenges or opportunities. As an example, population growth in developing countries may be viewed as a megatrend, while the associated need for the development of an effective and efficient health-care system to deal with its consequences may be viewed as a grand challenge.

Grand Challenges Today

Many fields of human endeavor, such as science, mathematics, engineering, economics, and politics, as well as various organizations and countries, have defined lists of their grand challenges. Michael Rogers cited some of these grand challenges during his plenary lecture, including NASA’s Centennial Challenges (e.g., power beaming to and from space; sample return robot; green flight); Grand Challenges in Global Health (e.g., creating vaccines that do not require refrigeration; determining which immunological responses provide protective immunity; developing therapies that can cure latent infections); the Grand Challenges of the National Academy of Engineering (e.g., making solar energy economical, preventing nuclear terror, providing energy from fusion, restoring and improving urban infrastructure); the Defense Advanced Research Project Agency (DARPA) Grand Challenges (e.g., development of an autonomous, driverless vehicle), and Augustine’s Dark Challenges (e.g., cleanup after nuclear terrorism, developing a response to a global pandemic event).

The grand challenges list of Richard Smalley (Nobel Prize in Chemistry, 2005) is appealing for the purposes of this exercise because it closely overlaps with RTI’s grand challenges and RTI’s mission of improving the human condition; therefore, it is actionable by our programs and capabilities. Mr. Smalley’s list begins with energy as the controlling challenge; other grand challenges tend to be subordinated to energy in that they either depend critically on energy, are prompted by energy issues, or they have a critical influence on what to do about energy. Mr. Smalley’s list continues with water, food, environment, poverty, terrorism and war, disease, education, democracy, and population.

The Fellow-sponsored Grand Challenge program of RTI was devised to address complex and critically important challenge topics that benefit mankind and whose solution would be enhanced by the wide array of cross-disciplinary skills at RTI. An additional return on the Institute’s investment in the Grand Challenges program is the cross-unit, cross-center communication that it fosters, along with the synergies that result from the diverse interactions. Some more specific grand challenges that may be relevant to RTI’s long-term capabilities and interests would include the following:

- What should be the optimal U.S. health care system? Can this problem, including its costs and cost escalation, assessments, and treatments, be defined and analyzed, and an optimized solution proposed?
• How can globalization be better managed, especially with regard to its effect on economies, employment, manufacturing, and competitiveness? How can we define, maintain, and enhance U.S. competitiveness in a globalized economy?
• How can energy externalities be used to justify the development and funding of alternate energy strategies?
• What is the solution to illegal immigration between the two non-workable extremes of collecting and expelling 11 million illegal immigrants and building a wall around the country, and providing unconditional amnesty to all? Is there a rational, optimal, and humane solution?
• How can we fund the overhaul and modernization of the physical infrastructure of the United States and maintain it into the future?
• How can we help provide the most basic human needs, including sanitation, clean water, clean indoor air, and nutrition, to reduce premature deaths among the very young in poor countries?

Retreat Discussions on Selected Grand Challenges

The Role of Nuclear Energy

Moderator: Dorota Temple
Rapporteur: Philip Cooley

Nuclear energy has great opportunities and great challenges. At this point, there seems to be plenty of inexpensive uranium. The challenges are to balance the positives of nuclear energy, which involve clean and safe energy if managed properly, against potential negatives, such as waste storage; the potential for catastrophic damage; high capital cost and capital risk; competition with currently plentiful natural gas; regulatory complexity; and public perception of the nuclear energy’s risks and benefits. While there have been a few safety incidents, those that have occurred tended to slow or halt nuclear plant construction for extended periods. Technologies on the horizon may significantly enhance the appeal for nuclear electricity; in escalating sequence of technical challenges, they include fuel reprocessing to save uranium and reduce the volume of nuclear waste; the use of “small” nuclear reactors (about one quarter of the current size, representing a reduced incremental capital investment and operational risk); intrinsically safe reactor configurations that extinguish rather than run away in cases of cooling system malfunction; fast breeders that utilize more of the energy content of the fuel rods and thereby extend uranium supply from decades to centuries; and finally, nuclear fusion, which would provide almost unlimited energy supply with little risk and hazardous waste storage problems. Thus, the fate of nuclear energy is a complex conundrum of competitive technologies, economics, and societal considerations. RTI’s opportunity is to analyze and model these forces.

Global Poverty and Democracy

Moderator: Kathleen Lohr
Rapporteur: Gary Bland

The interrelationships between prosperity, which may be viewed as economic freedom, and democracy, which may be viewed as political freedom, are complex and not well understood. In relation to global poverty and democracy, the following questions could be addressed: Which should be first in sequence of timing or importance? Will the elimination of poverty in a non-democratic system, such as in China, eventually lead to democracy, or will democracy in a poor country, such as India, eventually lead to eliminating poverty? How can we understand complex political upheavals like those in present-day in Egypt and Libya (“Arab Spring”)?
In developed countries, a demographic pyramid exists that provides economic security for the elderly. Some of the poorer countries have substantial youth populations ("youth bulge"); with no economic opportunities for their youth, their demographic safety-net pyramid does not exist. Economic globalization creates substantial pressures, both in developing and developed countries.

Globalization as a megatrend will continue to take place nevertheless; the question is, how best to manage its consequences. RTI is well equipped to deal with the above issues of democracy and poverty, and there is great need for more research on this topic. Towards this grand challenge, we can deploy our skills in statistical modeling and simulation, demography, epidemiology, pathology, immunology, sociology, anthropology, health research, education, communication, survey work, and information technology.

Non-Communicable Diseases and Global Health

*Moderator: Kenneth Rothman
Rapporteur: Thomas Hoerger*

Non-communicable diseases, including heart disease, lung and respiratory disease, cancer, diabetes, and Alzheimer’s disease, now account for more deaths than communicable diseases, largely owing to improved controls on the latter. The best approach for tackling the challenges of non-communicable diseases would appear to call for a combination of life-style changes such as smoking avoidance, eating healthful foods, exercising, and stress reduction. Such changes would be combined with technological developments, such as stents, scans, antibiotics, and implants, and with prevention-oriented drugs, including statins and anti-hypertensives. The overall balance would shift more toward prevention and away from treatment. The great success in reducing the mortality from heart disease in the United States by a factor of two may be an experience exportable to other countries. A great challenge in the United States is how to expand health care coverage without increasing the already very high costs. Life-style changes may be positively affected by the with the help of electronic media. The objective is the societally affordable extension of a high-quality life.

Clean Water Supply

*Moderator: Brian Stoner
Rapporteur: Rochelle Tyl*

Over a billion people are without adequate potable water, and an additional 3 billion live in water-stressed areas. In the United States, 80% of the “sweet” water is used for industrial and farming purposes, 15% for sanitation, and only 5% for drinking water. The definition of “clean water” depends on its uses. Forty-six of the 48 contiguous states are projected to have water shortages in the near future. Potable water is also an energy issue: given enough cheap energy, potable water can be readily manufactured with known technology. Water use standards were last set in the 1970s, and even those standards have not yet been met. The use of drinking water for sanitation and lawn care, car washes, and the like is wasteful. A dual water system might be a better idea.

The U.S. water infrastructure is old and requires urgent overhaul. The problems are likely exacerbated by population growth, mobility, and climate change, and may eventually grow into a national security issue. RTI’s capabilities in regulatory compliance, political science, psychology, education, policy work, chemistry, biology, and engineering could contribute to ameliorating the water-related grand challenges.
Global Climate Change and Quality Of Life

Moderator: Michael Halpern
Rapporteur: David Ensor

The climate-change issue is multi-faceted: is the climate changing, and if so, what causes it, what is the projected extent of future changes, can we mitigate climate change, and can we adapt to any changes we could not mitigate, or decided not to mitigate? Answers to these questions involve climate science, politics; energy policies, the roles of and impacts on rich, developing, and poor societies; time scales and priorities; the quality and credibility of climate predictions and forecasts; and society’s ability and willingness to tackle these issues.

Developing countries may be hesitant to compromise their development by initiating climate-change mitigation measures, and a portion of the U.S. society either believes that the nation has more urgent or more important challenges to deal with than climate change, or even doubts the validity of the problem. Clean energy programs, however, have many additional justifications beyond their climate-change impacts. Possible consequences of inaction, or ill-conceived action, may lead to economic and political dislocations or even disturbances, because beyond the quality of life, one must consider the ramifications of health, food, housing, transportation, education, and employment.
4. RTI Research Horizons

The Past and Present of RTI, with Implications to Its Future

Ivy Carroll, Distinguished Fellow, gave the plenary talk for this session. He reviewed the history of RTI, including its physical, fiscal, and intellectual histories; identified proactive and independent research as a key ingredient in RTI’s past successes; and called for increased effort to re-energize that mode of operation in a modernized fashion to meet RTI’s future opportunities.

Retreat Discussions on Selected Research Horizons

Social Sciences, Statistics, and Economics

Moderator and Rapporteur: Gary Bland

Statistical and social science research have been cornerstones of RTI since its inception. These disciplines have applications within each of the megatrends (i.e., population growth; global connectivity and globalization; sustainable planet; and health and health care) and grand challenges (i.e., nuclear energy; global poverty and democracy; non-communicable diseases and global health; clean water supply; global climate change; and quality of life) discussed at the retreat. Statistics allow us to measure, monitor, and evaluate these trends, while the social sciences allow us to understand the human role in responding to them.

This research session focused primarily on the horizons related to RTI’s work in international development, epidemiology, and statistics. A predominant trend in international development is to apply rigorous scientific methods that are commonly used in other fields (e.g., randomized trials, survey data collection, psychometrics) to quantify change. Another trend is to conduct continuous monitoring and evaluation of international development programs while they are in progress, rather than waiting until a program is complete, thereby allowing for more timely feedback to stakeholders and permitting program modifications, if needed.

In epidemiology, one trend is the movement to conduct prospective, longitudinal studies via the Internet. Recruiting and surveying volunteers via the Internet allows for quicker data collection with significant cost savings compared to traditional data collection methods. For example, this approach can be particularly helpful in studies involving recruitment of patients with rare diseases. Another trend in epidemiological and statistical research is to mine secondary data collected for other purposes, such as registries, electronic medical records, and claims from insurance companies.

Finally, an explosion in data collection and availability from a wide variety of sources, both nationally and internationally, combined with increasing demands for accountability and targeting of resources, have shaped the field of statistics. One resulting statistical trend, “omics,” is discussed in greater detail in the Biology and Biochemistry section, below. Another statistical trend is a growing demand for predictive analytics, which involves using existing data to develop models predicting future behaviors and events, thereby allowing stakeholders to target resources based on the expected course of events. While more commonly used in marketing and business applications, predictive analytics is increasingly used in research applications, such as predicting future disease outbreaks.

Other statistical trends include greater use of Bayesian statistics to incorporate available information into statistical analyses. For example, Bayesian adaptive designs may be used for planning clinical trials with fewer participants while obtaining sufficient statistical power by utilizing available information on anticipated effect sizes. Social network analysis may be used to capitalize on data concerning contacts.
among groups of people to identify opinion leaders and target social and health marketing messages to them. Comparative effectiveness research (described in the Health and Health Care section, below) also presents unique statistical challenges, such as the use of meta-analysis and other statistical methods to combine or compare data on treatment effectiveness from disparate studies with very different study designs and populations.

**Engineering and Technology**

*Moderator: Brian Stoner*

*Rapporteur: R.K.M. Jayanty*

The march of electronics into our everyday lives continues to accelerate. The old paradigm of semiconductor chips confined to the inside of computers is being replaced by a new paradigm: chips embedded in cars, airplanes, appliances, phones, medical devices, smart cards, cameras, and displays, networked and connected to the Internet, making the world around us increasingly smarter and more efficient. It is now projected that Moore’s law, which states that the information density of integrated circuits will double approximately every 1½ years, will continue to hold for the next 5 to 10 years, when feature sizes become limited by molecular dimensions. New types of electronic devices will emerge, such as organic transistors, spintronic devices, and quantum optical and quantum dot devices. New software algorithms will be allowed by super-fast parallel computers employing quantum computing. The semiconductor chip will gain increased functionality. Previously independent devices, including analog devices, memory, sensors, and actuators, will be increasingly integrated into single chips, resulting, for example, in smart sensors that will be able to provide sophisticated functions, such as image and pattern recognition, with minimal energy consumption. Many of these functions will imitate massively parallel signal processing that is characteristic of biological systems; the human brain, for example, is a massively parallel processor that consumes very little power, only about 16–20W. The increasing functionality of individual chips, coupled with the need for minimizing the size, weight, and power drain of the resulting electronic system, particularly in mobile communication and implantable biomedical devices, will require advanced 3-D integration techniques, which RTI is well poised to provide.

Clean energy technologies will gain increasing importance, performance, and economic viability, with their corresponding higher technical sophistication. RTI already has programs in solar cells, thermoelectrics, clean coal technologies, methane conversion technologies, biofuels, and solid-state lighting, with the underlying catalyst and catalytic process technologies, sorbents and sorbent-based separation process technologies, and materials and electronics technologies supporting the above. Growth opportunities may include electric and natural gas storage devices, which could be based on RTI’s skills in materials technologies, and a foray into related process design and scale-up capabilities.

In biomedical and biotechnology applications, opportunities include integrating stress monitoring devices, diagnostics (e.g., biomonitors for the early warning for cancer), and biologically active biomedical devices.

Environmental technologies will continue to advance, both in the form of devices and systems with low intrinsic effluents or emissions, and also in the form of after-treatment technologies. A significant part of environmental technologies involves sensors and monitors to feed information to automatic control systems.

Advanced materials, such as nanostructured polymers, nanofibers, nanoparticles, and high-temperature structural materials, find increasing applications in electronics, in energy conversion, energy storage, energy utilization, and biomedical and environmental systems. RTI is well positioned to participate in the future of advanced materials.
The overlaps between the above areas of technology also represent significant new opportunities, an example being the combination of electronics with biomedical materials to design new biomedical systems.

**Biology and Biochemistry**

*Moderator and Rapporteur: Lee Mobley*

Because there is an interaction among the genome, the epigenome, and the environment, it is crucial that we understand these dynamics so that we can manage outcomes related to environmental degradation that affect genetic or epigenetic adaptations and alter the threshold for human susceptibility to damage, disease, and psychiatric disorder. Population growth is likely to compound issues pertaining to sustaining the planet in ways that are relevant to the role of the omics fields in understanding and reacting to these individual or subgroup susceptibilities. Omics is a general term for a broad discipline of science and engineering for analyzing the interactions of biological information objects in various “omes.” These include genome, proteome, metabolome, expressome, and interactome.

There is also potential for trends in global health and health care to influence the ways in which RTI determines priorities for, and apply, the omics. The spread of disease, new strains of bacteria and other contaminants, aging populations, and other trends in health are likely to influence the research in and applications of the omics that will inform evidence-based treatment decisions and the targeting of treatment delivery systems.

The findings that have been compiled related to the omics disciplines (principally genomics) challenge the traditional view of our genetic blueprint as a tidy collection of independent genes with single-gene effects. Current views that have emerged since the completion of the Human Genome Project (HGP) 10 years ago suggest a complex network in which genes, along with DNA and RNA regulatory elements and other types of DNA sequences that do not code for proteins, interact in overlapping ways with each other and with environmental factors not yet fully understood. In summary, although focus of the HGP was collecting and sequencing genomics data, after 10 years of reflection and analysis, it is apparent that sequenced data are far from the complete story.

RTI’s current state of knowledge is only at the tip of the iceberg. We need to go beyond genomics if we plan to understand the major biological mechanisms and processes. Incorporation of other omics, in combination with other relevant disciplines, will more fully inform our understanding of dynamic biological systems, which underlie individual differences. RTI is now acquiring processes to collect data beyond genomics measurements. In the future, the Institute will be able to better incorporate and understand relationships among additional omics (e.g., epigenomics, transcriptomics, proteomics, metabolomics, populomics) to develop broader and more accurate insights.

New sequencers will be brought online, producing new data that go beyond genomics measurements. Synthetic biology experiments will add to RTI’s knowledge of biological mechanisms, satisfying the adage that if we build it, we understand it. The Institute will have available large collections of clinical and biological samples, including tissue repositories to support analytic investigations. The above will lead to a better understanding of individual susceptibility based on individual genetic and epigenetic makeup and its response to environmental change—across the omics spectrum from genomics to populomics.

A synergistic view of genetic or epigenetic interrelationships will prevail, supplanting the current “additive” norm. This change will affect fields of neuroscience, psychology, psychiatry, social sciences, and populomics, among others. We will see environmental geneticists, for example, ferreting out
interactive contributions of exposures and genomic traits. Multilevel modeling in genetics research and a systems biology approach will be common. There also will be increased coupling of body–brain imaging techniques and genomics.

Advances in the omics will stimulate an explosion in the amount of information on variations of diseases and disorders, who is likely to suffer from them and with what consequences and outcomes, and a somewhat better knowledge about which therapeutic methods will be most effective and in which individuals. In parallel, scanning and tracking in these fields will be increasingly less expensive and thus available to greater segments of the global population.

Health and Health Care

Moderator: Thomas Hoerger
Rapporteur: Kenneth LaBresh

Health is a major core area of research for RTI, and the near term offers great opportunities to continue the many types of questions and projects with which RTI is involved. In addition, there are several areas that offer new growth opportunities:

- **Health insurance**: Ways to reduce costs while improving the quality of care will be the major focus of public programs, such as Medicare and Medicaid. RTI’s opportunities include the evaluation of related demonstration programs. Uninsured populations and trends may call for expanded attention.
- **Quality of care**: Among the areas of likely work are quality measures and measurement; the use of quality measures in pay-for-performance or other “accountability” schemes, and outcomes assessment, including patient self-reporting of outcomes.
- **Effectiveness and comparative effectiveness research**: Systematic reviews for guideline development are likely to expand, perhaps through the Patient-Centered Outcomes Research Institute established by the Affordable Care Act. Quality and evidence-based practice can collectively be extended to translating efficacy and effectiveness data into practice guidelines and patient safety programs and then to evaluating how well health care systems are implementing them.
- **Long-term care**: Most health-care expenditures are associated with chronic diseases rather than acute illnesses, and occur mostly in the last year of life. These will grow in significance, owing to the aging population. Chronic diseases lead to disability and the need for long-term care services with growing RTI research opportunities.
- **Health information technology (HIT)**: HIT will continue to grow in importance. Electronic health records and health information exchange have great potential to enhance care coordination, reduce duplicate testing, reduce medication errors, and increase the delivery of evidence-based care.
- **Health technology**: Health technology is expanding in numerous ways. One major example is sensors and patient monitors that provide patients and clinicians with real-time clinical measures (e.g., blood pressure), behavioral changes, medication adherence, and safety (among others).

Additional areas of health-related RTI research activities and interests include health insurance exchanges to cover the uninsured; health personnel (workforce), including shortages and other workforce issues for physicians, nurses, long-term care personnel, and numerous other professional and paraprofessional staff; outcomes assessment, such as item banking, item response theory, computer adaptive testing, and similar techniques; translational research (to help implementation of clinical results in the field); and global or international health. Several of these represent significant future growth opportunities for RTI research.
5. Conclusions and Recommendations

RTI is in a truly unique position among organizations of its kind because it can tackle problems in a multi-disciplined approach (i.e., technological, economic, and societal dimensions). RTI has been and will continue to be responsive to funding requests from the U.S. Federal Government, our current main funding source; however, the growth and security of the organization are dependent on exploiting the multi-disciplined approach and expanding funding beyond that from the government. The implementation of the ensuing recommendations is not trivial in a contract research and development organization that relies on external funding for the great majority of its research activities.

Social Sciences, Statistics, Environment, and Economics

Conclusions

The social sciences cover almost every aspect of human behavior and the societal structures and systems established to support life. Thus, almost all of the foreseeable megatrends have direct or indirect implications for the future of social science research.

The explosion of information from multiple sources around the world will continue to accelerate, providing new opportunities for gaining knowledge but posing critical challenges in managing and analyzing data.

- Data are at the heart of all of RTI’s research initiatives. The ability to find, access, integrate, and appropriately analyze large and rapidly changing data sets will be critical to the future success of social science research.
- The emergence of mobile technologies and remote sensing devices will transform the data collection process as we know it.
- Economics and the distribution of wealth have always played a defining role in shaping everything from individual behavior to world events.
- Advances in health care and dietary improvements have dramatically changed life expectancy around the world, resulting in large increases in elderly populations.

Recommendations

Based on the above conclusions, the Fellows have the following recommendations:

- Make megatrends integral to the process when planning the future of social science research at RTI.
- Equip and staff for the future’s requirement for the delivery of a high level of sophistication in data discovery, management, and analysis. This will require powerful computing capacity and staffing that exhibits transdisciplinary intellectual leadership to enable a rational understanding, both in real time and longitudinally, of the limitations and implications of data emerging from such analyses.
- Develop new technologies (both software and hardware) for data collection and use. This work needs to be coupled with careful attention to the accuracy and reliability of such information and the ethical issues surrounding the use of mobile technologies and remote sensing devices.
- Continue the development of a deep understanding of factors that influence individuals and groups to adopt or reject preventive or environmentally beneficial changes in lifestyle or behavior.
- Develop and validate a range of effective strategies to ensure that advances in knowledge are translated into real benefits for individuals and society.
- Maintain and expand the Institute’s ability to conduct accurate economic forecasts and to estimate the real costs and benefits of various policy options.
- Adjust to rapidly changing economic circumstances, and understand how psychological and sociological forces interact with economic decisions both large and small.
- Add economic research focus on energy and food production while maintaining the intense study of health care costs.
- Assume a major leadership role in understanding the full range of challenges associated with an aging population and systematic study of alternative policies and practices.

**Engineering and Technology**

**Conclusions**

Technological progress is not only a key megatrend, it is also a megaforce that is the source for other megatrends that are powerful instruments of change. Economic growth, for example, is strongly tied to technological progress because better technologies make it possible to produce cheaper and higher-quality goods and services. In combination, these two megatrends—technological progress and economic growth—have driven and will continue to drive an astounding amount of change in modern society. RTI already has a strong position in critical technology areas.

- Clean energy technologies will continue to increase in importance; the performance and economic viability of existing programs in solar fuels, thermoelectrics, clean coal technologies, biofuels, and solid-state lighting likely to contribute solutions to the grand challenge of transforming the U.S. energy infrastructure.
- The plethora of natural gas (NG) offers both major opportunities and potential environmental challenges to the future of renewable technologies.
- Storage devices for electric power and for NG offer additional research opportunities.
- Both NG and clean energy technologies would benefit from the process design and scale-up capabilities of RTI’s Engineering and Technology Unit.
- There are increasing applications in electronics, energy conversion, storage and utilization, and biomedical and environmental systems that utilize nanostructured materials fabricated into nanofibers, nanolayers, and quantum dots. The RTI nanotechnology program will find opportunities to expand into broader and more diverse areas of technical usefulness.
- There will be continuing opportunities to demonstrate proactive leadership in electronics and energy to further develop our expertise, capabilities, and external recognition in specific technology areas. RTI’s close interactions with large companies that have driven the development of specific products for government defense and security markets have influenced the directions that clients (e.g., DARPA) have taken in advanced microsystem integration and thermoelectric technologies.
- The increasing global connectivity and the attendant massive information flow will require targeted analysis of the information in specific areas, culminating in recommendations for actions. The most precious and sought-after commodity in modern society is wisdom and insight, and these are facilitated through filtering and analyzing of the ocean of information.
Recommendations

Based on the above conclusions, the Fellows have the following recommendations:

- Provide small-form-factor and low-power 3-D microsystem solutions for multispectral and multifunctional sensing and communications.
- Leverage existing expertise in flexible electronics (e.g., electronics on curved or plastic substrates) and become more relevant as the interface between humans and computers becomes more seamless. This would include the development of components that would enable room surfaces or eyeglasses to serve as network interfaces, and the development of wearable and implantable “smart” sensors that support advances in personalized medicine and telemedicine.
- Expand technology programs to take advantage of expertise in social science programs emerging from the analysis of megatrends and grand challenges, including
  - Deploying our expertise in 3-D integration and flexible electronics to biomedical applications for the development of miniaturized, low-power implantable devices; ubiquitous, disposable, networked sensors, and wearable diagnostic devices.
  - Look for opportunities for collaborations with academia to translate basic research in post-silicon electronic materials into manufacturable device technologies.
  - Create a focus area spanning electronics, energy technologies, and nanostructured materials for the development of energy storage solutions.
  - Add expertise in polymer technology to support both the electronics and energy programs.
  - Expand multidisciplinary technology analysis offerings in the energy domain.
- Build relationships with large commercial companies, culminating in joint development projects (JDPs) for specific product lines. This approach is likely to be a more effective use of investment funds than a fully internal turn-key technology development, which requires huge investments. Successful JDP relationships would generate license fees and royalties to expand RTI discretionary funds.
- Consider and study the dissemination of our reports through marketing to a network of subscribers or through purchase the open market. The energy domain appears receptive to multidisciplinary analyses—energy infrastructure is incredibly complex and large, with new technologies emerging all the time, unavoidable economic imperatives, and wild card social factors.

Biology and Biochemistry

Conclusions

A large part of the future of biology research depends on interdisciplinary studies that focus on all three dimensions (technological, economic, and societal). Some refer to this as Systems Biology.

The past few years have seen a remarkable number of technological advances in Systems Biology, among them the ability to read the expression of not one but thousands of genes and hundreds of proteins at a time. RTI has an opportunity to explore how the parts are integrated into a system and how, in a sense, the whole becomes greater than the individual parts. In addition, we can explore how our Systems Biology expertise can best be connected and coordinated to generate synergies beyond those available today, which could help harmonizing resources and expertise across the organization.
Recommendations

These recommendations are made to bolster this effort and present a unified front across the Institute to capitalize on the wide range of capabilities and intellectual capital we have in-house:

- Become a significant player in the accelerating evolution of molecular and cellular biology. Emphasize our unique position as one of the few organizations that house laboratory scientists and computational biologists under one roof.
- Provide capital investment to (1) develop a competitive infrastructure that includes computational platforms; (2) recruit renowned scientists with the requisite knowledge and leadership experience; and (3) cross-train our scientists in technologies that will change our methods of operation (e.g., the development and use of parallel processing and cloud-computing technologies).
- Develop mechanisms that facilitate the synergistic cooperation across research silos. Develop appropriate incentives to make this happen.
- Expand and integrate ongoing activities devoted to the repositories for biological data and samples (e.g., the National Institute of Diabetes and Digestive and Kidney Diseases [NIDDK] data and sample repository).
- Build mechanisms into our infrastructure to tangibly link the bioinformatics experts, who are available in multiple RTI units, with our niche scientists that pursue translational medicinal science and personalized medicine.
- Increase participation of biological scientists in discussions to identify common interests and capabilities that are specific to individuals to promote cross-silo collaboration.

Health and Health Care

Conclusions

- The recent recognition of non-communicable diseases (NCDs) as the world’s number one health problem provides RTI with a major opportunity to address the critical issues in U.S. health care and to use our experience and understanding of health care systems to address NCDs around the world.
- In the United States, the significant reduction in deaths from heart disease is largely related to the reduction in the development and control of risk, which, in turn, relates directly to structural change in the environment and to behavioral change in individuals. Improved outcomes for individuals with cancer also reflect reductions in risk behaviors, as well as increases in screening for early detection and improved treatment options. Effective strategies to support behavior change and self-management of chronic diseases will be increasingly important skills to address NCDs.
- The translation of behavior-change strategies to other cultures presents a major opportunity for RTI to diversify its funding base.
- Efforts to improve access to health care coverage to all of our citizens are creating a critical need for the development of more efficient and effective primary care delivery systems.
- Surveillance methodology to obtain health risk data from populations will be important to planning efforts and tracking the progress of public and health system efforts to reduce risk and prevent recurrent events.
Recommendations

- Create closer interactions between RTI’s expertise in clinical effectiveness research and health services and economics expertise to address efficiency in health care guided by the effectiveness of public health and clinical processes.
- Continue to pursue work that combines health communications, behavior change support, and health information technology to create novel integrated approaches to reducing the risk of NCDs.
- Expand RTI’s competencies and capacity in the design, implementation, and evaluation of mobile-health and other digital strategies to address health behaviors.
- Leverage RTI’s experience with payment incentives, quality of care, and quality measurement to develop international projects to address NCDs and other health-related issues.
- Examine international health care practices, and identify lessons applicable to the United States.
- Create more effective communication strategies within RTI to better leverage our current clinical expertise and more effectively add to that expertise to meet the growing need for solutions to important health issues, especially the problems posed by NCDs.
- Use existing relationships and other strategies to develop and enhance effective partnerships with health care systems to facilitate the evaluation of strategies to improve the quality and efficiency of care.

6. Final Comment

The recommendations above are the product of limited and focused discussions, as explained in the introductory parts of this report. The Fellows were not able to cover RTI’s huge pallet of scientific disciplines, limited by the time available and by the specialized expertise and interests of the Fellows involved. In addition, while the Fellows looked at a longer time horizon, they found the need for making some shorter-range recommendations as well, and they have also been included in this report.

The Fellows hope that this report will initiate a deeper and more structured analysis of RTI’s future, involving not only the whole spectrum of our science but also the Institute’s opportunities in enhancing cross-disciplinary work and creating new business opportunities. Building on top of RTI’s considerable successes in generating knowledge to improve the human condition, we see a continued bright future for the Institute.