Making America More

Competitive, Innovative & Healthy

“The United States must try to compete in this world *and* maintain the quality of life we have enjoyed thus far. This challenge is far more daunting for us than for any other country.”

–Charles M. Vest, President, National Academy of Engineering

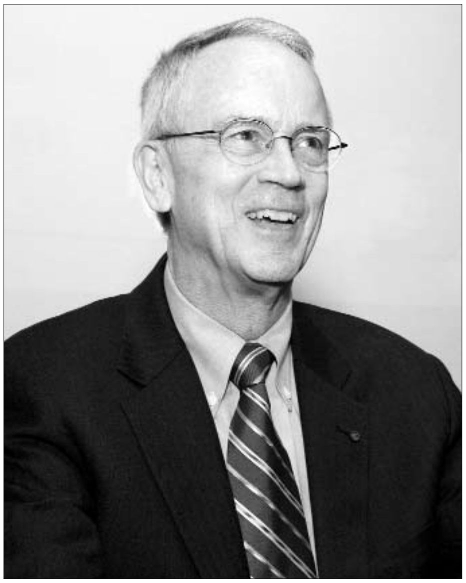
On April 14, 2011, at the House of the Academy in Cambridge, three Academy Fellows, leaders from the nation’s engineering and medical sectors, offered their views on the interconnections between American competitiveness, innovation, and health.

Charles M. Vest, President of the National Academy of Engineering, opened the discussion by focusing on U.S. research universities, which “produce much of the most important basic knowledge and technologies,” and U.S. companies, which “convert new ideas into real products and services that drive our economy forward.” Vest warned that political, social, and fiscal challenges are undermining this special relationship, including deficiencies in K-12 education that affect the university’s role in developing an educated workforce.

Drawing on her experience at Bell Labs in the late 1970s through mid-2000s, **Cherry A. Murray**, Dean of the School of Engineering and Applied Sciences at Harvard University, described institutional characteristics that create and sustain innovation. She pointed out that “more than money is required”; physical proximity to universities, for example, and support for interdisciplinary collaboration also play a part in fostering “local innovation ecosystems.”

Harvey V. Fineberg, President of the Institute of Medicine, highlighted the positive interaction between an individual’s health behaviors and “innovation in health technology and processes.” He cited Johnson & Johnson’s Live for Life, a health promotion program for its employees, as one successful new approach, and he advocated further innovation: for example, a national competition among U.S. mayors to support local health initiatives.

The panel discussion served as the Academy’s 1970th Stated Meeting; it was held in collaboration with the National Academy of Engineering, the Institute of Medicine, and the Harvard School of Engineering and Applied Sciences. The following is an edited transcript of the discussion.



Charles M. Vest

Charles M. Vest is President of the National Academy of Engineering and President Emeritus of the Massachusetts Institute of Technology. He was elected a Fellow of the American Academy in 1991.

Tonight's discussion centers on how to maintain a competitive, innovative, and healthy nation, goals that are interrelated in many ways. Not surprisingly, I will anchor my comments on U.S. competitiveness in the work of the National Academies' report *Rising Above the Gathering Storm: Energizing and Employing America for a Brighter Economic Future* and the recent update of that report.[1]

Because we have been so blessed in this country, we tend to assume that we are the best in the world. Yet we should take note of the areas in which we are not, by most metrics, ranked number one. For example, we are sixth in global innovation-based competitiveness and fortieth in the rate of change in that measure over the last decade. We are eleventh among OECD (Organisation for Economic Co-operation and Development) countries in the fraction of our young adults who have graduated from high school (a number that is truly appalling) and sixteenth in college completion rate. We are twenty-second in our provision of broadband Internet access to our citizens; twenty-fourth in life expectancy at birth; and twenty-seventh among developed nations in the fraction of our college students receiving degrees in science or engineering. Finally, according to the World Economic Forum (and I admit that this measure is somewhat subjective), we are forty-eighth in the quality of our K-12 math and science education. These figures put American exceptionalism in context: we are number one, except when we are not.

When this knowledge began to emerge six or seven years ago, a bipartisan group of members of the House of Representatives and the Senate requested that the National Academies undertake a study to answer the following questions: "What are the top ten actions, in priority order, that federal policymakers could take to enhance the science and technology enterprise so that the United States can successfully compete, prosper, and be secure in the twenty-first century? What strategy, with several concrete steps, could be used to implement each of these actions?" Our committee of twenty individuals, led by Norm Augustine, concluded that if we as a nation want to be competitive, we first have to pay attention to the fundamentals: to education and access to it; to investment in research in order to develop new ideas, understandings, and technologies; and to the policy infrastructure and, in some cases, physical infrastructure that bolster our national competitiveness.

The *Gathering Storm* report outlined four general recommendations. First, and most important, we must increase America's talent pool by vastly improving K-12 science and mathematics education. Second, we need to sustain and strengthen the nation's traditional commitment to long-term basic research. Third, we should strive to make the nation the most attractive place to study and perform research so that we can develop, recruit, and retain the best and brightest students, scientists, and engineers from the United States and around the world. Finally, we must ensure that the United States is the premier nation for innovation, investment in downstream activities such as manufacturing and marketing, and creation of high-paying jobs based on innovation. Largely on the basis of this report, but also on work by other groups, especially the Council on Competitiveness, the America COMPETES Act of 2007 established a pathway for the United States to reinvigorate its basis for being competitive in the twenty-first century. It passed unanimously in the Senate and by a huge bipartisan margin in the House, and was signed into law by President Bush.

Ralph Cicerone, President of the National Academy of Sciences, Harvey Fineberg, and I, recognizing that the bill would be up for reauthorization in 2010, called the committee members back together. We asked them to take a look at what had happened in the intervening five years and decide whether the country was on a good path and where the weaknesses and strengths were in implementing the original recommendations. The second report, subtitled "Rapidly Approaching Category 5," has a dark blue cover, as opposed to the bright red of the original report; a message lies therein. There is also a message in the opening epigraph, a quote from Ernest Rutherford that says, "Gentlemen, we are out of money. It's time to start thinking." In Washington today, we often find that we are out of money.

The group found that the report's original recommendations remain the right ones to implement, but that we have fallen far short of realizing our goals. The federal government has not advanced K-12 education according to our advice. Support for basic research, however, was strengthened throughout the last years of the Bush administration and in the first year of the Obama adminis-

[1] Committee on Prospering in the Global Economy of the 21st Century and Committee on Science, Engineering, and Public Policy, *Rising Above the Gathering Storm: Energizing and Employing America for a Brighter Economic Future* (Washington, D.C.: National Academies Press, 2007); Members of the 2005 "Rising Above the Gathering Storm" Committee, *Rising Above the Gathering Storm, Revisited: Rapidly Approaching Category 5* (Washington, D.C.: National Academies Press, 2010).

tration. The federal budgets for physical science and engineering research tracked closely with what we had recommended, but they are under precarious circumstances nonetheless. The funding was largely added on in a supplemental appropriation in one of the last two Bush budgets and was mostly funded by the stimulus package in the first Obama budget. While substantial, this funding appears tenuous going forward. On related recommendations, such as increasing the number of H1B visas awarded; making the R&D tax cut permanent; implementing changes in intellectual property law; and, especially, reforming export control, no substantial progress has been made.

Meanwhile, many other countries have heeded the call to invest in science education and scientific research. A science-and-technology-based university with a $10 billion endowment recently opened. There will be 200,000 students studying abroad at the cutting edge of science and technology. An innovation city of 40,000 residents is under construction. A new global nanotechnology hub has emerged, and may at some point have fourteen advanced universities in its vicinity. A high-level government commission patterned on the *Gathering Storm* story has been established. Unfortunately, these developments occurred in Saudi Arabia, China, Russia, India, and the United Kingdom, respectively – not in the United States.

Every nation is facing difficult challenges, particularly following the economic and financial declines of the past few years. But the United States must try to compete in this world *and* maintain the quality of life we have enjoyed thus far. I believe this challenge is far more daunting for us than for any other country. Our fundamental finding in revisiting the *Gathering Storm* report can be summed up thus: "On balance, the United States' long-term competitiveness outlook (that is, jobs) has further deteriorated since the report was published five years ago." Commentators across the political spectrum have backed similar views. *New York Times* columnist Tom Friedman has endorsed the report's agenda and its urgency. So has *Washington Post* columnist George F. Will. Two weeks ago, when *Times* columnist David Brooks weighed in on the budget, he based his thinking on the perspective of declining U.S. competitiveness.

If we as a nation want to be competitive, we have to pay attention to the fundamentals: to education and access to it; to investment in research in order to develop new ideas, understandings, and technologies; and to policy infrastructure and, in some cases, physical infrastructure.

In the United States, we have what is loosely called the "innovation system." This system consists of three elements: our research universities, our policy and funding network, and ultimately, the companies that convert new ideas into real products and services that drive our economy forward. Our research universities, particularly our public universities, are at substantial risk today, yet they are the element without which none of this innovation can happen in the long run. Our universities produce opportunity for our graduates by preparing them to be good citizens, to have good jobs, to contribute to our economy and well-being. But universities also provide opportunity to companies, through the ideas they spawn and the graduates they send to employers. Universities create opportunities for states, regions, and nations by strengthening society and economies. They produce much of the most important basic knowledge and technologies. A federal dollar spent on our institutions, public or private, does double duty: it provides an education for the next generation and produces research results. Sponsoring research based on competition among ideas is a better system than any other society has managed to put forward.

These days, however, public discourse has become vitriolic. Many of those in positions of political power fundamentally believe that university research produces nothing of value, that universities should get back to the business of teaching and leave the research to industry. In response to such thinking, I would point to a few of the significant university-based innovations from the last half of the twentieth century: the computer; the basic framework for the global positioning satellite, or GPS, system (which began at Harvard University with fundamental atomic physics and development of the atomic clock); the genomic revolution; the laser; the deployment of the World Wide Web; the Internet; numerically controlled machines that manufacture virtually everything today; and most of modern medicine. Given that we are all concerned about jobs, I challenge those who would take away funding for university R&D to name one job in the United States that does not depend on one or more of these contributions. We must address the precarious state of our entire education system. While the United States is properly, largely focused on how to restart and reinvigorate our primary and secondary education, what we do in universities is also extraordinarily important; in particular, we must keep them open to people of all socioeconomic strata who have talent.

I think we do have a serious strategic crisis. While the situation in the United States is one of political and social gridlock, other countries such as China are forming innovation systems of their own, and with a long-term strategic vision in the areas of energy, environment, and economic development. On the upside, this is the most exciting era in human history for science and technology. What our young people are doing today is stunning; we just have to be sure that we support them, and give them the opportunity to create as great a society as we had as young people. The United States has a democracy, a free enterprise system, a diverse population, and a stunning history. But to capitalize on our potential, we must produce two things: well-educated women and men, and new ideas that come from basic science and engineering research. And there is hope. As Winston Churchill famously remarked, "You can always count on the Americans to do the right thing, after they've exhausted all the other possibilities."

Cherry A. Murray

Cherry A. Murray is Dean of the School of Engineering and Applied Sciences at Harvard University, where she is also the John A. and Elizabeth S. Armstrong Professor of Engineering and Applied Sciences and a Professor of Physics. She was elected a Fellow of the American Academy in 2001.

In my discussion of American innovation in the twenty-first century, I will begin by describing two twentieth-century innovative environments that I have experienced firsthand. I will explain how to create or replicate a "localized" innovative ecosystem within a company or institution; within a community or city; and on a national scale similar to the one that formed in the United States following World War II. Then I will address how technology and globalization are changing these conditions in the twenty-first century. Finally, I will share my views on how we can sustain American ingenuity and entrepreneurship by focusing on education, and thus, how we can maintain a strong economy and standard of living.

Since the end of World War II, the United States has been the global leader in technology innovation. Here, *innovation* means bringing new products and services to the market, in addition to the process of invention. As noted economist Joseph Schumpeter explained, technological innovation often includes creating new technology and market paradigms or developing new technologies and industries that displace older ones to generate both wealth and social well-being.

What is an innovative environment? What is required to create and sustain such an environment? As an example, I offer my observations of a great twentieth-century supplier of technological innovation: Bell Labs research in the 1970s to 1990s. I began working at the company in 1978, as a member of the technical staff in the physical research laboratory, and was Senior Vice President of Physical Sciences and Wireless Research by the time I left in 2004.

AT&T, which owned Bell Labs, was one of several large U.S. companies with industrial R&D labs, including Xerox Palo Alto Research Center and IBM Research. These companies emerged as powerhouses of invention and innovation in the post–World War II American economy. All held a monopoly or near monopoly position in their market; all were focused on a variant of information technology; all were vertically integrated; and all had resources to support relatively basic research as well as pure product development.

The research staff in these labs published much of their work in the open literature (in addition to and after patenting their ideas) and thus served as a research supplier for the entire information technology industry. For example, Bell Labs and IBM published semiconductor electronics research on first demonstrations of new technologies that both Intel and Taiwan Semiconductor Manufacturing Corporation relied on to determine the semiconductor electronics technologies that were feasible and worth developing further.

Alas, these powerhouses no longer exist. Due to inevitable market forces, maturation of the technologies, growth of supply chains that supported de-layering, and government deregulation of these industries, very few technology companies can now support a large central research lab with relative intellectual freedom. There are, however, some key insights to be gleaned from how these companies operated.

From the 1970s to 1990s, the Bell Labs research area had roughly twelve hundred scientists and engineers, predominantly PhDs. The development area more closely associated with AT&T (and, after trivestiture, Alcatel-Lucent) business units had roughly thirty thousand employees, with a smaller percentage of PhDs (10 to 20 percent) supervising bachelor's-level personnel and technicians. Flow of ideas, people, and communications between R&D was encouraged by executive management, especially around conceptualization of new products and solving problems in the development of the next generation of products. In this "problem-rich atmosphere," a ventures business unit spun out small businesses around inventions that were not taken up by the various internal business units. Relevant parts of R&D were sometimes collocated, and the two sectors met regularly. Roughly 25 percent of postdoctoral scholars hired into research later found jobs in development, thereby forming a strong link between their former research supervisor and their new development team. Top researchers (usually first- or second-line managers) recruited outstanding PhD graduates from their alma maters and placed them in technical positions in science and engineering teams throughout the company.

In this vast pool of talented, highly trained technical staff, it was up to the entrepreneurial researcher to find scientists and engineers with the relevant expertise and then to interest them in his or her problem. Researchers inevitably ran into one another in the hallway as they moved from office to laboratory. Nearly everyone engaged in spirited technical arguments over lunch in the cafeteria and in the many seminars given by internal employees and a large number of distinguished visitors. Researchers learned what their colleagues were doing in hallway conversations; more often, they bumped into other Bell Labs researchers while attending major scientific conferences.

A number of creative tensions helped the company thrive:

- Lofty long-term goals (do the best science; create the future of telecommunications) were coupled with incentives to patent and push inventions into the market quickly. Some research organizations within Bell Labs focused more on one or the other goal; most were balanced and supported both.
- Researchers were considered career employees but were not guaranteed employment. A meritocratic management and performance review system led a small percentage at the bottom to leave the company each year.
- The management structure was strictly hierarchical at the same time that no professional or management titles were used and all staff were on a first-name basis, from technicians up to the president of Bell Labs.
- With research largely funded internally, managers allocated the finances they procured based on two competing priorities: generating the world's best scientific and engineering research, and generating the most business impact for the company. Managers were judged on their success recruiting talent into the organization and on how well they accomplished both conflicting goals. This task involved considerable risk: betting on creative people and their novel ideas rather than on projects that would succeed but would be more of the same.
- The company maintained a highly competitive yet collaborative environment. Bell Labs had an explicit policy whereby "empires" were not permitted to grow; therefore, employees had to team up to do something big or collaborate to acquire others' expertise or equipment.
- Teams were allowed to "self-assemble," or were occasionally brought together by management, depending on the project.
- Choosing problems to pursue was largely a bottom-up process (that is, managers would let a thousand flowers bloom, but quickly devote resources to the most promising few and cull the rest), but sometimes the route was top-down (that is, a manager would set a challenging goal and let the staff invent how to accomplish it). Perhaps the most well-known top-down project at Bell Labs was the solid-state amplifier that led to the transistor.
- Research was at an intellectual "critical mass," with sufficient expertise in many disciplines, yet most projects were starved for resources, which forced prioritization.

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What is required to create such an environment? This question is important precisely because the type of environment that allowed these major corporate labs to flourish no longer exists.

More than money is required: the risks funders are willing to take on ideas and people are even more important than sheer volume of funds. Bringing together, or allowing to self-assemble, a critical mass of interacting scientists and engineers over a considerable length of time – sometimes up to ten years – is necessary to provide an innovative solution to a particular problem. The practice of not allowing empires to form is probably also important.

I believe that at least some of the creative tensions that existed at Bell Labs must be present in an innovative environment. The best technical innovations come from interdisciplinary teams, not from individuals working alone. A culture of scientific meritocracy is essential. The managers directly supervising or funding research scientists and engineers must themselves be world-class scientists or engineers with a broad view of where a new invention might be best used to create value.

Making highly trained, inventive people available and willing to join an organization's research team requires a strong relationship with the top research universities in the relevant fields, or for the research to come directly from a leading research university. Major U.S. universities have had a better record of educating creative and inventive people than institutions in any other country, and teams of experts working on interesting and challenging projects tend to attract other first-rate scientists and engineers.

When a research team is exposed to challenging real-world problems that require multidisciplinary and diverse expertise, the resulting problem-rich atmosphere generates inventive ideas. Understanding market needs as well as customer reactions to an invention is important. Note also that a challenging problem might require a portfolio of subprojects that exist in three Stokes' quadrants at any one time: Pasteur's problem-driven science, Bohr's curiosity-driven science, and Edison's "do what works" approach. This implies a relatively large team of scientists and engineers working together on a specific technology, yet that team must be small enough to communicate and cooperate effectively. A critical mass could vary from fifteen to one hundred researchers, depending on the range of expertise needed.

At the same time the great industrial R&D labs were forming, another type of complex innovation ecosystem began to emerge, one that integrated public funding with the work of research universities. During and immediately following World War II, the United States established national labs to take over the functions of the Manhattan Project. The federal government also funded a cadre of university scientists, initially recruited to work in the wartime effort, to provide research in the service of national security. After the war, Vannevar Bush, the president's science advisor, provided the imperative for what eventually became a multiagency federal funding source for university research in science and engineering fields related to U.S. economic and national security. This infusion of federal research funding into universities, coupled with the 1980 Bayh-Dole Act, which permitted universities to own the intellectual property generated as a result of federally financed projects, greatly enhanced a scientific revolution in the last two decades of the twentieth century and had a profound effect on industry and innovation. In 1970, two thirds of R&D funding in the United States was from the federal government, a lion's share of the more fundamental scientific research at universities. University research led to the publication of scientific ideas, served as a source of PhD recruits for large, research-intensive companies such as AT&T, and produced a number of entrepreneurial spin-off companies, the disruptive technologies of which, in a number of years, successfully competed with established technologies.

Several complex innovation ecosystems evolved in regions around major universities: notably, Silicon Valley developed around Stanford University, the University of California, Berkeley, and the University of California, San Francisco; and Route 128 grew up around MIT and Harvard University. These entities, in contrast to the large industrial labs, integrated various institutions, sources of venture capital, and the federal and local governments, rather than relying on a single monopolistic employer with mostly internal funding streams. Outcomes for communities and regions were often profound: the North Carolina Research Triangle,[1] for example, was the result of a state investment in innovation services around three major universities. After more than fifty years, it is still a boon for North Carolina's economy.

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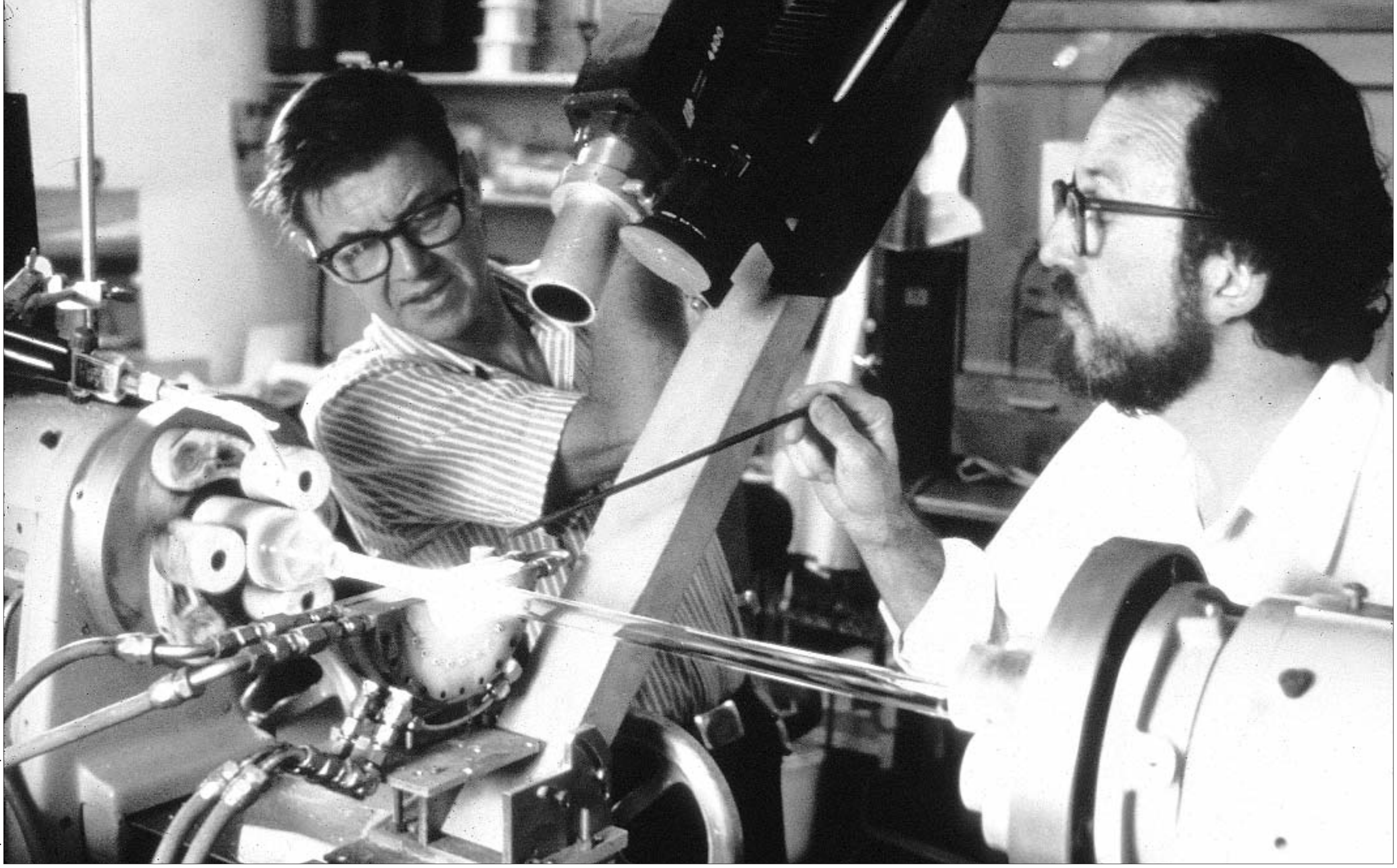
What made these local innovation ecosystems successful? Certainly, they shared many of the qualities I observed at Bell Labs. Much research has been done on this subject, including several books by Roger Geiger, an education scholar at Pennsylvania State University.[2] Geiger's findings suggest a few lessons.

[1] Rick L. Weddle, Elizabeth Rooks, and Tina Valdecanas, "Research Triangle Park: Evolution and Renaissance," paper presented at the 2006 International Association of Science Parks World Conference, Helsinki, Finland, June 2006.

[2] Roger L. Geiger and Creso M. Sa, *Tapping the Riches of Science: Universities and the Promise of Economic Growth* (Cambridge, Mass.: Harvard University Press, 2008).



Bell Labs researchers John B. MacChesney (left) and Paul B. O'Connor heat a silica tube on a glass lathe. In 1980, the pair received a patent for a fiber-making process in which highly purified glass layers are formed from chemical vapors that react inside a silica tube when it is heated. Called modified chemical vapor deposition, the process has been widely used by telecommunications firms in the United States and internationally to produce hair-thin glass fibers for transmitting telephone conversations.

First, the ecosystems' physical proximity to several major universities provides a source of people, ideas, and intellectual property. In the late twentieth century, American universities were the predominant source of published scientific research, a notable fact given that the most effective patents on which new revolutions in technology and industries are based have inevitably been those that cite scientific literature. The back-and-forth movement of people from institutions to industry is the best source of knowledge transfer, and it is highly localized around universities.[3] Both Stanford and MIT have undertaken studies showing that a large part of the U.S. and world economy stems from the institutions' respective local environments.

Second, entrepreneurial service providers such as patent lawyers, venture capitalists, human resource specialists, loan providers, laboratory services or machine shops available for fees, mentoring, and relatively inexpensive space to start ventures tend to thrive in close proximity to a cluster of major universities, which are their source of talent and ideas. Encouragement and incentives by local government often help maintain these entrepreneurial services.

Third, intense technical exchange is more likely to occur between university professors and students, venture capitalists, and employees of startups if they regularly run into each other informally at coffee shops or lunch spots.

Fourth, a critical mass of highly motivated and diverse scientists and engineers is a requirement for any innovation ecosystem. (There are debates about what constitutes critical mass in this type of regional ecosystem, but it is greatly enabled by proximity to a cluster of universities, and it surely consists of a complex size distribution for all these elements.)

Fifth, in an environment where venture capital and angel funders bet on people and ideas, a perverse meritocracy persists: that is, entrepreneurs are used to and learn from failure – more so than in large corporations such as Bell Labs.

In the twentieth century, the broad U.S. innovation ecosystem was characterized by a partnership of four key entities: K-12 education, which provided an educated pipeline for universities; research universities, producers of both educated people and knowledge; industry; and government, a source of funding, governance, and regulations. The national system comprised a complex array of many local ecosystems that have generated the vast majority of technological and economic breakthroughs. The 2005 National Academies report *Rising Above the Gathering Storm*, as Chuck Vest discussed, recommended steps the United States could take to maintain all four essential parts of this engine.

In the twenty-first century, how will the impact of technology, market forces, demographics, and – especially – globalization affect this picture of a working, if not ideal, national innovation ecosystem? Will it continue to include local and regional ecosystems? Is it still important to maintain close physical proximity and an easy exchange of

3 Adam B. Jaffe and Manuel Trajtenberg, "Flows of Knowledge from Universities and Federal Laboratories; Modeling the Flow of Patent Citations over Time and across Institutional and Geographic Boundaries," *Proceedings of the National Academy of Sciences* 93 (1996): 12671 – 12677.

people between the parts? In the Internet and social media age, what kind of connections between people will suffice to create innovation? Are we educating our workforce to compete in a global ecosystem?

As we have observed over the last decade, major corporations are global companies driven by market forces to put their R&D close to their biggest markets – and put their manufacturing in the least expensive and most favorable labor markets. Corporate research labs are moving to large offshore markets such as China and India, countries with educated workforces and research universities that are growing in scientific and technical eminence. Meanwhile, U.S. demographics and entitlements are putting pressure on both federal research budgets and state support of public research universities, and the endowments of private universities were weakened by the 2008 stock market plunge.

The back-and-forth movement of people from institutions to industry is the best source of knowledge transfer, and it is highly localized around universities.

For the United States to flourish in the twenty-first century, we will need a source of entrepreneurial scientists and engineers. I want to focus on how we can change our engineering education, in particular, to foster innovative thinking. As Scott Page, a social scientist at the University of Michigan, has pointed out, a diversity of ideas optimizes problem-solving.[4] Diverse teams may take longer to solve a problem, but they produce a better and more profound solution. Teaching in-depth thinking about problem-solving in a number of different ways is important. I like to think of creating "T-shaped" individuals who are deeply immersed in one discipline but able to communicate across and work with other disciplines.

We also need engineering leaders who will take the long view and be able to hold the creative tensions in an organization in balance. To speak to this need, I will conclude by reading from an editorial that venture capitalist Andy Garman and I wrote on the subject, published today in *The Harvard Crimson*[5]:

> [B]ehind every technological advance inevitably lies an engineer.
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> China, Korea, and India understand this well, graduating enormous numbers of new engineers. The debate about the need to train and produce more engineers to maintain U.S. competitiveness, however, has obscured an important issue. We don't just need more engineers; we need a different kind of engineer. What we need are engineers who lead, driving not just inventions, but institutions.
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> The greatest challenges our country and the world face – energy, information access, climate change, sustainability, healthcare, economic development and growth, even financial reform – require the technical knowledge and analytical skills of people trained in the engineering sciences.
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> [...]
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> Those who rise to the top of organizations do so in large part because of interpersonal and communication skills, tolerance for real-world ambiguity, and a holistic understanding of organizational needs. Business and law schools tend to attract people with these characteristics and then reinforce them by the nature of their programs and culture.
>
> To provide a foundation for engineering leadership, engineering schools should take a lesson from law and business schools. We aspire to create a new generation of engineers who have deep technical training in a domain, and the breadth of knowledge and character to effectively collaborate with and lead others.
>
> Of course, it takes a great deal of classroom and lab time to be prepared to solve complex technical challenges. The tolerance for technical error is low: airplanes must fly, bridges must stand, and power plants must run.
>
> Without aiming for breadth of knowledge beyond just the technical though, universities risk educating engineers lacking the qualities required for corporate and government leadership. Thankfully, the philosophy of "engineering as a liberal art" – in which engineering discipline is part of a liberal arts curriculum, and students learn by working in multidisciplinary teams to solve real-world problems – is catching on.
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> We need to foster this holistic way of thinking about the world.

[4] Scott Page, *The Difference: How the Power of Diversity Creates Better Groups, Firms, Schools, and Societies* (Princeton, N.J.: Princeton University Press, 2007).

[5] Cherry A. Murray and Andrew Garman, "Engineers Who Can Lead," *The Harvard Crimson*, April 14, 2011.

Harvey V. Fineberg

Harvey V. Fineberg is President of the Institute of Medicine. He was elected a Fellow of the American Academy in 1994.

Competitiveness, innovation, and health are all interconnected. We are never going to have a competitive society without a healthy workforce and a healthy population, and we cannot become healthy without innovation in health technology and processes. As has been stated, America currently ranks very poorly on life expectancy – twenty-fourth in the world. For infant mortality, another common, international measure, we are again far behind the frontrunners at thirty-first in the world. There is, however, one health measure in which the United States outdistances all its competitors: how much we spend on health. We spend double the OECD average per capita on health. That's an additional $4,326 per person and with worse results.[1] This grim picture, however, also teaches a very important lesson: we cannot spend our way to better health. Simply spending more money is not going to solve our health challenge; we have run that experiment for fifty years, and it does not work.

To be fair, we are mainly falling behind in a relative sense. Viewed historically, America's track record for population health has been a remarkable success. At the beginning of the twentieth century, the infant mortality rate in the United States exceeded one hundred per one thousand live births.[2] In the early 1900s, the most dreaded disease was tuberculosis[3]; TB was to the beginning of the twentieth century what cancer is to the beginning of the twenty-first century. In 1900, life expectancy at birth was less than fifty years of age[4]; in the space of just one century, life expectancy at birth increased by more than twenty-five years. This last achievement is perhaps the best argument for birth control: wait another year, and your child will have an additional three months of life expectancy! Truly, this past century was an incredible period of progress in health unparalleled in history.

The success of the United States is impressive when measured against its own history, but less so when measured against the staggering pace of improvement in other countries. In the United States, heart disease became the leading killer by the 1920s when it overtook the great infections, going on to peak in the mid-1960s[5] – at about the same time as the first Surgeon General's report on tobacco.

The country with the highest rate of cardiovascular mortality in the 1960s was Finland. Diets there were rich in butter and salt, and Finns were heavy smokers. In 1971, the North Karelia Project (named for the province in Finland it targeted) took up the challenge of trying to rein in this epidemic.[6] The Finns adopted a preventative approach based on the understanding that just as we cannot spend our way to better health, we cannot cure our way to better health: we have to stop the problems before they begin. Armed with this understanding in North Karelia, program officials introduced an array of interventions involving physicians, community organizers, nongovernmental organizations, and government, while launching massive education programs. They intervened at every possible level. The results, after twenty-five years, are quite striking: mortality from heart disease in North Karelia is down by 85 percent; mortality from lung cancer is down by 80 percent; all cause mortality is down by 62 percent. The program was expanded across Finland, and Finland's average life expectancy has now surpassed that of the United States.[7]

Other countries, such as Singapore, have performed similarly – once lagging behind the United States, they are now ahead of us.[8] All of these countries have nearly universal health insurance coverage and have stressed prevention of disease.

We don't have to look abroad for models of exemplary public health policy and practice. There have been major localized successes within the United States. The percentage of U.S. adults smoking tobacco was 42.4 percent in 1965 when the first National Health Interview Survey took place.[9] It has

[1] OECD, *Health at a Glance 2009: OECD Indicators* (Paris: OECD Publishing, 2009); http://www.oecd-ilibrary.org/social-issues-migration-health/health-at-a-glance_19991312 (accessed January 17, 2011).

[2] National Center for Health Statistics, *Vital Statistics of the United States, 1982* (Washington, D.C.: Public Health Service, 1985).

[3] National Center for Health Statistics, *Leading Causes of Death, 1900–1998,* ed. Public Health Service (Washington, D.C.: Public Health Service, 1998).

[4] National Center for Health Statistics, *Vital Statistics of the United States, 1982*.

[5] National Center for Health Statistics, *Leading Causes of Death, 1900–1998*.

[6] Pekka Puska, "The North Karelia Project: 30 Years Successfully Preventing Chronic Diseases," special issue, *Diabetes Voice* 53 (2008): 26–29.

[7] OECD, *Health at a Glance* 2009.

[8] The World Bank, World Development Indicators, 2011; http://data.worldbank.org/data-catalog/world-development-indicators?cid=GPD_WDI (accessed May 24, 2011).

[9] Centers for Disease Control and Prevention, *CDC – Trends in Current Cigarette Smoking – Smoking & Tobacco Use*, 2010; http://www.cdc.gov/tobacco/data_statistics/tables/trends/cig_smoking/index.htm (accessed May 24, 2011).

since declined by more than half and is currently around 20 percent. However, success has been uneven across the United States, and some communities have done more to solve the problem and have seen better results. In New York City, there are now three hundred fifty thousand fewer smokers than there were in 2002.[10] Smoking has been banned from public buildings, restaurants, and even parks and beaches.[11] Whereas before, discouragement only came from social norms, it is now being reinforced by public law. Although tobacco played an important part in U.S. history, it is a role best relegated to history. In another hundred years, people are going to look back at this century's attachment to tobacco with utter bafflement.

We can do more. After tobacco, the next critical opportunity is in improving diet and physical activity. Both of these are crucial to solving the obesity epidemic, a growing problem and threat to the future well-being of America. In fact, some estimates are now projecting that obesity has the potential, for the first time, to reverse the continuing curve of advancement in life expectancy.[12] The mayor of Boston recently announced that he was expanding his ban on sugar-sweetened drinks, taking them out of all public buildings in the City of Boston,[13] a strong step in the right direction. That is one area where Boston has now jumped ahead of New York City, and I suspect Mayor Bloomberg is paying attention to Mayor Menino's policy.

We can also learn from the examples set by companies like Johnson & Johnson, which started Live for Life, a health promotion program for employees, more than twenty-five years ago. A recent study compared health and health care costs among Johnson & Johnson and other similarly sized companies from 2002 to 2008.[14] According to this study, the program has yielded healthier employees and an average annual savings of $535 per employee per year in 2007 dollars. Johnson & Johnson was able to build a "culture of health" at the workplace, where American adults spend a large proportion of their time.

There is one health measure in which the United States outdistances all its competitors: how much we spend on health.

There is much to be learned from these individual initiatives. I would love to see a national competition among the mayors of the United States to see who can do more locally to encourage healthier lifestyles. I would love to see governors competing to see which can be the first state to diminish the proportion of overweight and obese. I would love to have a national debate on health that focused not only on the health care system, but also on prevention. Prevention of disease and promotion of health are both connected to health care and to many aspects of policy and daily life, and prevention is the surest path to a healthy nation.

We can do more at every level – personal, family, community, state, and nation-wide. We can learn from our history of what worked, and we can appreciate the power of prevention. We can learn from models of excellence that have been successful at reducing key causes of disease – tobacco, lifestyle, and diet – and we can become a healthier nation, more competitive in the world, and more successful at home. ■

10 New York City Department of Health and Mental Hygiene, *New York City Smoking Rates Fall to Lowest Rate on Record*, 2009; http://www.nyc.gov/html/doh/html/pr2009/pr023-09.shtml (accessed February 21, 2011).

11 Javier C. Hernandez, "Council Passes Smoking Ban for City Parks and Beaches," *The New York Times*, February 3, 2011.

12 Susan T. Stewart, David M. Cutler, and Allison B. Rosen, "Forecasting the Effects of Obesity and Smoking on U.S. Life Expectancy," *New England Journal of Medicine* 361 (23) (2009): 2252–2260.

13 Meghan E. Irons, "Menino Expands Sugary Drink Ban: Some Beverages Won't be Allowed on City Properties," *The Boston Globe*, April 8, 2011.

14 Rachel M. Henke, Ron Z. Goetzel, Janice McHugh, and Fik Isaac, "Recent Experience in Health Promotion at Johnson & Johnson: Lower Health Spending, Strong Return on Investment," *Health Aff (Millwood)* 30 (3) (2011): 490–499.