Cultures of Innovation

A Conference Presented by the Lemelson Center for the Study of Invention and Innovation at the Smithsonian Institution's National Museum of American History

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[Introduction]

In the Costa Rican countryside, grass can grow to lengths of twenty meters. If farmers don't chop it into portions, their cows choke. So, day in and day out, farmers in Costa Rica cut the grass. It is a task that Juan Carlos, owner of ten acres and eight cows, grew too weary of doing forever.

In search of a way out of this chore, he went to the big city, San Jose, his nation's capital. There he found a machine that probably could have cut the grass for him. But its $1,000 price tag was enough to purchase five more cows. Carlos, with no more than an eighth-grade education, left San Jose without the machine.

Instead, he brought home a passion to invent a grass-cutting machine of his own, perhaps one that would serve his purposes even better than the one a richer farmer might have bought. Back at his farm, he gathered three of his mechanically inclined neighbors and together they built a grass-cutting machine that Carlos had designed.

"I am trained as a mechanical engineer and I have never built a machine of value," remarked Satheesh Namasivayam, who was then senior program manager for the Portland, Oregon-based Lemelson Foundation, at the Lemelson Center's "Cultures of Innovation" meeting. "And here is a person who has gone only to the eighth grade and has created a perfectly functioning machine," Namasivayam said of Juan Carlos. Namasivayam had learned about Juan Carlos through a Lemelson Foundation program called "Invention for Sustainable Development."

The machine worked so well at cutting the grass down for cows that when nearby farmers saw it in action, they wanted one, too. So Carlos set up a small manufacturing operation and began making the machines for local farmers. Now he and a small staff make about 60 of the machines each year, selling them for about $400 each. "He has a beautiful home and an expanding income potential," Namasivayam noted.

Carlos could have taken his innovative enterprise farther. The technology caught the attention of those beyond his local radius in which he and his coworkers were the known experts. A number of more distant farmers began copying his machine. Instead of feeling that they were stealing his invention, however, Carlos's response was, "God bless them all." That's not how most entrepreneurs in the developing world would respond, but for Carlos, in his context, it was the right response.

The story of Juan Carlos embodies many of the issues surrounding the human ability and compulsion to invent—the creative act by which a new device, machine, technology, process, or service emerges—and to innovate, which scholars often define as the process by which inventions are rendered practical and available for one or for all.

[Foreword]

Defining a Culture of Innovation

For purposes of comparing and contrasting invention and innovation in different places and times, Carlos's story was mentioned repeatedly during the weekend of May 13–15, 2005, at the "Cultures of Innovation" conference in Washington, D.C. The conference was convened by the Lemelson Center for the Study of Invention and Innovation at the Smithsonian Institution's National Museum of American History.

Attending were a mix of people, consisting broadly of those who reflect upon history and those who make it. Perspectives were interdisciplinary and cross-cultural, with many different regions of the world represented. Some two dozen historians, inventors, scientists, engineers, educators, policy specialists, anthropologists, social scientists, and other observers and practitioners of invention and innovation met that weekend. They grappled with the complex interplay of personality types, social structures, cultural traits, and technical, legal, and governmental infrastructures that conspire to make or break inventions.

The conference ranged from specialized case studies to broad theory. We covered such topics as education and gender, the arts, philanthropy, anthropology, policy, and intellectual property in a sampling and probative way. During the discussion, participants shared an intricate diversity of factors that they had discovered relevant to invention and innovation in different contexts. Among these were India's vast and growing reservoir of technically educated citizens, the concept of the individual among some Indonesian ethnic groups that impinged on the spirit of innovation, the positive embrace of older retirees in a waste reduction program in America's rural South, and the attitudes toward distance learning in a deteriorating higher educational system in Sub-Saharan Africa.

Considering the extent of the topic, the goals for the conference were necessarily limited. This program was designed, not as a definitive or comprehensive treatment, but as a probe, an experimental forum on a vast subject. Final answers were neither solicited nor ventured. Simply put, it was a start, not an end.

In the spirit of those intentions, we hope that participants left the event with one of the most valuable payoffs they could have expected: renewed and expanded insight into various large and small factors that play into invention and innovation, and a refined sensibility of what we do not yet understand about these processes. What everyone did seem to agree on was that innovation is a ubiquitous human phenomenon that is universally valued.

In today's world, nothing seems more highly prized than innovation. The term is invoked everywhere for practically everything. It is a word for corporate slogans and logos, for presidential pronouncements, for grant solicitations and proposals, and, as I couldn't help noticing in London recently, in banner ads on the sides of public buses. The basic theme is the same: Innovation is the key to national wealth and happiness, to military strength, and to new

technologies of communication, energy, manufacturing, and biology. To remain or become competitive, nations around the world—this seems especially true in the developing world—are striving to nourish a culture of innovation. But what is the truth underlying this heated rhetoric? The fundamental question before this conference was: What is that culture, and how do we define it?

Speakers offered different takes on this question, collectively yielding a multiplicity of concepts, case studies, and open questions about what encourages and dissuades invention and innovation and how these most pivotal of human activities ought to be examined and studied.

Before proceeding further, it should be noted that despite its title, the conference considered both invention and innovation. To the general public, and even to many specialists, the terms are for all practical purposes synonymous. Some historians and sociologists, however, make this distinction: Invention is the birth of an idea, the creative act, albeit always the invention of some *thing*, often put into prototype form or outlined as a new process. Innovation, on the other hand, puts that idea to use in society. Usually we think of commercial applications, but for the purposes of this conference, we stretched the definition of innovation to include things that reach people through the public domain or touch peoples' lives through governmental initiatives.

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Discussion brought us to questions about the origins of invention: where do invention and novelty come from? To many people invention is a series of single acts by individuals. However, at our conference we heard less about heroic types than about unheralded inventors working at a grass roots level. Their individual contributions, however small, often add up collectively to something of real social consequence.

Tracing the origins of invention inevitably leads to something like the nature/nurture controversy in developmental biology. Are inventors made or are they born? One thing we know about them is that they are unstoppable sorts, unwilling to take "no" for an answer. They are passionate about what they do, often working against heavy odds—traits that are especially pronounced in independent inventors, that is, those who work not within the protection of corporate, academic, or government settings, but on their own.

Even fiercely independent inventors do not, however, work in a social or cultural vacuum. What then is the role of culture? At the highest levels it can unleash torrents of innovation. Of this, there is no more dramatic example of the mutual reinforcement of technical and artistic invention than the Italian Renaissance. But others abound: England during the Industrial Revolution, or the United States between the era of 1870 to 1970, which historian Thomas Hughes has called "America's Golden Age of Invention." Interestingly, Hughes originally cut off that era at 1970

but has since revised his timeframe to embrace the ensuing high-tech revolution. Soon, we will probably make reference to surges in Japan, Korea, and China in much the same way, and undoubtedly historians will eventually detect prior conditions of cultural preparation.

How then do such "golden ages" happen, if they can be described as such? We still know precious little about how invention and innovation arise and operate, though there have been numerous theories on the subject. Early in the last century, the sociological theorist Max Weber famously declared that the Protestant ethic lay behind the rise of capitalism, inspiring in turn an extension of this religious thesis to the rise of modern science and the Industrial Revolution by historians and sociologists like Christopher Hill and Robert Merton. Scholars continue to look for connections between religion and economic and technological phenomena, but there has been little in the way of systemized investigation of other factors.

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Innovative activity, of course, is not limited to such watershed moments. It often emerges in a quieter, but no less consequential way. A recent American history textbook, *Inventing America*, for example, includes the expected heroic figures—men such as Whitney, Colt, Bell, and Edison—but does not dwell on their spectacular achievements. Instead, adopting a broader and bolder thesis, it places them in their times. The authors argue that innovation broadly defined is key to the development of America in all its facets. While Article 1, Section 8 of the U.S. Constitution, which set forth an inventor's rights to hold patents, was the most direct manifestation of the inventive spirit of the nation's founders, such documents as the Constitution were no less an invention. Indeed, they were perhaps America's supreme contribution to invention and innovation. Such books are beginning to shed much-needed light on how invention and technology weave themselves into the fabric of a nation's history and culture. In our compartmentalized world, there is public and even official ignorance of these broader cultural factors. It is time to bring them out of academia to the worlds of policy and action. Not only important historically, such investigations are critical prerequisites to effective policies, both governmental and private, designed to increase the output of technical innovation.

Our conference took us beyond the borders of the United States to distant places and societies. Such international perspectives are no longer merely interesting as an academic exercise, they have become a necessity in today's global economy. To survive in the world marketplace, countries who choose to enter are obliged to reckon with the diverse and changing culture of innovation. Not every country values individual achievement over the group or understands intellectual property in the same way. Religious beliefs, educational practices, and political traditions as well as gender and interethnic relations are deeply implicated in the creation, acceptance, or transfer of new technologies. Countries and their leaders who ignore these cultural differences do so at their own peril.

By the end of the "Cultures of Innovation" conference, the participants had begun to define a new, multidisciplinary field of inquiry in invention and innovation studies. This report is a distillation of the vast content that each speaker offered, as well as of some of the lively discussion that ensued. We hope that what follows can begin to address gaps in our knowledge about cultural factors underlying innovation and provide food for thought for historians, political leaders, policy makers, technical and scientific experts, and other private and public activists who are attempting to bring beneficial technologies to the developing world.

On behalf of the Lemelson Center, I wish to thank The Lemelson Foundation for its key support for the conference and its continuing efforts to foster a greater understanding of innovation on a global basis. Thanks go also to the Lemelson Center team, especially Alison Smith, Joyce Bedi, Claudine Klose, Paul Rosenthal, and William Eastman, whose efforts were essential to getting the conference and this publication together. We also thank Vijaya Melnick and Robert Kargon, who advised on the program throughout all stages of development, and Ivan Amato for recording and distilling the proceedings. We are grateful to the conference attendees for their enthusiastic participation, and extend warm greetings to readers of this report whom we hope to engage in a continuing dialogue on the nature and development of "Cultures of Innovation."

— Art Molella, Jerome and Dorothy Lemelson Director
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[Chapter One]

The National View
Abdallah S. Daar

Abdallah Daar, a transplant surgeon with an interest in ethics and a belief that emerging biotechnologies can and ought to be harnessed to address health, agricultural, and other problems in the world, has had a rare opportunity to study the styles and records of biotechnology innovation in developing countries. With funding from Genome Canada, the Rockefeller Foundation, the Bill and Melinda Gates Foundation, and other organizations, Daar and his coinvestigators at the University of Toronto's Joint Centre for Bioethics surveyed Brazil, China, Cuba, Egypt, India, South Africa, and South Korea. They published their findings in December 2004 in a special supplement of *Nature Biotechnology*.

To compare the countries, he and his colleagues used an analytic approach known as the National System of Innovation (NSI) framework. It looks at the innovation process as a system including knowledge creation (the invention and its intellectual bases) and distribution and use of inventions (some would call this innovation), and the way these affect a country's productivity, competitiveness, and economic and social development.

The same framework can be applied to smaller contexts such as regions within countries or even individual companies. It also can be applied to larger contexts such as free-trade regions or continents. Some specific elements that Daar and his colleagues considered within this framework are government policies, financial and educational institutions, and the research and development infrastructure.

"We used this for gap analysis to see what needs to be changed," Daar said, referring to discovering ways to encourage innovation or remove constraints that are hindering it. One way to categorize the results of such analyses of many developing countries is within a simple grid that apportions countries according to the ability of its citizens to invent and to innovate.

For example, Daar noted that Brazil can boast of "incredible scientific output." Its pool of PhDs is substantial and growing, it has demonstrated leadership in such cutting-edge scientific and technical arenas as genomic sequencing, it has a good university infrastructure, and its scientists publish in such journals as *Science* and *Nature*. What Daar and his colleagues found using the NSI approach was that the knowledge creators in Brazil are not communicating effectively with those people and institutions that can convert the knowledge into useful and commercial products. Partly as a result, while Brazil is good at producing excellent science, it has so far not had great success innovating and converting this science into useful products.

Cuba is an example of a poor nation that nonetheless has proved it can invent and innovate with the best of them in specific contexts. For example, Daar noted, "Cuba is the only country in the world that has made meningococcal meningitis B vaccine." The United States is willing to buy this vaccine from Cuba, he added. The incentive to get creative became intense in the

1980s when an upsurge in meningitis B infections swept Cuba. "Its kids were dying," Daar said. That provided the need for the vaccine, and Cuba's innovation system provided the infrastructure for a successful vaccine production program. Meningitis B has now almost been eliminated in Cuba, and the Cuban vaccine is now increasingly being used in other countries around the world.

India traditionally has been stronger on innovation than on invention. For instance, the country licensed some existing recombinant DNA techniques and then found innovative methods of using the technology to produce insulin. This has dramatically dropped the cost of insulin for diabetes patients in India compared to imported insulin produced by the world leaders in the United States (Eli Lilly) and Denmark (Novo Nordisk). Said Daar, "In one year, the cost dropped [from 300 rupees] to under 100 rupees and it will go down to perhaps 10 rupees because it only takes about 3 rupees to make a vial." India didn't develop the diabetes treatment, but it did find innovative ways of bringing its costs down.

> "... innovation process as a system including knowledge creation (the invention and its intellectual bases) and distribution and use of inventions (some would call this innovation), and the way these affect a country's productivity, competitiveness, and economic and social development"

Another example of an innovation that has bestowed a large benefit on many people in India was the development of infrastructure for delivering rabies shots locally in villages rather than only in cities. That's important because the longer the delay between a rabid bite and treatment, the worse the prognosis becomes. Each year, 2.5 million bites of potentially rabid animals are reported in India, and 30,000 people die of rabies. To stem that deadly tide, the Hyderabad-based company, Indian Immunologicals, a wholly owned subsidiary of the National Dairy Development Board (NDDB), leveraged existing local health facilities to set up 1,500 clinics that can supply the rabies vaccine far more quickly and effectively than before. The NDDB already was the world's largest supplier of vaccine for hoof and mouth disease and it was able to apply its expertise to the rabies vaccine problem.

India now is building its own momentum in the invention arena, especially in the areas of drug development and information technology tools. As it builds its own invention base and couples it to its innovation skills, India stands poised to become a global powerhouse of new technology development and economic activity.

The Middle East provides a supranational context. A millennium ago, Daar noted, "All innovation was there." Now, except for Israel and a few isolated spots, there has been little invention and innovation going on in the region. This is because many of the ingredients for invention and innovation discussed here are missing, although in a few places such as Dubai, this is changing quite rapidly.

From these and other examples, Daar asked the rhetorical question: "How do you take a Bangladesh or a Bolivia or an Ethiopia, and convert it into a Brazil or South Africa, and then

convert those into a United States, Europe, or Japan?" In other words, what steps can be taken to transform a country that is poor in both invention and innovation into one that is successful in both of these. Asks Daar: "How can we take people away from aid and toward trade?"

Momentum in these directions appears to be building in many countries, Daar noted. More and more, scientists in developing countries are publishing papers that are highly cited by other researchers. India and China are producing more patents, another sign of inventive activity. Some companies in the biotech sector in these and other countries are selling their products in international markets.

Among the conclusions he and his colleagues have been able to draw from their analyses of biotechnology innovations in seven countries, Daar noted some trends. "A good education system, linkage of the research community with the health system, and presence of entrepreneurship and development capital are absolutely crucial" to translate research into health biotechnology products. Such a strong linkage has been central to Cuba's successes in biotechnology.

The lack of venture capital places great constraints on how far innovation can go. Another challenge for countries aiming to rev up innovation is the loss of their brightest minds to other countries. Just as India has improved its own context for innovation enough to reverse what had been a raging brain drain, other countries need to find ways to hang onto their brightest and most creative thinkers; to attract them back after having obtained their education and training elsewhere; or to make use systematically of the knowledge, skills, and other resources of those who have permanently emigrated to the developed world—the diaspora option.

Daar and his colleagues have been identifying technologies that would be valuable for realizing the United Nation's Millennium Development Goals, which include such endpoints as halving extreme hunger and poverty and reducing maternal mortality by three-quarters, all by 2015. He envisions innovation as being driven more by these egalitarian goals than ones that consolidate power and wealth in ever fewer hands.

Bolstering that vision, he summoned a decades-old quote from Lester Pearson, the late prime minister of Canada: "There can be no peace, no security, when a few countries with a small minority of the world's population alone have access to the brave and frightening new world of science and technology, while the large majority live in deprivation and want, shut off from opportunities of full economic development, but with expectations and aspirations aroused beyond the hope of realizing them." Implicit in the quote is a question: What ought the goals of inventors and innovators be on personal, community, national, international, and global scales?

[Chapter Two]

Culture? What Culture?
Ian Inkster

There is a tacit assumption in a conference titled "Cultures of Innovation" that there are just such cultures to be found, that there are cultures that tend to encourage innovation and others that tend to constrain it. Historian Ian Inkster of the University of Trent, Nottingham, told those gathered at the conference that he wasn't so sure about the validity of this assumption.

He introduced his argument using a pie chart depicting the national distribution of patents issued around the world from the Renaissance to 1913. Even by that early twentieth century endpoint, for whatever reasons, a great divide had emerged. A small minority of Western countries had come to vastly dominate the world's patent portfolio. Inkster's chart showed that 98% of all patents issued during the time period were granted to the United States, countries in Europe, or dependencies of Great Britain. The rest of the world accounted for only 2% of all patents issued.

It might be possible to use the data as preliminary support for the notion that different cultures are better or worse at inspiring and nurturing invention and innovation. Inkster argues, however, that the great divide apparent in the patent data reflects how successful the developed countries have been at monopolizing patent systems. That asymmetry in patenting power, in turn, served as a constraint against innovation for those not working in the United States and England, and other insider countries.

Inkster also went after the foundations of a seminal case study that has become a poster child of anti-technology and anti-innovation. The Luddites came to refer to a nineteenth-century group that destroyed industrial-revolution machinery, which was threatening to transform the textile industry in which the Luddites worked.

"It's very tempting to see that resistance as cultural," acknowledged Inkster. "The whole history of Luddism has been expressed as a cultural rejection of machinery in the second half of the nineteenth century in Britain."

But that would be the wrong way to interpret it, argues Inkster. Rather than abhorring innovations in technology and machinery, the Luddites were opposed to a new industrial organization that the application of the new technology was bringing. "Resistance to technology was symbolic, but their real resistance was an opposition to capitalism in a certain form," Inkster said at the meeting.

A lesser known, but related revolt occurred in Taiwan at the end of the nineteenth century. At the time, Japanese imperialists were bringing in a new technology for efficiently harvesting camphor from trees that were growing on aboriginal lands. Camphor was a commodity of growing importance because it was a necessary ingredient for making celluloid, a harbinger of the polymer industry that would become ascendant in the twentieth century.

The Taiwanese killed off Japanese camphor harvesters by the hundreds, perhaps by the thousands. It wasn't because the aboriginals hated the innovation in camphor production that the Japanese were deploying, Inkster argues. It was the reduction of living space—the clearance of large tracts of land—that was the central issue. They were getting pushed toward "the highest cliffs on Earth," says Inkster. "They were fighting for their lives." To say now that that the Taiwanese aboriginals' rejection of the Japanese camphor harvesters was a reflection of a cultural backlash against technology is far too simplistic, Inkster argues.

Moreover, he continued, "Every time one searches for culture as the thing to blame for why innovation doesn't occur or is not adopted in some place and time, you find that maybe it's not. Very often, there are good reasons, such as the destruction of living space, to resist a new 'best practice' or an innovation."

Another way to account for the appearance that cultural drivers of innovation exist is to recognize that powerful individuals, business professionals, or politicians are deliberately attempting to engineer the existing cultural context to take up or nurture an innovation.

"What I have suggested is that from the historian's point of view, the notion of a simple cultural trajectory for innovation, or for resistance to innovation, is fraught with problems," Inkster said. Indeed, he suggests, historians will find themselves hard pressed to find instances of cultural restraints that stop technology. That said, Inkster then suggested that by downsizing the cultural context from the macro level to the micro level—that is, to one that encompasses sites within cultures, such as regions within a country, industries, or even individual companies—then widely applicable properties of innovation indeed might be discovered.

"The whole of Scottish culture was not brought to bear on the [innovation of] the steam engine," Inkster noted. However, the Glasgow University workshop, the Lunar Society (an eighteenth-century salon in England of technically-minded and progressive sorts), and other microcultures, or cultures within a culture, did have a role. Moreover, Inkster noted, the transfer and adoption of advanced technologies does not take place by nations as a whole, but in nurtured sites within nations.

Societies that are rife with invention and innovation often are the agents of constraints on other cultures that otherwise might be more inventive and innovative. Prominent in this context are patent systems that favor the developed countries by making it too legally difficult, expensive, and otherwise onerous for others to apply for patents. "Intellectual property rights are now so vehemently condemned by developing nations because they secure monopolies for others," Inkster said. Systems like these can hinder microcultures from harnessing practices, skills, and plans that would make them loci of innovation. It will be by examining how various microcultures fare and interact within different national, legal, corporate, and other contexts that scholars of the invention and innovation process will gain new insight.

[Chapter Three]

Here Comes India!
Vijaya Melnick

Last Christmas, Vijaya Melnick was visiting her cousin in India. One day, in the middle of the week, her cousin's six-year-old daughter was home from school on a "study holiday" so that she could prepare for exams the following day. "I asked her what the exam was in," recalled Melnick, professor and director of the Office of Sponsored Research and Programs at the University of the District of Columbia. To her great surprise, the little girl answered, "I.T." the acronym insiders use for Information Technology. The girl then proceeded to show Melnick how skilled she was at using the Microsoft Windows environment.

"And this essentially captures the story of India today." India, in other words, is developing the knowledge base, human resources, and infrastructure for becoming a world leader of high-technology invention and innovation. As such, India can provide a laboratory for what helps and hinders invention and innovation.

India is a nation of contrasts, Melnick noted. It is the fourth-largest economy in the world, according to data from the International Monetary Fund, yet it is home to 25 percent of the world's poorest people. The country has 250 universities educating 3.2 million science students, yet there are 500 million illiterate Indians, most of them women.

Harbingers of things to come are the 60,000 software and I.T. professionals that create $16 billion of wealth each year, $13 billion of it for export to 133 countries. Also telling is that India has the second largest English-speaking population in the world and this is the language of science and business. It has the second largest pool of technical manpower and the lowest labor costs, about one-tenth that of the United States and Europe.

Meanwhile, the brain drain of India's intellectual talent is reversing. Indians who earn their PhDs overseas and get technical training elsewhere are now returning in great numbers. "By 2020, this silent repatriation will make India the number-one knowledge producer in the world," predicts Raghunath Mashelkar, director general of the government body known as the Council of Scientific and Industrial Research.

Invention and innovation in I.T. that are now being deployed in India provide a window on what the country can and most likely will be bringing to the global table in the future. Among these is software that can work across the five major languages spoken in the country.

One organization that is helping Indians build their inventions into consequential innovations is the Honeybee Network, which was organized by the 12-year-old Society for Research and Initiatives for Sustainable Technologies and Innovation, or SRISTI. In Sanskrit, SRISTI means creation. The mission of SRISTI has been to create bridges and to fan entrepreneurial activity wherever it has a chance of igniting. To carry out their mission, SRISTI personnel

scout out and document grassroots innovations of peasants and farmers. Out of that and other efforts, SRISTI has accumulated a modest but growing portfolio of patents that have been developed into products. The Indian Department of Science and Technology is now supporting efforts to implement the Honeybee model all over the country.

One example of a social innovation that is leading to payoffs in terms of reducing educational and skill inequalities is known as the Hole-In-The-Wall project, run by Sugata Mitra. Project workers go into slum areas and set up Internet-connected computers in publicly accessible locations where they nonetheless can leave the machine unsupervised. In no time, children, mostly from six to thirteen years old, discover the computer and teach themselves how to use it and how to surf the Internet. Computers have been installed in rural villages all over the country, north, south, east, and west. Another example of innovative information technology goes by the name Shakti, developed by ITT in Chennai, India. The technology enables a computer to translate input from a standard English keyboard into the script of the various Indian languages.

In a dramatic example of social innovation, Kerala, one of the most backward and impoverished districts in the world, has become 100 percent computer-literate. Known as the Akshaya project, the effort in Kerala is managed by local entrepreneurs with the backing of the government. At its base are 630 small computer centers set up in local villages, each one with five to ten PCs. One member from each of 650,000 households in the district was invited to get computer training at their local center. Almost 70 percent of the participants were women. By the end of 2004, access to the Internet had increased from 0.1 percent of the population to more than 20 percent and computer literacy rose from about 1 percent to just about 100 percent.

These are but a few of many examples of inventions and innovation now unfolding in India and the list is only getting longer, Melnick said. Some of the characteristics of innovation that Melnick identified in the Indian cases she has studied are:

- Innovation is a process between those who identify a problem and those who can supply a solution. Innovation, therefore, takes place within social systems that can be nurtured.
- Communication channels that link various organizations and individuals are key.
- It is imperative to identify the societal level at which an innovation is intended—at the individual, the community, the state, the nation, an international region, or the globe.
- Innovation unfolds within legal, political, financial, regulatory, and other infrastructures that help or hinder it.

And then there's a question of the purpose of entrepreneurial ambition. As Melnick sees it, innovation should be pursued in a context of development that incorporates economic gain but is not defined by it. Such a context has three prongs, she says: acceleration of economic growth, reduction of inequality, and the eradication of poverty. Not everyone will buy into this model, Melnick acknowledges. Striving to reduce inequalities among different sectors of the population, for example, could, in the short term, retard economic growth. Even so, this is the model that Melnick champions and the one she would prescribe for the world.

[Chapter Four]

Styles of Innovation
Robert Lemelson

Robert Lemelson grew up in the household of one of the most prolific inventors of this era. Son of the late Jerome Lemelson, whose philanthropic foundation created the Lemelson Center, Robert Lemelson knows the power that one passionate and capable human being can bring to invention and the process by which those inventions become practical, commercially viable, and widely used.

But Lemelson, an anthropologist at the University of California in Los Angeles, also knows how many other factors feed into a complex dynamic of invention and innovation. This vibrant process, he suggests, takes on the texture of fiberglass: try to pick out an individual component and it becomes something that it is not. That makes it hard to tease out general properties of invention and innovation.

> "These are remarkable inventions, usually invented by one person for one purpose. That's quite different from inventors, who, with evangelical zeal and hopes for riches, strive to spread their inventions far and wide."

One way to generally assess how invention has furthered the cause of humanity is by appreciating the message that comes from skeletal analyses of Neanderthals, Lemelson noted. The types of bone breaks they suffered closely resemble those of rodeo bull and bronc riders today. "They were getting up close and personal with the mammals of the late Paleolithic," Lemelson remarked. "And they were getting gored [to death]."

About 50,000 years ago, the human lineage underwent an evolutionary innovation that was biological at its base, but cognitive and social in its consequences, Lemelson suggests. The biological innovation came by way of evolutionary processes. They showed up in the form of brain cells known as mirror neurons, which are associated with an increased ability to mimic the behaviors of others. It would have provided a great leap in the ability of individuals to experiment with behaviors. Some of these experimental behaviors presumably caught on because they had benefits in terms of survival, pleasure, or convenience.

These days, Lemelson said, "We see invention everywhere." He chronicled the work of one investigator in India who walked from rural village to rural village in search of inventions. In

every place, Lemelson reported, he found one or two people inventing great things. "The notion that traditional societies are mired down and stagnant just is not the case," Lemelson said.

In his own anthropological fieldwork in Indonesia, he has seen the same kind of ubiquitous invention. The occupational hazard of lethal falls from coconut trees was the driver of one such invention. Instead of using bare hands, feet, and perhaps a supporting cloth that could and sometimes did fail, one inventor came up with a metal device that attaches to the tree climber's feet. A ratchet mechanism enables the climber to essentially walk up the coconut tree in a way that is far safer than before. Another inventor came up with a device that can dehusk a coconut in five seconds.

"These are remarkable inventions, usually invented by one person for one purpose. That's quite different from inventors, who, with evangelical zeal and hopes for riches, strive to spread their inventions far and wide," noted Lemelson.

One classical set of cultural categories relevant to innovation that Lemelson observed in Indonesia is that of sociocentric societies, which are group-oriented, and egocentric societies, in which the individual is the more prominent social unit. In sociocentric societies, to innovate is to stand out and that is to go against the grain. "It is looked on poorly," Lemelson observes.

For example, one of the worst things you can be called in Bali and other places in Indonesia is *sombang*, which means arrogant. You might be called this if you directly berate someone or if you do something such as come up with a clever invention that might reveal others' deficiencies or inabilities to achieve what you have achieved. "To avoid the jealousy and malign intentions of others, people go through great lengths NOT to stick out," Lemelson has found. One fine reason to make such an effort, he adds, is that Bali is in a part of the world where accusations of sorcery and witchcraft can get you killed. The incentives to minimize *iri hati*, which means envy and refers to a feeling of heartsickness in others caused by your own achievements, could be a cultural barrier to individual initiative and innovation.

Not that this cultural value is always an impediment to innovation. Japan, a place in which, as Lemelson put it, "The nail that sticks up gets battered down," is an example in the developed world of a sociocentric society excelling in innovation.

[Chapter Five]

Seeking the Cultural Template
W. Bernard Carlson

In March 1844, Londoners woke up to find a Chinese junk docked in the Thames. "It just showed up one day," said Bernie Carlson. "It scared the daylights out of the British Admiralty." They knew it meant that the Chinese had good ships and world-class navigational know-how. It was a demonstration that technological innovation and prowess was not going to remain a monopoly of the West, nor would other cultures necessarily innovate in ways that reflected Western values and interests. The message then remains the same today, says Carlson: "Nonwestern cultures will innovate in new ways that grow out of their own cultures, values, and ideas."

As editor-in-chief of the seven-volume *Technology in World History*, published in 2005 by Oxford University Press, Carlson has been immersed in a compare-and-contrast mind-set with respect to technology and innovation in different places and times. *Technology in World History* covers eighteen civilizations and spans the Stone Age to globalization.

> "People invent for three primary reasons: to acquire material abundance (get rich or at least comfortable), to achieve social and political order, and to express cultural values."

Carlson said that one of the biggest lessons of this project for him is that technology per se doesn't change the world; people, who use technology, change the world. As he says, "Different people use technology differently to pursue their different needs, wishes, and values."

With the perspective that comes with a major project like this book series, the diversity of innovation in the world becomes particularly apparent. "My new slogan," quips Carlson, "is that all cultures have [and produce] technologies, but every culture uses technology differently."

Carlson said he agrees with Ian Inkster that teasing out the process of invention and innovation should be an exercise of microcultural analysis. Even so, Carlson said, standing back and seeing the forest for the trees also has a heuristic value: it helps you get your arms around the incredible diversity of human innovation.

He suggests that people invent for three primary reasons: to acquire material abundance (get rich or at least comfortable), to achieve social and political order, and to express cultural values. Some inventions are driven by two or all three of these. For example, the Polynesians designed and built their boats so they could fish and harvest the ocean for goods that they could use

and trade. That falls into the material abundance category. But whether on land or at sea, their boats also served as metaphors for how they organized their work and society, Carlson said.

For example, in New Zealand, the Maoris organized themselves into social units called *waka*, which means "canoe" in their language. On the island of Muyuw, people use the language of boats and boat-building to organize the work related to their gardens. For example, when discussing the need to build a fence around the garden, Muyuw islanders talk about it terms related to cutting the planks needed for the outriggers of their boats. These islanders often plant their gardens in the shape of a boat. That falls into the category of inventing to create or maintain a social order of some kind. Finally, Polynesian navigational innovations had everything to do with their cosmology and so were wrought with cultural meaning.

Different societies emphasize different parts of the abundance, order, and meaning triad. Early modern France, suggests Carlson, placed a high value on social and political order; as a result, it directed material abundance and cultural meaning toward this goal. To manifest their power and authority, the French kings insisted that all roads and canals radiate from their capital, Paris. In addition, rather than produce ceramics and textiles for the masses, the French monarchy pushed artisans to manufacture the finest porcelains and fabrics for use at the French court. So the drivers of material abundance and cultural meaning served to support the intentions of the State.

The Industrial Revolution, Carlson argues, then, was very much about a change in ideology in which societies (such as Britain and America) came to believe the amassing of material abundance would permit them to make choices about the social order and culture they wanted. It's not a sure thing that the contemporary proliferation of this framework, through globalization, will always continue or be welcome by other societies. "Different cultures have different technologies, and different ideas about how to use technology to achieve a good society," says Carlson.

If you adopt that point of view, then the measure for assessing progress becomes more relative, requiring us to look at what the ideas and values that different cultures feel should be implemented by means of technology. "We believe that more technology is a good thing," but not everyone in the world has to share that view, Carlson noted.

One general property that Carlson observed in his own macroscale look at innovation is that the list of any society's portfolio of technological, social, and cultural innovations, which includes things like governments and educational institutions, only grows.

Often these institutions take on unique characters in different places. For example, temples were central to coordinating and regulating water use in India and served the important role of keeping the people supplied with rice. "In America, if you told me that churches were controlling water, I'd have a problem," Carlson said. "Different cultures clearly make choices about resources and social institutions."

Looking at the history of technology on a global scale reminds us that people everywhere are creative, but in ways that reflect their cultural goals, values, and wishes. And that means their innovation may not always be obvious to those looking from the perspective of another culture with different goals, values, and wishes. Technological innovation, to Carlson's way of thinking, is just one element in human history and not the only yardstick by which human progress should be measured.

[Chapter Six]

Planting Seeds of Innovation in the Desert
Maha Alsenan

Maha Abdullah Alsenan, a lecturer at the Art Educator College in Riyadh, Saudi Arabia, participated in the conference via a confluence of technological innovations. As she sat in her office thousands of miles away, participants in Washington, D.C., watched a PowerPoint presentation projected onto a screen as Alsenan narrated via a telecommunications link.

Although the Arab world had been the center of innovation in earlier eras, it is not well known for innovation now. In a project to enhance the art education of girls in their teens, Alsenan and her colleagues are battling a number of constraints that have hobbled innovation in her country and have made it particularly difficult for women even to have ambitions to become innovators. "We aim to use art as a means of moving us toward an innovative mind-set," said Alsenan.

The conjecture under which the program has been designed is that teenage girls, if they are taught art skills and to think creatively like artists, will develop both practical skills in manipulating materials as well as the thought processes that have characterized many of the world's innovators. Now still under development, the program selects participants for an intensive, four-week summer program from applications submitted by girls aged fourteen to seventeen.

> "... to use art as a means of moving us toward an innovative mind-set"

"We aim to expose learners to different sources, and teach them techniques combined with problem-solving, thinking, communicating, evaluating, and searching skills, which will help them create art," Alsenan explained. To do this, teachers employ a variety of sources, including nature, museum and gallery visits, field trips to cultural sites, lectures, art demonstrations, and access to books, CDs, the Internet, and other media. Also central to the program are workshops and extensive studio work in which the girls create paintings in styles ranging from still life and murals to abstract and visionary. They also produce their own ceramic and fabric tableware, including decorated cups and tablecloths, three-dimensional ceramic sculptures, and works made with photographic and computer graphic techniques.

Formal tests and other measures have shown that girls who have finished the program develop creative skills and abilities as well as academic and intellectual progress that surpass those of cohorts who have not taken the summer course. It's a humble start, Alsenan admits. But she hopes it will point the way toward a larger program of "cultural engineering" aimed at shifting Saudi Arabia and other Islamic countries away from innovation-stifling ideologies and social practices and toward ways of thinking and acting that reopen the region to world-class innovation.

[Chapter Seven]

Entrepreneur University
B. K. Singh

To hear soil scientist B. K. Singh describe a life journey that has landed him at EARTH University in Costa Rica is to hear what it takes for someone to become a global citizen. Born in Nepal, he attended Lumumba University in the former Soviet Union where he received an M.S. in agrochemistry. He lived for a time in Florida, where he earned a Ph.D. in soil science, and then moved to Brazil, where he acquired a love for the tropics.

EARTH University is a private, nonprofit institution founded by a Costa Rican businessman with funds from the Kellogg Foundation and USAID. Its goal is to produce graduates who are skilled at solving the agricultural problems of Latin American societies. Located in the province of Limón, the university now has 400 handpicked students from all over Latin America and 40 faculty members. Says Singh: "We go to their homes, we meet them, and provide scholarships to 80 percent of them." Each year, the university gets 1,300 applications for 100 new slots. "From day one, the focus is entrepreneurship," Singh says. "We want our students to go back to their countries and create jobs." The university's goal, he notes, is to create entrepreneurial cultures all over Latin America.

On their first day, students begin forming companies and developing business plans. Once a week, they go into communities and see what people are doing and what kinds of products and services might be useful and commercially viable.

"There must be some structure to nurture and support innovators and entrepreneurs."

In particular, EARTH wants to encourage young people to remain in rural areas and to value agriculture. "They have seen their parents [work as farmers], and each year they see their parents get poorer," Singh said. One way to improve the situation is to expand their approach to agriculture beyond mere crop production and into adding value to those crops in the form of products. "If you want to play in the big leagues, you need to add value, you can't just produce rice and corn," Singh says.

The entrepreneurial urge can get quashed both by local interests that perceive change as threatening and by developed countries whose infrastructures, such as patent systems, make it hard for the small would-be innovator in a developing country to jump into the fray.

"There must be some structure to nurture and support innovators and entrepreneurs," Singh says. More than that, however, EARTH is striving to produce innovators who are responsible global citizens and who embrace the ethic of sustainability. "We want people who know how to really solve problems. Along with coursework, along with science, we teach ethics."

> "If you want to create culture, don't just preach, but practice what you preach."

Most models of education in developing countries were imported from elsewhere decades ago, but they have not changed with the needs of the countries adopting those models. At EARTH University, Singh explains, professors are not assessed only on their research and teaching per se, but on how much their contributions have transformed knowledge into something useful for society. Says Singh, "If you want to create culture, don't just preach, but practice what you preach."

The University as a whole embodies this value. On 10,000 acres, it grows and/or exports bananas, pineapples, mangoes, and paper. "This makes the students feel that they can do things with agriculture," Singh explains. The program also includes infrastructural elements, such as forming associations with banks that can provide start-up loans for student-owned companies and with legal assistance to help them license technology. Thus, an entire entrepreneur-building package has been assembled at EARTH.

EARTH already has placed several products into commercial markets. Among them are ECO-HUM, a biostimulant for growing plants, banana paper, and yogurt. Almost three-quarters of students who have gone through the program are now in the private sector and 90 percent of them are working in Latin America. Those are measures of success and signs that the university is fulfilling its mission, Singh notes.

[Chapter Eight]

From Ashes to Assets
Elaine Marten

In sections of otherwise scenic western North Carolina, there are enormous heaps of coal ash. Much of it is as fine as face powder. Scrubbed out of the smoke with emission control systems, it's the primary waste product of coal-fired power plants. It takes a shifting of the mind to look at it as anything other than an ugly headache, but history has shown over and over again that one person's trash is another's treasure.

To Elaine Marten and a cadre of about 50 fellow retirees with 1,500 years of collective expertise in areas ranging from mechanical engineering to accounting, the coal ash waste stream is an opportunity to achieve many goals simultaneously. Known as Waste Reduction Partners (WRP), Marten describes the members of this cadre as a "groovy bunch of seniors with a long shelf life."

The organization itself is an innovation. Rather than retiring and abandoning their respective areas of expertise, these partners are redefining retirement as an opportunity to feed their skills and knowledge back into their own communities. As seniors, Marten points out, "We have seen it all. We have learned to manage problems."

What's more, she notes, WRP is an ideal setting for destroying myths about women not fitting well in technical arenas. "Women are known to balance things. We are persistent. We are good at making choices. We are good team players and good at collaborating," traits that are pivotal to the success of projects that involve a number of stakeholders whose own interests and goals might not always coincide, Marten says.

Another innovation of this group is to provide their services for free. No longer working because they need to make a living, WRP staff work to improve the community and create opportunities for others.

When a local business calls on them, WRP dispatches a team to an industrial site or a nursing home, for example, where the team conducts an on-site investigation of energy efficiency, water use, lighting design, or some other environmental or resource-use issue. From those analyses, the team makes specific recommendations. Clients who have implemented these recommendations collectively save over $5 million per year, Marten says.

"We want to provide innovative cost-saving strategies via on-site assessments and we want to do pollution prevention," she says. Indeed, WRP has established its own goal of reducing the amount of solid waste in western North Carolina. Since 2000, Marten notes, WRP has diverted over 56,000 tons of waste from the local landfill.

The largest portion of this waste stream is that ugly coal ash. "Our coal burning plants generate over 110 million tons of coal ash each year," Marten notes. Most is stashed in sluice ponds or

sent to landfills. Yet there is extractable value in the various types of ash that come from coal burning. The "bottom ash" that falls to the bottom of the burners, for example, is rich in minerals and can be used immediately for making high-quality concrete. Fly ash, the fine powder residue that used to just go up smokestacks to pollute the air with dangerous particulates, now gets scrubbed out of the effluent. Fly ash comprises 85 percent of the ash from a coal-burning plant and new regulations are likely to cause power plants to burn coal in such a way that even more fly ash will be produced, Marten notes.

Marten and her WRP colleagues have found that they can combine nine parts of fly ash with one part of organic waste, which is readily available in the cellulose wastes from paper mill sludge and from hog waste. When these ingredients are combined, formed into pellets, and then fired in a kiln at 2200°F, the organic material incinerates and the fly ash vitrifies into a very tough material. "The process is like popping kernels of corn in a microwave," says Marten. Such pellets are in demand for use in premium lightweight concrete block.

> "History has shown over and over again that one person's trash is another's treasure."

The next step, Marten says, will be to set up one or more pilot plants on so-called "brownfield" sites. Such locations once hosted industrial operations that have since come to an end, leaving environmental and often economic problems behind. In addition to making high-quality cement, fly ash can also be used to revitalize soils for growing peanuts and trees, among other plants. Developing countries with sandy soils could benefit by using this high-calcium ash, Marten says, adding that it's also possible to make lightweight paving material using the ash. For example, Nicaraguan engineers, using ash from the burning of sugar cane detritus, were able to make a cellular concrete that has extremely high thermal and sound insulation as well as excellent resistance to cracking.

Another waste stream that WRP is taking on is shipping pallets. "We will divert 300,000 tons of pallet waste from landfills," Marten says. Pallets usually end up rotting in landfills, yet they often are made of hardwood lumbers that could be put to good use. WRP has developed a process for converting this waste material into beautiful high-end hardwood flooring.

The practice of using one sector's waste as the feedstock for another sector is known as industrial ecology. If done well, it's an all-win situation for the stakeholders. It could be a far more widespread practice than it is now, but pulling it off requires all stakeholders to alter what they do, Marten says. It might require the waste-producer to handle, store, and transport the material differently than usual. Or it might require that builders work with a material with properties that are slightly different from what they are used to. Convincing stakeholders to embrace these kinds of adjustments is part of the innovation process, and it's the sort of role that organizations of experts like WRP can play, Marten notes.

[Chapter Nine]

If You Build It, They Still Might Not Come
Esther Hicks

You don't have to have a Ph.D. to invent something great, but education surely nurtures invention and innovation, said Esther Hicks, an anthropologist by training and formerly a senior policy analyst with the Stanford Research Institute. That was the spirit behind the creation of the African Virtual University (AVU) in sub-Saharan Africa (SSA). Originally a World Bank project based on the idea that building a more knowledgeable and educated populace would lead to more self-initiated development, the goal of the AVU program was to establish learning centers at institutes of higher learning in SSA countries. At these centers, students would have access to computer- and technology-based curricula and have the opportunity to earn degrees in technical areas that the institutions themselves might be unable to offer.

"You don't have to have a Ph.D. to invent something great, but education surely nurtures invention and innovation."

The AVU now includes 47 centers in 24 African countries, but its success has been spotty at best, says Hicks, who has analyzed the program. The AVU was supposed to build on conventional distance-learning programs in Africa that relied on the postal system. The intended focus of the AVU was to fill gaps in this learning strategy by offering courses in science, engineering, medicine, and business, all of which are hard enough to do well in sufficiently financed and equipped institutions in developed nations, Hicks noted. Using emerging information technologies, the AVU was intended to leapfrog obstacles that so far had kept these subject areas from becoming strong at African colleges and universities.

As it turns out, the AVU has been beset by problems, Hicks observed. Dragging the program down drastically has been a variety of technical, political, and organizational issues. Infrastructural problems, including a lack of computer maintenance technicians and unreliable power supplies, have also created difficulties.

It can take months to get a computer repaired and cheap connectivity to the Internet is hard to come by in Africa. In addition, affordable content for the courses has been difficult to obtain. Another problem, Hicks said, is that the governance of the learning centers in existing university infrastructures has led to confusion about policy, hiring, and other administrative realities.

[Epilogue]

Capturing "Surges of Innovation"

Awash with a diversity of ideas and case studies with which to understand, analyze, and manage invention and innovation, participants of the conference were eager to carry discussions much deeper and ponder the next step.

In a response to a question about Cuba's knack for innovation in biotechnology, Abdallah Daar laid out a number of relevant factors. More specifically, he noted that the trade embargo, national pride, strong education and health systems—as well as a personal interest by Fidel Castro in the promise that biotechnology held for the health of his country's citizens—were important drivers.

Satheesh Namasivayam raised a different question: Why did Finland produce a company like Nokia and its innovations with cell phones? His answer was that the Soviet Union was the cause. In the 1950s, Namasivayam explained, Finland had to find a way to intercept KGB discussions and they did this with innovations that led to the tools, technologies, and infrastructures needed for cellular phone systems.

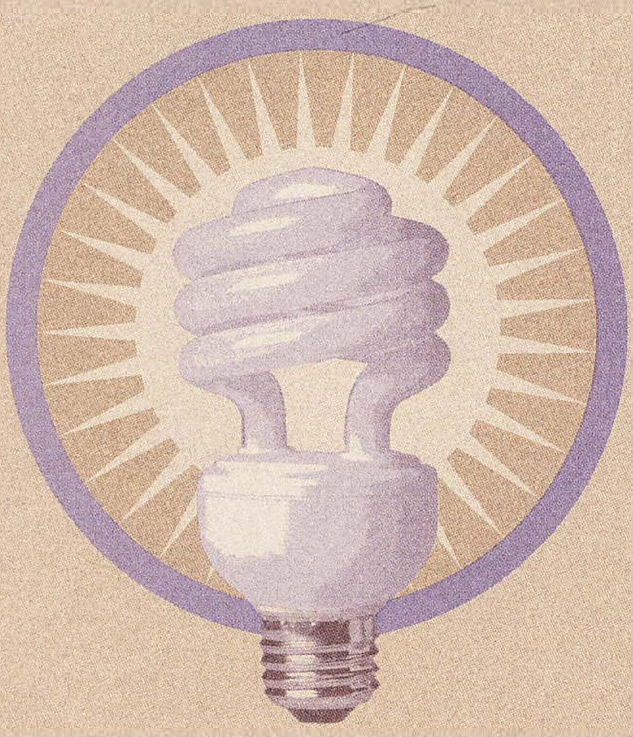
Building on the infrastructure idea, Dan Melnick, a social science consultant, noted that infrastructure defines the context of what is possible. The innovation that actually happens, therefore, is determined by the accessibility people have to that infrastructure. The people who control that access are the ones who determine who can do what.

Ian Inkster, in turn, suggested that if railways and other aspects of infrastructure can reduce costs of production, distribution, and other challenges that small firms must meet, then these cost reductions may cascade into widespread "surges of innovation." That is why state-funded development of infrastructure can have powerful secondary effects on the private sector.

David Allison, chairman of the Division of Information Technology and Communication at the Smithsonian's National Museum of American History, reminded the gathering to not forget the ongoing process of globalization and how it is transforming the context of invention and innovation. "Look at a PC," he said. "It has parts from all over the world." The implication of this, he notes, is that industries such as the computer industry are seeding microcontexts for innovation in many places around the world.

In short, as Lemelson Center Director Art Molella said at the outset, this is too vast a subject to be covered by one short meeting. This program was a probe, an experimental forum on a vast subject. There is so much more to discover.

This is indeed a start, not an end.



Cultures of Innovation was a success thanks to the time and talents of many people, especially our featured speakers. More information about each contributor can be found on the next three pages.

[Contributors]

Maha Abdullah Alsenan is a lecturer at the Art Education College, Ministry of Education, Riyadh, Saudi Arabia. As an artist, art critic, and historian, her work has focused on examining women's role in the cultural life of Saudi Arabia. In cooperation with the King Abdulaziz Foundation for the Gifted in Riyadh, Alsenan is designing and supervising enrichment programs for gifted girls. She holds bachelor's and master of fine arts degrees in art education, and is currently studying for her Ph.D. in art history at King Saud University in Riyadh. Her dissertation focuses on ancient art in Saudi Arabia.

Ivan Amato is a freelance print and radio writer and the author of *Stuff: The Materials the World Is Made Of, Pushing the Horizon*, an institutional history of the Naval Research Laboratory, and *Super Vision: A New View of Nature*. He has written for radio programs and print publications, including National Public Radio, *Fortune*, *Technology Review*, *Science* magazine, and the *Washington Post*.

W. Bernard Carlson teaches at the University of Virginia in the Department of Science, Technology, and Society and the History Department. His research focuses on how inventors, engineers, and managers employed technology to build major companies between 1870 and 1920. His publications include *Technology in World History* (2005) and *Innovation as a Social Process: Elihu Thomson and the Rise of General Electric, 1870–1900* (1991). Along with Wiebe Bijker and Trevor Pinch, Carlson edits a book series for MIT Press, "Inside Technology: New Approaches to the History and Sociology of Technology." To date, the series has published over 25 titles. With support from the Sloan Foundation, Carlson is currently writing a biography of inventor Nikola Tesla.

Abdallah S. Daar is professor of public health sciences and of surgery at the University of Toronto, where he is also director of the Program in Applied Ethics and Biotechnology, codirector of the Canadian Program on Genomics and Global Health, and director for policy and ethics at the McLaughlin Centre for Molecular Medicine. He has published four books and more than 250 publications in immunology, immunogenetics, transplantation, surgery, and bioethics. He chaired the WHO Consultation on Xenotransplantation and wrote the WHO Draft Guiding Principles on Medical Genetics and Biotechnology. He is a Fellow of the New York Academy of Sciences. Daar's current research interests are in the exploration of how science and technology can be used effectively to ameliorate global health and developmental inequities.

Esther K. Hicks is an anthropologist and Near Eastern archaeologist, philologist, and historian. She earned her bachelor's and master's degrees in anthropology/archaeology and ancient history at the University of Michigan, Ann Arbor, and holds doctorates in cultural anthropology from the University of Leiden, and in the social sciences from Erasmus University, both in the Netherlands. She has worked on development-related research policy at the Dutch Ministry of Foreign Affairs, Directorate-General for International Development Cooperation, serving as General Secretary to the National Development Research Advisory Council and project

director of a multi-country study to generate policy strategies for improving the flow of social scientific information in sub-Saharan Africa. Most recently, she has been a senior policy analyst with Stanford Research Institute.

Ian Inkster is research professor of International History at Nottingham Trent University. He has also held visiting appointments at Hitotsubashi University, Japan; the Institute of Developing Economies, Tokyo, Japan; the National Institute of Science, Technology, and Development Studies, New Delhi, India; the Institute of European Studies, Nanhua University, Taiwan; and the University of Pennsylvania. The author of several books on industrialization in Asia, his recent publications include Culture and Technology in Modern Japan (2000), Japanese Industrialisation: Historical and Cultural Perspectives (2001), The Japanese Industrial Economy (2001), and "Technological and Industrial Change: A Comparative Essay" (in Cambridge History of Science, 2002). Inkster is a Fellow of the Royal Historical Society.

Robert Lemelson is co-vice president and secretary of The Lemelson Foundation. An anthropologist who received his M.A. from the University of Chicago, and Ph.D. from the Department of Anthropology, UCLA, Lemelson is currently a lecturer in the departments of Anthropology and Psychology at UCLA. He was a Fulbright scholar in Indonesia in 1996-1997, has conducted research for the World Health Organization, and is additionally trained as a clinical psychologist. His area of specialty is Southeast-Asian studies, psychological anthropology, and transcultural psychiatry. He is also the president and founder of The Foundation for Psychocultural Research, a nonprofit research foundation supporting research and training in the neurosciences and social sciences.

Elaine Marten made her career in the chemical industry with DuPont and Eastman Kodak. She has authored a variety of technical publications and has contributed to a number of industrial patents. After retirement in 1991, she taught as a volunteer instructor at the University of North Carolina Asheville College for Seniors. Her major volunteer activity for the past eight years has been with Waste Reduction Partners, a nonprofit group of technical retirees. She works collaboratively with clients at no charge to improve economic competitiveness and to preserve and enhance environmental resources. In addition to their efforts in energy-saving and water conservation, her group has been recognized for conversion of solid wastes into useful products. Marten holds a Ph.D. in organic chemistry from the University of Rochester.

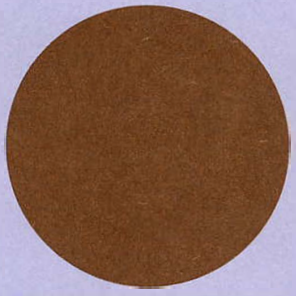
Vijaya L. Melnick is director of the Office of Sponsored Research and Programs at the University of the District of Columbia (UDC), Washington, D.C.; associate director of the International Center for Interdisciplinary Studies in Immunology at Georgetown University Medical Center; a member of the Health Care Ethics Faculty at Howard University Medical College; and the first vice president of the International Health Awareness Network, a United Nations affiliated organization. She has served as professor of Biological and Environmental Sciences and director of the Center for Applied Research and Urban Policy at UDC, and has been science advisor and member of the faculty of the Einstein Institute for Science, Health, and the Courts. Trained as a cell biologist, Melnick received her Ph.D. from the University of Wisconsin, Madison.

Arthur P. Molella is Jerome and Dorothy Lemelson Director of the Lemelson Center for the Study of Invention and Innovation at the Smithsonian's National Museum of American History. He served as head curator of the Smithsonian's Science in American Life exhibit and

co-curator of the international exhibition, Nobel Voices. He has written widely on the relations among science, technology, and culture, and on the politics of science museums and displays. His recent publications include "Exhibiting Atomic Culture: The View from Oak Ridge" (in History and Technology, 2003) and Inventing for the Environment (2003), co-edited with Joyce Bedi. He received his Ph.D. in the history of science from Cornell University.

Satheesh Namasivayam was a senior program officer at The Lemelson Foundation, where he supported the development and implementation of the Foundation's U.S. and international programs. He served as a teaching fellow at Harvard University's John F. Kennedy School of Government and conducted research there on varied institutional approaches to technology-enabled development. Namasivayam earned a Masters Degree in Public Administration from Harvard University, an MBA and M.S. in Information Management from Arizona State University, and a B.S. in Engineering at Regional Engineering College in Trichy, India. During his bachelor's work, Namasivayam co-designed a "shrimp-peeling" machine, an innovative model that was awarded funding by the state government. He was also a member of the team that created the first intra-city ATM banking network in India.

B. K. Singh is professor of soil science at EARTH University in Costa Rica. He teaches soil fertility and plant nutrition and carries out research on biostimulants for plant growth, sports drinks with natural ingredients, microbial metabolites for sanitation, plant metabolites for drug development, slow release intelligent fertilizers, and the creation of community centers to promote invention, innovation, and entrepreneurship. He has developed commercial plant biostimulants derived from naturally occurring humic substances. He has also participated in coordinating a seminar series entitled "Sustainability, Education, and Management of Change in the Tropics," conducted for a period of five years in Africa, Asia, Europe, and Latin America. Singh holds an M.S. in Agrochemistry from Lumumba University, Moscow, and a Ph.D. from the University of Florida.



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