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WHAT WE DON'T KNOW DOES HURT US. HOW SCIENTIFIC ILLITERACY HOBBLES SOCIETY

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ILLUSTRATION: ALLAN M. BURCH

In an oft-told variation of the Hindu myth of cosmology, a young boy asks his father what holds up the Earth. Amused, the father assures his son that the world rests on the back of a very large turtle. "But what holds up the turtle?" the boy asks. After brief reflection, the father says, "A huge elephant." "But," the boy continues, "what is under the elephant?" Sensing that he is rapidly losing control of the conversation, the father finally exclaims, "Son, it's elephants all the way down from there!"

As one who interacts frequently with the public, I often hear similarly disconcerting explanations about the "cosmology" of the modern world. If one asks a new owner how their home computer works, one is likely to hear: "You plug it in, push the "on" button...and it's all microchips from there on down."

Apathy about science and technology seems especially rampant among my fellow Americans, among whom indifference toward scientific understanding is almost considered a badge of honor. A recent National Science Foundation survey showed that less than half of American adults understand that the Earth orbits the sun yearly, only 21 percent can define DNA, and just 9 percent know what a molecule is. Another poll showed that one in seven American adults—roughly 25 million people—could not even locate the United States on an unlabeled world map. NASA administrator Dan Goldin cites a question he received while defending funding for the space agency: "Why are we building meteorological satellites when we have the Weather Channel?"

The disdain toward science is hardly restricted to the United States. The lead character in British writer Muriel Spark's play *The Prime of Miss Jean Brodie* states very frankly: "Art and religion first; then philosophy; lastly science. That is the order of the great subjects of life, that's their order of importance."

Somewhat more reassuring to those committed to the fields of science and technology, novelist C. P. Snow was appalled at the lack of technological understanding on the part of much of the public. He would occasionally ask an individual if they could describe the Second Law of Thermodynamics. He almost always got a negative response. "Yet," said Snow, "that is about the scientific equivalent of 'Have you read a work of Shakespeare's?' "

The great irony, of course, is that as much as any other on Earth, the American economy and our attendant standard of living are based on a foundation of rapid scientific advances. Today, we take for granted that skyscrapers do not collapse, satellites in geosynchronous orbit allow us to communicate reliably and near-instantaneously with others around the world, elevators in 100-story buildings operate perfectly, dams do not fail, automobiles do not break down on the hottest days or the coldest nights, a vast electric power grid faithfully delivers energy to millions of homes and enables us to keep our pizza hot and our ice cream cold, barcode scanners in supermarkets do not make mistakes (if humans make the proper data inputs), jet airliners carry us safely to our destinations, advanced medical devices function for years within our bodies without significant degradation, and a trillion dollars in electronic transactions are flawlessly entered into millions of individual accounts each day.

Our utter dependence on these advanced technologies became distressingly clear to millions of North Americans this past winter, when a freak ice storm toppled major power lines across eastern Canada and the northern United States. Suddenly, simply switching on an electric light became for many a distant dream; weeks went by before power was restored to many communities. As this episode dramatically demonstrated, much of what separates our modern way of life from that of our cave-dwelling forebears is the product of science—and its sister field, technology.

But despite the innumerable positive contributions of science, and despite the remarkable technological innovations that are constantly being fashioned from that science, there is a great challenge to our scientific community today—one that seems likely to intensify in the years to come. I am referring to what I have from time to time called the challenge of "socioscience."

To a not inconsiderable segment of the public, the word "science" conjures up images of Chernobyl, Bhopal, Thalidomide, Challenger, and the atomic bomb. Too often science is perceived as the *cause* of problems rather than the *solution*, as something to be avoided rather than something to be embraced. This aversion to modern technology was the stated rationale of the Unabomber—a viewpoint that traces its history back to the Luddites and other early anti-technology movements. But as Intel CEO Andrew Grove has observed, "Technology happens." And so, I would add, does science.

In a corresponding vein, we have seen huge court judgments rendered against companies for a variety of transgressions based on highly questionable "proof," at least insofar as scientists understand the term. Many juries seem to give about as much weight to the opinions of astrologers as to astronomers. We have seen life-saving medical devices forced off the market by the crushing costs of litigation. And we have the "not in my backyard" syndrome carried to absurd extremes. Recently an outraged citizen demonstrating against a proposed biomedical research laboratory reportedly exclaimed, "They're trying to bring *DNA* into my neighborhood!"

In short, while scientists have generally considered themselves to be the intellectual descendants of the "Benjamin Franklin" model of the benevolent scientist, bringing enlighten-

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ment to humankind, too often scientists are actually perceived by the public to be more in the "Dr. Frankenstein" mold, unleashing scientific havoc on an unsuspecting world.

The lesson we need to draw from this phenomenon is increasingly evident: Modern scientists (and their first cousins, engineers) must become as adept in dealing with societal and political forces as they are with gravitational and electromagnetic forces—and, candidly, up to this point I would not give us a passing grade. Today's scientists are no longer constrained simply by the laws of nature, as was generally the case in the past, but also by the laws (and attitudes) of the land. For example:

Could we send men and women to Mars? Technologically speaking, I believe we could. But politically there is no will to do so.

Could we vastly increase the amount of electricity available to Americans through safe, nonpolluting nuclear power plants? Almost certainly—as is in fact being done in Europe and Japan even today—but communities in America are still repelled by the notion of nuclear power, especially after the horrendous example of Chernobyl.

Could we build automated highways that would increase convenience and reduce accidents? Absolutely. But who is to pay for them—and who is to insure their builders in today's litigious society?

Would an inventor be permitted today to introduce a new product that would create millions of jobs and make people's lives far more convenient, if projections showed it would cost the lives of 50,000 Americans a year? I do not know what Karl Benz, Gottlieb Daimler, and Henry Ford would answer, but I would seriously doubt it.

Could we build a superconducting supercollider? A manned base on the moon? Open new Alaskan oil fields? Create a reliable ballistic missile defense against terrorist nations? Quite likely—if anyone wants us to.

In a sense, scientists and engineers in the past have been fortunate, for we became accustomed to being measured by nature itself—an unwaveringly fair and consistent, albeit unforgiving, judge. Today, in contrast, we are often judged by humans—with all the vagaries, special agendas, and inconsistencies that entails. This has led me to propound what I have called Augustine's Second Law of Socioscience (and engineering), with due apologies to Sir Isaac Newton: "For every scientific (or engineering) action, there is an equal and opposite social reaction."

As scientists and engineers, our achievements are increasingly taken for granted and our occasional failures subject to intense public criticism. A portion of the problem is due to the fact that there is still widespread scientific illiteracy even among those who hold high-level decision-making positions. For example, only 20 of 435 members of the U.S. House of Representatives have a science or engineering background (which is, by the way, an increase from the recent past). There are only two in the Senate and none in the Cabinet. Of the 50 governors, 9 have a science or engineering degree. Keep in mind that these are the people who must make the decisions regarding automobile pollution standards, approval of a space program, funding of the superconducting supercollider, the human genome project, and developments in bioengineering such as the possibility of human cloning.

The danger to all when those to whom we entrust our well-being do not understand the rudimentary scientific aspects of critical issues was eloquently noted by the late Isaac Asimov, who wrote, "Increasingly, our leaders must deal with dangers that threaten the entire world, where an understanding of those dangers and the possible solutions depends on a good grasp of science. The ozone layer, the greenhouse effect, acid rain, questions of diet and heredity—all require scientific literacy. Can Americans choose the proper leaders and support the proper programs if they [themselves] are scientifically illiterate?"*

All of this leads inevitably to my proposal for a two-pronged effort to help Americans survive—and thrive—in the technologically driven 21st century. First, we need "rocket science for beginners": It has often been debated whether scientists need to be exposed to the liberal arts; a more compelling need, in my opinion, is for poets to be exposed to physics. In reality, uninformed decisions about scientific issues are the equivalent of denying ourselves the future.

Second, living as we do in a "sound bite" world, scientists must learn to communicate far more effectively with nonscientist audiences. In my judgment, this remains the greatest shortcoming of most scientists and engineers today. The time has arrived when scientists will have to come down from the Ivory Tower and enter the arena of real-world debate, bubbling controversy, and—brace yourselves—politics.

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It is no longer viable to place our candle under a bushel, for at best we will find ourselves in darkness and at worst our bushel will go up in flames. One must ask why, in today's technology-based society, scientists' voices are so seldom heard along with those of all the others who choose to express their views on scientific issues? We must equip scientists of the future to present their cases in almost every forum imaginable—from town meeting to state legislature, from *The New York Times* to *Sixty Minutes*, from the Congress to the Oval Office.

If, as we have in the past, we put our trust solely in the primacy of logic and technical skills, we will lose the contest for the public's attention—and in the end, both the public and the scientific and technical communities will be the losers. If, on the other hand, we become more adept at explaining science and technology, while at the same time encouraging more "rocket science for beginners," our future will be bright indeed.

And already a few encouraging signs are beginning to emerge. A recent U.S. Supreme Court decision strengthened the hand of trial judges to exclude evidence from scientifically frivolous studies or dubious "expert" witnesses. This would seem to be common sense, but for many years we have seen such questionable tactics go unchecked, leaving complex technical arguments to be decided on the basis of little more than the emotion of jurors. The Supreme Court decision reinforces a comment once made by former Secretary of Defense and Secretary of Energy James Schlesinger that "Everyone is entitled to their own opinion...but no one is entitled to their own facts."

Over the long term, I am an optimist. I believe our fellow citizens will ultimately come to understand the critical link between scientific advances and our generally comfortable way of life. I believe we will realize that the answers to many of the problems that still confront us will need to be solved by scientists and engineers who understand the complexities of the societal problems their work impacts. Ultimately, I endorse the view of that great "honorary" American, Winston Churchill, who is reported to have said, "Americans will always do the right thing...after they have exhausted all the other possibilities."

ILLUSTRATION: TERESE WINSLOW