CHAPTER 1

Science Policy Defined

What Drives U.S. Science Policy?

On October 4, 1957, the Soviet launch of *Sputnik I* sent shock waves around the world—shock waves felt most strongly in the United States, where the news of the launch of the world's first artificial satellite indicated that the country's Cold War rival had beaten the United States into space. The result was widespread panic among the American people, a fear that the nation had lost its scientific and technological superiority.

At the time of *Sputnik,* the struggle between the United States and the Soviet Union was more than a chess game, an ideological struggle with science and technology as surrogates for the issues involved. At stake for the United States was a potential nuclear attack and takeover by a Communist nation. Coming on the heels of the McCarthy era, *Sputnik* produced a climate of near-hysteria, fueled by a sense that there was now an eye in the sky capable of looking down on the United States at will. Perhaps bombs could eventually be released from outer space—weapons against which the country had neither the scientific nor the technological ability to defend itself.

More than any other event in U.S. history, the *Sputnik* crisis focused the attention of the American people and policymakers on the importance of creating government policies in support of science and of education, with the aim of maintaining U.S. scientific, technological, and military superiority over the rest of the world.

The year 1958 was a milestone in the history of science policy, as the United States undertook a series of major actions that cemented the foundation for more than half a century of national science policy. A little over a month after the launch, President Eisenhower appointed James R. Killian, president of MIT, to be the first special assistant to the president for science and technology. Killian's appointment was a sign of the ascension of science to a new position of importance: as his memoir notes, "Only when Jefferson was his own science advisor and Vannevar Bush was advising Franklin Roosevelt during World War II was science so influential in top government councils."[1]

Sputnik also led to passage of the Space Act of 1958, which created the National Aeronautics and Space Administration (NASA). NASA was charged with carrying out the space program and developing long-term aerospace research for civilian and military purposes. That same year, Congress also enacted the National Defense Education Act, which was designed to encourage a new generation of students to pursue degrees in science and engineering.

Finally, 1958 saw Eisenhower's creation of the Advanced Research Projects Agency (ARPA)—now known to many as "DARPA"—within the Department of Defense (DOD). ARPA was charged with preventing technological surprises like *Sputnik* and with developing innovative, high-risk research ideas that held the potential for significant technological payoffs.[2]

Funding for existing science agencies also increased dramatically during the years immediately following *Sputnik*. In 1959, Congress increased funding for the National Science Foundation (NSF) to $134 million, from a figure of just $34 million the year before. This explosive growth was characteristic of the entire post-Sputnik era. The NSF's budget grew from just $3.5 million in its first full year (FY1952) to total funding of $500 million by 1968.[3]

At the same time, further activities and policies sparked the development of a new university and national laboratory system, which would eventually nurture unparalleled scientific growth. Perhaps the first major building block in this structure was a report delivered a dozen years before the *Sputnik* crisis: *Science—the Endless Frontier,* prepared by Vannevar Bush. It was requested by President Franklin D. Roosevelt and submitted to President Harry Truman in July 1945.[4] This document was the foundation for modern American science policy, and provided the impetus for Truman's signature on the legislation that created the National Science Foundation.

Other major research agencies had been emerging from the late 1940s onward. The Office of Naval Research and the Atomic Energy Commission—the precursor of today's Department of Energy—were both created in 1946 to channel government sponsorship of major research. The army and the air force created their own research offices in 1951 and 1952, respectively. New health institutes had been created in the late 1940s, including the National Institute of Mental Health, the National Heart Institute, and the National Dental Institute; in 1948, Congress passed legislation aggregating them under the new name of the National Institutes of Health (NIH).

The building blocks put in place at the end of World War II and in response to *Sputnik* established the general structure in which science is conducted in the United States today. Major policy decisions established universities as the primary vehicle through which government-sponsored basic research would be conducted, created our system of national laboratories for the purpose of advancing science in support of national security and other needs, and inspired a generation of students to pursue degrees in science and engineering. Immediately following World War II and during the early years of the Cold War, government support of science grew, and the scientific enterprise flourished. During the 1960s science was at the heart of one of the nation's goals—namely, sending a person to the moon. The 1970s and 1980s brought energy shortages and crises, and citizens once again turned to science to provide a solution. Scientists and engineers were instrumental in meeting the nation's defense needs as the Cold War progressed. With the end of the Cold War in the early 1990s, the U.S. scientific enterprise turned its attention to meeting the demands of an aging population and finding cures for major diseases. This shift translated into significant funding increases beginning in the late 1990s for health research at the NIH.

Today, some scientists and others fear that public enthusiasm for government support of science may be waning, even as science and innovation grow more important to our economy and national security. Indeed, concerns have emerged that America's global leadership in science may be in danger from neglect and inattention. These range from fears that have emerged post September 11, 2001 that U.S. policy makers have failed to understand the importance to science of openness and the free movement of ideas and people, to worries about the politicization of science, to laments about governmental neglect of science and math education.[5]

Further and quicker scientific advances will be necessary if the United States is to outrun its competitors in the new, knowledge-driven global economy. This will require a renewed commitment to science and to the government policies that support it. Concern over the commitment of the government and the public to science has led some, including Representative Vernon Ehlers R-MI, the first PhD physicist ever elected to Congress, to ask, "Where is Sputnik when we need it?"[6] Others, such as Microsoft chairman Bill Gates, have echoed this wish for a *Sputnik*-like event, a so-called Sputnik moment, that would once again lead to farsighted government science policies.[7]

The serious tone of a 2005 National Academy of Sciences report, Rising above the Gathering Storm, provides good reason for focusing on and reevaluating our existing national policies for science.[8] Unlike *Sputnik,* the next crisis may be difficult to detect at first, with no advance warnings to capture the attention of the American public and leading policymakers. In fact, some individuals, such as Shirley Jackson, former president of the American Association for the Advancement of Science and president of Rensselaer Polytechnic Institute, have suggested that we already face a "quiet crisis."[9] During a National Press Club event in February 2005 at which business and academic leaders outlined their concerns about growing competition from emerging Asian nations such as China and India—competition that threatens U.S. scientific and technological superiority—Intel CEO Craig Barrett remarked: "It's a creeping crisis, and it's not something the American psyche responds to well. It's not a Sputnik shot, it's not a tsunami."[10] Award-winning *New York Times* columnist Thomas L. Friedman claims that this crisis "involves the steady erosion of America's scientific and engineering base, which has always been the source of American innovation and our rising standard of living."[11]

There are many reasons why we should be concerned. Our students perform poorly on international science and math tests. Many of our industries are losing their traditional leadership roles to companies from abroad. More and more U.S. jobs are being outsourced to foreign nations. Major research advances are being made outside the United States, as other countries increase their commitments to their own scientific research efforts. More and more of the brightest students from around the world decide against enrolling at American universities, choosing foreign institutions that are beginning to rival our own in the quality of research and instruction. Meanwhile, the United States faces major scientific and technological hurdles to national challenges such as reducing our dependence upon foreign oil, addressing the potential for a global pandemic, and defending against the threat of biological attack.

While these problems are not likely to generate the kind of popular alarm provoked by the Soviet launch of *Sputnik,* they should not be ignored. After all, these challenges, and many others like them, beg for increased attention, and thus for public awareness of how our government guides our country's scientific and technological advancement. It would be unfortunate if the United States were to become a follower, as opposed to a world leader, in science and technology. At the same time, policies must be in place to ensure that science continues to be conducted, and its results used, in an ethical and socially acceptable manner. Determining what policies meet these conditions is a major challenge, as will be made clear in the remainder of this book.

Beyond Sputnik focuses on governmental policies that affect the conduct of science. We explore areas where government regulation of the areas of inquiry and the practices followed by scientists is clearly required, such as the use and protection of human research subjects. We explain how the government has devised structures and policies intended to advance science and technology, and discuss governmental and nongovernmental approaches to supporting research and development (R&D). Moreover, we try to address as fully as possible the questions of what science policy entails, and what policymakers must do to derive maximum advantage from scientific and technological advances. We also address how science policies sometimes emerge as a result of larger societal needs and goals.

Before we start to do all this, however, we should first define what we mean by science and public policy.

Science Defined

What exactly is science? The word itself derives from the Latin *scientia,* meaning "knowledge." The term *science* can be used to describe both a process and an outcome—the process of obtaining knowledge, and the knowledge that is obtained. Thomas Kuhn, a physicist and historian of science, hints at this duality when he notes that science is "the constellation of facts, theories, and methods collected in current texts," while "scientists are the men [and women] who, successfully or not, have striven to contribute one or another element to that particular constellation."[12]

Carl Sagan, the late astronomer, popularizer, and dogged critic of pseudoscience, highlighted this same tension. Even though he was not certain what science *meant* when he was young, he was rapt with the splendor of the stars and the expansive night sky. He wanted, he said, to take part in the activities leading to both the discovery of new things (process) and the understanding of what it all meant (outcome). "Science," Sagan wrote, "is more than a body of knowledge; it is a way of thinking."[13]

Science is ultimately about both the search for "truth" and new knowledge. Central to its pursuit is the conviction that truth must be obtained in an objective and systematic manner, by incorporating standard models and methods, statistical analyses, controlled experiments, and replication. Its goal is to better understand the world in which we exist, and to create rational and probable models that explain occurrences within it. Science is ideally impersonal and value free. In fact, one important test of scientific validity is the susceptibility of findings from one scientist or group of scientists to duplication by others.

While there is no single, exact scientific protocol, researchers employ what is referred to as the scientific method. The steps involved include observation and characterization of a phenomenon or group of phenomena; the development of hypotheses and theoretical explanations; the use of evidence to predict phenomena or observations; and the use of experiments to test those hypotheses and predictions. The scientific method is used cooperatively over time by all scientists (including the social scientists) to describe aspects of the world and its inhabitants in a reliable, nonarbitrary manner.

After World War II, when the U.S. government began to formally provide major support for scientific research, there was much debate about whether to include the social sciences. Those favoring exclusion won out in the first round, and when the National Science Foundation was established in 1950, its mandate did not include the social sciences. Only four decades later, in 1991, did the NSF establish its Directorate of Social, Behavioral, and Economic Sciences. Today, the NSF is not the only agency funding the social sciences. The National Institutes of Health and the Department of Defense are also heavy sponsors of social science research: the mission of the NIH includes not only biomedical but also social and behavioral research, while the DOD is increasingly interested in these areas as they pertain to national defense. The departments of Agriculture and Commerce have also traditionally devoted funding to work in economics.

However, there is a tendency to consider disciplines of the social sciences—political science, economics, sociology, and psychology—as different from physics, chemistry, biology, and geology. The former have often been referred to as the "soft" sciences, while the latter are known as the "hard" sciences. This distinction refers not to the level of intellectual talent or skill required from practitioners, nor to the use of the scientific method, but rather to the ease with which a discipline's observations can be predicted and reproduced by future experiments, or whether a phenomenon can be explained from its component parts. Advances in computation and mathematical modeling now enable social scientists to make far more reliable predictions than ever before, and differences between the methodologies used by the various science disciplines is narrowing. Nevertheless, the social sciences are still periodically attacked by policymakers as unworthy of government support.

Science versus Technology, Research versus Development, and Science versus Engineering

The general public, policymakers, and even scientists are sometimes confused about differences between *science and technology,* or S&T, on the one hand, and *research and development,* or R&D, on the other. Confusion about these terms is understandable, inasmuch as they are frequently used synonymously: one often sees *S&T* and *R&D* used to refer to the same activity, for example. For our purposes, however, it is important to define science and technology, and to distinguish them from research and development, even though in some cases the lines between them are blurred.[14]

As we explained earlier, science may be thought of as the objective pursuit of knowledge and understanding through the scientific method. The understanding produced by science is articulated through concepts, words, theories, and equations. Science may also be viewed as the world's store of knowledge about the natural universe and those who inhabit it. Technology, in contrast, derives from a conscious attempt to draw upon existing scientific or engineering knowledge for the purpose of achieving a specific material result.[15] The use of both science and technology can significantly affect our lives, in positive or negative ways.[16]

Research may be thought of as the process through which scientific principles are developed and tested. The NSF defines research as systematic study directed toward fuller knowledge or understanding of the subject studied. In contrast, it defines development as systematic use of the knowledge or understanding gained from research, directed toward the production of useful materials, devices, systems, or methods, including design and development of prototypes and processes.[17] Quality control, routine product testing, and production are all excluded from this definition.

Research is often classified by federal agencies as either "basic" or "applied," depending upon the objective of the sponsoring agency. *Basic research* is aimed at gaining more comprehensive knowledge or understanding of the subject under study without specific applications or products in mind. *Applied research* is aimed at gaining new knowledge or understanding to meet a specific, recognized need. It focuses on the creation of knowledge that has a specific application or commercial objective relating to products, processes, or services. In contrast, development can be thought of as the use of knowledge gained from research to produce useful materials, devices, systems, and methods. Development includes designing and developing prototypes and related processes.[18]

The term *R&D* comprises basic research, applied research, and development. When we refer to funding for R&D, this includes funds spent for R&D personnel, program supervision, and administrative support directly associated with R&D activities. Expendable or movable equipment needed to conduct R&D—for example, microscopes or spectrometers—is also included.

In examining *science policy,* we often use the component terms of *science* and *engineering,* or *S&E,* interchangeably. We would note, however, that science and engineering are quite different, with engineering most often referring to the practical application of science to specific problems. Just as there are several different disciplines of science, there are several different disciplines of engineering, including aerospace, electrical, chemical, civil, mechanical, environmental, and computer science.

Pasteur's Quadrant

One reason for the frequent confusion between *science and technology* and *research and development* is that it is not always clear where one ends and the other begins. It is important to keep in mind that many of the policies formulated since World War II operate under the assumption that research and development exist on a sequential continuum, starting with basic research, then going to applied research, then to development and the creation and deployment of new technology, with each stage building upon the one preceding it. This understanding of the transformation of scientific knowledge into technology is known as the *linear model* (see fig. 1.1). The linear model has been used by both scientists and policymakers as the primary paradigm for interpreting the nature of research since World War II, and it continues to be used even today.[19]

Questions are now being raised about the relevance of the linear model to twenty-first-century research.[20] Much of the skepticism has been precipitated by Donald E. Stokes's book *Pasteur's Quadrant,* published in 1997.[21] Stokes argues that research falls into one of four quadrants (see fig. 1.2). The first represents what is traditionally viewed as pure, "basic," or largely theoretical research, in which researchers have no interest in seeking potential uses for their findings, but are working solely to advance knowledge. This quadrant is exemplified in Niels Bohr's research on the structure of the atom. The second quadrant represents strictly "applied" research, or research with a practical end in mind, as represented by Thomas Edison's quest to create an effective lightbulb. The third quadrant includes work that is neither basic nor applied. Examples include taxonomic or classificatory research, which, while important, is not conducted with the creation of new knowledge or the development of practical solutions in mind.

The fourth and final quadrant represents what Stokes defines as "use-inspired basic science." He labels this "Pasteur's quadrant," after Louis Pasteur, whose work had significant theoretical *and* practical applications. In this quadrant, the researcher works to advance scientific knowledge, but remains acutely aware of the potential practical applications for his or her findings.

Stokes's model illustrates that the relationship between science and technology is more complex and dynamic than the linear model suggests.[22] Under this new paradigm, knowledge can be initiated in any of the quadrants and may ultimately have an impact on all of the other quadrants. Indeed, Stokes's work suggests the path by which scientific knowledge is applied and used is not necessarily linear or sequential; that use and desired applications can and often do pull both science and technology. One might therefore think of science and technology as being parallel tracks of cumulative knowledge that continually interact with each other and that have many connections and interdependencies (fig. 1.3).[23]

FIG. 1.1 The linear model

Research is inspired by:

		Considerations of use?	
		No	Yes
Quest for fundamental understanding?	Yes	Pure basic research (Niels Bohr)	Use-inspired basic research (Louis Pasteur)
	No		Pure applied research (Thomas Edison)

FIG. 1.2 Pasteur's quadrant. (Donald E. Stokes, *Pasteur's Quadrant: Basic Science and Technological Innovation* [Washington, DC: Brookings Institution Press, 1997], figs. 3–5.)

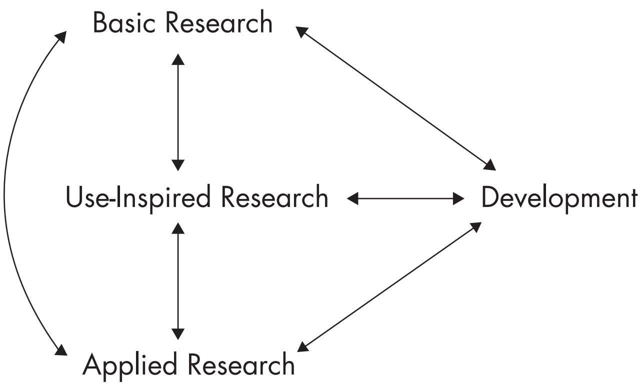

FIG. 1.3 A dynamic and parallel model of research and innovation

Stokes's revised dynamic model better describes the interaction and feedback that occur between knowledge generation, the application of knowledge, and technological innovation. As Stokes points out, adopting a more complete understanding of the relationship between scientific advancement and technological innovation is important in order to craft effective science policies and to renew the post–World War II compact that emerged between science and the government.[24]

Scope of the Scientific Enterprise

Scientific investigation in the United States is carried out in a large number of venues, ranging from national labo-

Beyond Sputnik:U.S. Science Policy in the Twenty-First Century
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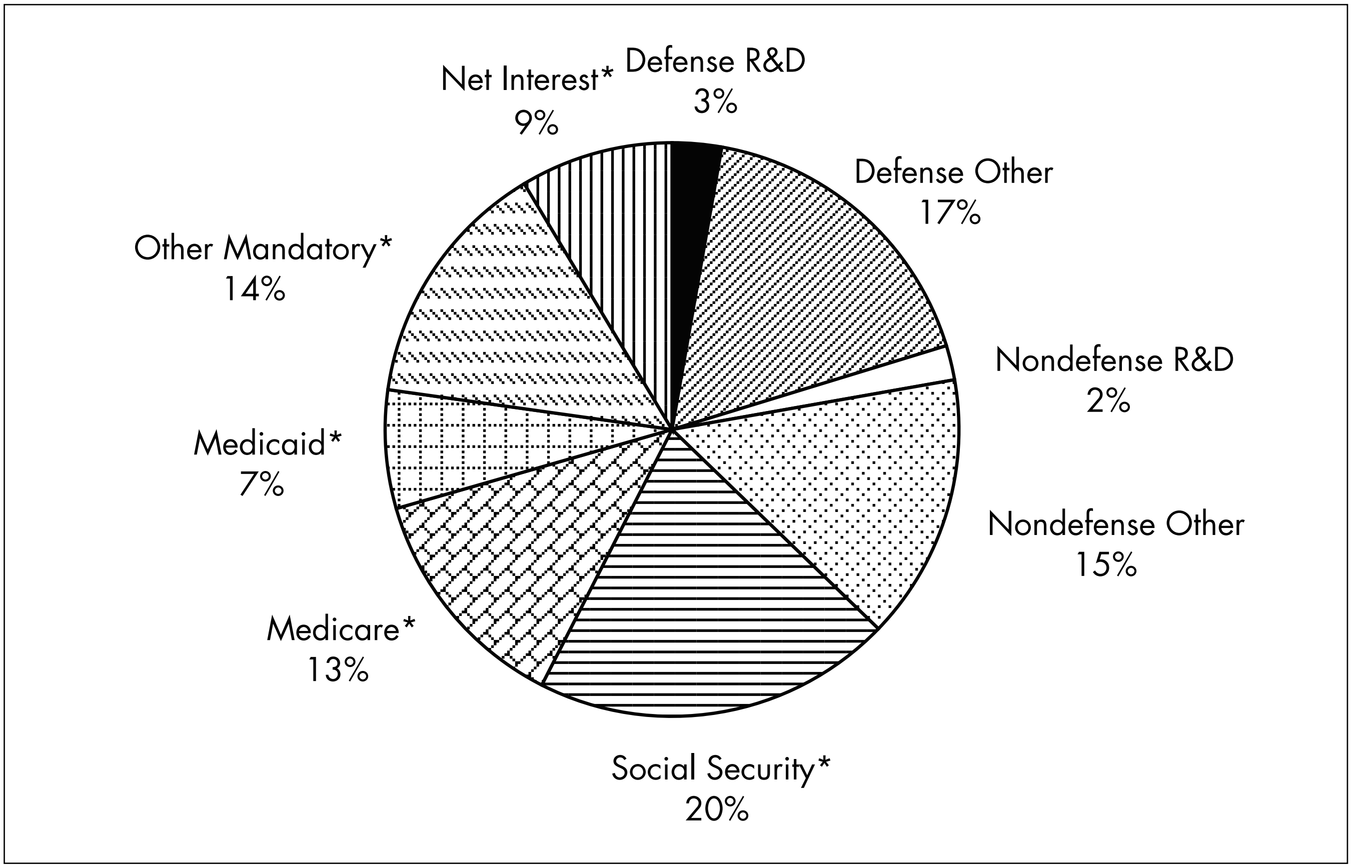

FIG. 1.4 Composition of the FY2006 federal budget. * = nondiscretionary spending. (Office of Management and Budget, *Budget of the U.S. Government FY2008*, as taken from AAAS, table I-2, "Distribution of the FY2008 Budget [outlays in billions of dollars]," http://www.aaas.org/spp/rd/08ptbi2.pdf and AAAS, table 1, "R&D in the FY2008 Budget by Agency [budget authority in millions of dollars]," http://www.aaas.org/spp/rd/prev08tb.htm.)

ratories to universities, research institutes, and industry. The researchers who conduct science are commonly referred to as the *scientific community.* In 2003, more than four million workers in the United States were employed in formal science and engineering occupations in the United States, and there were more than fifteen million S&E degree holders in the workforce.[25]

The federal government provided approximately 30 percent ($93 billion in FY2004) of all private and public funds expended for research and development in the United States ($312 billion in FY2003).[26] In FY2005, R&D expenditures (defense and nondefense combined) represented 5.4 percent of the overall $2.4 trillion federal budget and 16.1 percent of the proportion available for domestic discretionary (nonmandatory) spending.[27] While overall defense and nondefense R&D spending represents a relatively modest share of the total U.S. budget (see fig. 1.4), the federal government's R&D investment plays an essential role in supporting the nation's science and technology enterprise. Indeed, a majority of the support provided to basic research comes from the federal government.

Public Policy Defined

Notable political scientists have asserted that the search for a specific definition of public policy can quickly "degenerate into a word game."[28] Indeed, many definitions of public policy have been developed, and agreement on a single definition does not exist.[29] Even the Supreme Court has been unable to render a precise definition of the term, stating that "no fixed rule can be given by which to determine what is public policy": it is, the Court notes, "a very uncertain thing" and "impossible to define with accuracy."[30]

For our purposes, public policy may be thought of as the processes and players involved in making governmental decisions, the factors that influence their decisions, and the manner in which those decisions are carried out. This definition encompasses the roles of the various players in the process, the factors that motivate them, and the effectiveness of their actions. Concisely defined, *public policy* refers to the outcome produced when public officials arrive at some decision regarding the best course of action for addressing an issue of public concern. The policy itself is typically expressed in the form of a law, an executive directive, an agency policy, a rule, or a regulation. The outcome may be reached through legislative, executive, or judicial action or through a public referendum.

Like *science, policy* refers to both a process and a product.[31] We will spend a great deal of time examining the process of public policy, exploring the hows, whos, and whats of the process as it relates to the conduct of science. Who are the players in making science policy? What mechanisms and tools do they use? At what levels are key science policy decisions made? Who implements and enforces them? How? What motivates individuals involved in science policy to act as they do? What role do external actors and forces, including practitioners of science, play in influencing decisions on policy?

Once we've answered these fundamental questions, we will turn to outputs, examining specific science policy issues, and describing how policymakers have labored to address them.

Science Policy Defined

National science policy refers to the federal rules, regulations, methods, practices, and guidelines under which scientific research is conducted. It also refers to the dynamic, complex, and interactive processes and procedures—both inside and outside government—that affect how these rules, regulations, methods, practices, and guidelines are devised and implemented. In a sense, national science policy is nothing more than public policy governing matters of science (and, to some extent, technology), including research, development, regulation, and overall support of the national scientific community.[32] Therefore, it should be consistent with the general tenets of "public policy" and "public policy–making." Science policy involves, at some level, all three branches of government and is the result of a continuing dialogue between policymakers and the scientific community. As is the case for all public policy, science policy is often neither rational nor comprehensive. It is incremental and somewhat disjointed by nature, and may seem especially so to those who do not fully understand how it is created.[33]

Ideally, science policy should support the needs of citizens, and intrude on the conduct of science only when such intrusion enhances the public good. Moreover, it should not interfere when doing so would limit the progress of science without a concomitant reduction of public risk. In reality, however, specific science policies often do not live up to this high standard. Furthermore, the incremental nature of the policy-making process means that unforeseen problems often have to be fixed "on the fly," in response to outcries from those in the scientific community who are most greatly affected. Finally, most of those making science policy are nonscientists with no clear concept of the scientific method, much less the expertise and research experience needed to evaluate a particular line of research. Thus, the creation of science policy, like all public policy, is far from exact. As aptly described by political scientist Charles Lindblom in his discussion of the incremental and evolutionary—as opposed to revolutionary—nature of the policy-making process, science policy is, itself, a "science of muddling through."[34]

The Difference between Science and Science Policy

As the analyst Phillip Griffiths has noted, science policy is very different from the conduct of science itself. While science is ideally value free and objective, as we have noted, Griffiths describes science policy as "concerned with the incentives and the environment for discovery and innovation; more mundanely, science policy deals with the effect of science and technology on society and considers how they can best serve the public. As such, it is highly visible, value-laden, and open to public debate."[35]

Because of the subjective nature of science policy, whether a specific policy is "right" or "wrong" is often impossible to prove. Moreover, the evaluation of science policy outcomes is often driven by ideology, as opposed to provable facts. This has led many in the scientific community to shy away from engagement in the policy process. Ironically, the scientific voice has often been absent from debates over major policies affecting the scientific community and its work.

In a democracy, government-funded research must be conducted within the rules, regulations, and laws governing the society in which the work is embedded. For example, researchers may not violate the constitutional separation of church and state by using federal funds to promote or question the beliefs of specific religions. Scientists must also be accountable for the expenditure of public funds used in carrying out their projects. As with all sound public policies, those regulating publicly funded research should always have the welfare of society as their preeminent consideration.

These lofty principles, however, pose many dilemmas for scientists and policymakers seeking to balance short-term and long-term risks. Is it more efficient, for example, to invest in activities that will produce incremental but certain advances? Or is it wiser to invest in radical ideas that, though unlikely to produce immediate results, might make remarkable advances in the future? Consider Christopher Columbus sailing west from Europe into uncharted waters, in search of a shorter passage to India. As we know, his voyages and exploits took several years and did not produce the desired end, but it did result in his finding the New World, one of the greatest discoveries in history. A more recent example is the laser, which grew out of government-sponsored research. One of the most influential technological achievements of the twentieth century, at the time of their invention lasers were dubbed “a solution looking for a problem,” for their specific applications and societal benefits were yet unknown.[36] Today lasers are essential to the operation of compact discs, bar code readers, computer printers, long-distance telephone communications over fiber optic cable, LASIK eye surgery, and many other applications.

It would be helpful, of course, to articulate clear principles that would govern the conduct of all publicly funded research. Unfortunately, this will never occur: scientific research represents the search for knowledge and understanding, and for the foreseeable future, nature’s full truth will not be known. Nevertheless, policies embraced by scientists and public alike offer the best chance for the steady advancement of both science and society. Such a common understanding can be difficult to achieve. Many of the most challenging issues for twenty-first-century science are encountered right where the scientific community’s views diverge from those of the broader public.

“Policy for Science” versus “Science for Policy”

Science can both influence and be influenced by government policy. Science can and does affect decisions in many areas of societal importance (e.g., health, energy, environment), and this interaction can in turn affect science policy. Harvey Brooks, a pioneer in the study of science and public policy, is credited with first making the distinction between *policy for science* and *science for policy.* Brooks characterized *policy for science* as decision making about how to fund or structure the systematic pursuit of knowl-

POLICY DISCUSSION BOX 1.1

Who Knows Best: Scientists or Society?

As one of the primary tools permitting society to extend the frontiers of understanding, science is often caught between existing societal beliefs and the attempt to redefine them. The fate of Galileo, condemned as a heretic for proclaiming that the sun—not the earth—was the center of the known universe, exemplifies how the search for truth can place a scientist at odds with the cherished beliefs of society.

Publicly funded research may also lead to findings that challenge deeply held societal and religious beliefs, a tension alive in current debates over evolution versus creationism and intelligent design. Similar arguments are raging over the use of human fetal tissue and embryonic stem cells in scientific research and the creation of genetically modified crops. On the one hand, these research methods and the scientific advances derived from them may conflict with religious, moral, and ethical beliefs. On the other hand, human embryonic stem cell research may ultimately lead to cures and treatments for spinal cord injuries, heart disease, and Parkinson’s disease, while genetically modified crops may be more nutritious and disease resistant, helping to feed the hungry in poorer nations around the world.

Conflict between science and religious, moral, and ethical beliefs lies at the heart of some of today’s most contentious debates over policy. In the end policymakers are left to grapple with daunting questions: Who knows best, scientists or society? Whose wishes should predominate in instances of conflict? Do moral and religious concerns trump the need for new knowledge that might lead to scientific advances and beneficial technologies? And finally, at what point does depending upon what society believes to be true inhibit the progress of the very science that might ultimately contradict those beliefs?

edge, while *science for policy* concerns the use of knowledge to assist or improve decision making.[37]

Because of their complementary nature, the distinction between *policy for science* and *science for policy* is often murky.[38] While the two are easily confused, the former is a direct application of policy to regulate and oversee the conduct of science, or policy for science. It must be differentiated from policy that is informed by science, that is, where science is used specifically to inform the policy-making process, or science for policy. For example, policies that rely on science—such as laws, regulations, and standards pertaining to air and water quality, pesticide usage, food processing and handling, drug usage and building codes, to name a few—are not policies governing science. Rather, they are largely policies that have been informed by science. While such policies are discussed in this book, the reader will find that much of the focus is on government policies designed specifically to shape, guide, and regulate science and its conduct.[39]

If a better understanding could be reached between scientists and policymakers about the two very different worlds in which they operate, perhaps we could more fully realize science's potential to inform policy-making. Such increased understanding would also go a long way toward ensuring that policymakers do not unintentionally or needlessly constrain scientific research.

Why Do We Need a National Science Policy?

It may be surprising to some that the United States has a national policy for science. Aren't many current science policies just by-products of efforts to achieve other national objectives? Certainly, there is some truth to this assumption; in fact, prior to World War II, there was no well-defined U.S. strategy for the support of science.[40] However, the war itself led to recognition of the value in knowledge for its own sake. New knowledge, it was agreed, was critical to progress in the war against disease; to the creation of new products, industries, and jobs; and to the development and improvement of weapons for national security. Such new knowledge could be obtained only through basic research. Vannevar Bush's *Endless Frontier* report put the case succinctly: "Science, by itself, provides no panacea for individual, social, and economic ills. It can be effective in the national welfare only as a member of the team, whether the conditions be peace or war. But without scientific progress no amount of achievement in other directions can insure our health, prosperity, and security as a nation in the modern world."[41]

The level of science conducted in the United States is largely determined by the amount of federal funding made available to researchers in universities, national laboratories, government agencies, and industries. National science policy provides the structure for determining how much funding will be allocated to the federal agencies that support research, how they are to use and distribute funds, and the policies and regulations that will govern research conducted with federal dollars. U.S. science policy also provides mechanisms for promoting science education and *technology transfer,* activities that fuel economic growth, where scientific results or technology developed by one entity is transferred to another entity, oftentimes for development for commercial use.[42] Essentially, national science policy is meant to ensure that science is conducted in a way that enhances the public good; that the nation's research enterprise is supported and advanced; and that uniform guidelines exist for conducting science within the United States.

The scientific community, like most other organized groups, operates most effectively when it shares norms and guidelines. That said, most members of the scientific community prefer that these norms and guidelines be created by the community itself, rather than imposed upon it from outside. An example of such self-regulation is the case where molecular biologists decided to put a moratorium on the use of recombinant DNA (rDNA) after the initial development of the technique. These scientists recognized the concern the rDNA might raise among policymakers and the public and believed that it would be better to establish guidelines and policy recommendations themselves while more was being learned about the potential impact of the new discoveries. In such cases, involvement of the public in deliberations is very important, both to make sure that its concerns are addressed and to reassure policymakers that community-developed policies and guidelines are adequate.

The Importance of National Science Policy

To appreciate the importance of science policy, one must recognize the enormous impact science has on modern society. Science and technology have underlain nearly every major advance in quality of life over the past century. Scientific discoveries have enabled us to fight polio, smallpox, tetanus, cholera, and many other debilitating diseases. Noninvasive scanning devices employing x-ray, PET (positron emission tomography), and MRI (magnetic resonance imaging) technologies have led to innumerable medical advances. Famine, at least for the present, has become an issue largely of food distribution, not supply—a remarkable stride from just a few decades ago. Radio, television, cellular phones, and high-speed travel all tie individuals together in ways once unimaginable.

In addition to these spectacular advances, more routine technological innovations have changed the way we experience our world. Ancient mariners considered themselves lucky if they were able to determine their position to within hundreds of miles; now, with a small, twenty-dollar Global Positioning System (GPS), weekend hikers or boaters can instantly know their position to within a few feet. Today's average car has more onboard computer power than the original lunar lander module. Handheld devices have many times the computing power of the early, room-sized supercomputers. We have seen stunning technological advances over recent decades, and the pace of scientific advance is quickening.

Economists attribute as much as half of our economic growth over the last fifty years to scientific advances and technological innovation.[43] Technological advances resulting from past government support of scientific research have contributed immeasurably to our nation's economy, spawning whole new industries and market niches. For example, federally supported research in fiber optics and lasers helped create the telecommunications revolution that brought about unprecedented American economic expansion and job creation during the late 1990s, with the telecommunications and information technology now comprising one-seventh of the U.S. economy and representing almost $1 trillion in annual revenues.[44] Meanwhile, the inception of research in molecular biology during the 1940s and 1950s, and of recombinant DNA research during the 1960s and 1970s, opened the door for today's multibillion-dollar biotechnology industry.[45] And the Internet, with its vast impact on our daily lives, was spawned by government-sponsored research conducted by the Department of Defense and the National Science Foundation.[46]

Besides enhancing the overall economy and quality of life, scientific and technological advances enable us to better understand the universe in which we live. Because of science, we know more than ever about the structure of the atom, the rules under which atoms form molecules, how molecules array themselves to make proteins, and the composition of the basic building block of life itself—DNA. With new insights into how the universe may have formed and evolved, including such novel discoveries as black holes, we have gained an added appreciation of how our solar system developed. Such strides address some of the oldest questions of humankind—our deep desire to understand the universe, how and when it was formed, and the relationship between the earth and the other parts of the solar system and the universe.

Where did we come from? What are we made of? How are the characteristics of one generation passed to the next? Such questions exemplify the inquisitiveness of human beings—our ability to question, to dream, to wonder about the world and universe that envelop us. The quest for answers leads to the discovery of new ways to enrich life itself, often spawning stunning scientific, humanistic, and artistic advances. A vibrant, inquiring society that is knowledgeable about the present and intrigued about the future is best prepared to advance technologically, and to improve quality of life for all its people.

We can now look toward a horizon of new and exciting breakthroughs: the colonization of space, the use of nanomachines that can be sent into the body to repair specific cells, the creation of computers the size of dust particles that can control our personal environment, the growth of transplantable organs from single cells. The world ahead will no doubt be as awe-inspiring to us as the current one is to our grandparents. The advances necessary to bring us safely to this new world will require robust science policies, to guide and govern its evolution—to serve as a bridge to our future.

Science in Support of Public Policy

As we have already mentioned, Vannevar Bush, an engineer and inventor, served as science advisor to President Roosevelt during World War II. Before the end of the war, Roosevelt requested recommendations on the role that science should play in the nation's future. Bush's response came in the form of his aforementioned report, *Science—the Endless Frontier,* which was received by President Harry Truman on July 25, 1945. In it Bush suggested that government support for research be directed toward improvements in three major areas: national security, health, and the economy.[47] American science policy has been focused on these three areas ever since.

Nowhere in his report did Bush recognize the role that science and federal support of science might play in informing and guiding the formulation of public policies themselves. Because it generates new knowledge, science can in fact help to create better public policy. This is true, for example, in the formulation of environmental laws and regulations. As science has allowed us to better understand the impact of human actions on ecosystems, and as the public's environmental consciousness has grown, new standards have been developed and laws enacted to protect our wilderness, better manage our natural resources, reduce the pollution of our air and water, and preserve our planet for future generations. The increasing use of science in addressing environmental issues and formulating public policy led Jim McGroddy, former vice president for research at IBM, to conclude that "no serious student of history . . . would today substantively revise [Vannevar] Bush's rationale or conclusions in any major way, other than perhaps to add a fourth area of impact, the improvement and management of our environment."[48]

Despite the power of science to influence policy, there is an inherent tension between science and policy-making. The norms and processes that drive science are profoundly different from the politics of democratic institutions. This has led some to conclude that science and democracy (or perhaps the political processes within democracy) are "like marriage partners who get along best when they respect each other's differences."[49]

Such tensions result, in part, from the deductive process through which new scientific knowledge is generated. Scientific knowledge often raises more questions than it answers. Policy formation, on the other hand, is inherently inductive and aimed at concrete solutions. This difference in purposes often leaves policymakers frustrated with the inability of science to provide clear answers to political questions. The Honorable Sherwood Boehlert (R-NY), former member of the House of Representatives and chairman of the House Science Committee, summed up the role of science in policy-making: "Science is a necessary, but not sufficient basis for policy. It must inform all of our policy decisions, but it cannot be the determinate of any of them. . . . And asking scientists to answer what are essentially political questions can only distort the science and muddle the policy debate."[50]

The Positive and Negative Potential of Science

Any treatment of science policy should acknowledge that scientific advances can have negative effects. Knowledge may be used to inflict harm on others; or incomplete knowledge may be used to produce short-term gains at the expense of long-term good. Indeed, such considerations emphasize the need for the development of sound science policies.

Science has, for instance, enabled us to create nuclear weapons, deploy biological agents, and pollute the environment at a prodigious rate. Its dual-edged sword is also evident in the debates surrounding cloning and the use of human embryonic stem cells. While most people agree that "reproductive" cloning—the creation of an exact replica of a human being—is an immoral use of science and should be illegal, much disagreement exists over the morality of therapeutic, or research, cloning for the treatment of cystic fibrosis, Huntington's disease, or diabetes.[51] These ethical and moral debates will be discussed in more detail in chapter 14.

An important distinction must be drawn between the creation and the use of knowledge. For the purposes of our discussion, we assume that knowledge is inherently good and that the creation of knowledge should be supported. At the same time, we realize that science can be used for both good and ill, and that actions enabled by science can have adverse impacts. Sound public policy therefore must be developed to guide the use of knowledge. We do not, however, subscribe to the notion that new knowledge should not be sought out of fear that someone might misuse the resulting knowledge.

Given the importance of science and technology to civilization's progress, one is led to ask if our national policies are optimally structured to foster advances. In spite of remarkable advances, we continue to face huge scientific challenges. Along with these challenges come policy issues of mammoth proportions that may not be easily addressed by science policy.

Policy Challenges and Questions

Each of the subsequent chapters includes a section that raises specific issues of policy. In this introductory chapter we call upon the reader to contemplate the scope of the questions that must be addressed in the decade ahead if the United States is to increase its standard of living and protect its national security. Examples are these: How will we educate our children to be globally competitive in science and technology? How will we decide the scope of national investments in research? How should universities, national laboratories, and industry partner with the government to best meet national objectives? What is the role of the states and the public in setting science policy? How will we decide what avenues of research should have priority?

To illustrate the complexity of just one of these issues, consider the challenge of determining what fraction of a research budget should be provided to one field or another. In spite of the structures that have been developed for review of research proposals and to assess the relative needs of various disciplines, no system has been perfected to determine how much funding should be provided to each scientific discipline.

Over the years, the nation has shifted its priorities to achieve specific public and political goals. President John F. Kennedy's goal of placing a man on the moon, for example, required the dedication of millions of R&D dollars to the space program. During the oil embargo and energy crisis of the early 1980s, the federal government made significant investments in research on energy.

Our country has recently been involved in emphasizing research in the life sciences. To many, this seems an appropriate priority: the baby boomers are approaching old age, and the life sciences may generate major medical advances. Others note, however, that an overconcentration of resources in one area may inhibit progress in others. According to this argument, the unpredictable nature of fundamental research means that targeted funding may not lead to desired advances. In addition, we should remember that breakthroughs can come from unexpected directions: without the discovery of DNA by Francis Crick (a physicist), James Watson (a biologist), Rosalind Franklin (a physical chemist), and Maurice Wilkins (a physicist), today's tremendous opportunities in the life sciences would not exist. It is also worth noting that many of the tools used by life scientists—including mass spectrometers, electron microscopes, and automated sequencers—are the results of advances in the physical and engineering sciences. Thus, focus on one discipline at the expense of other disciplines may be ill-advised.

Such complex issues can only be resolved through deliberations involving all relevant players. Given the government's substantial support of research, government officials will obviously play a major role in determining how these funds are applied for, awarded, and expended. At the same time, members of the scientific community must play a significant role in developing policies that affect their research on behalf of the nation. Moreover, the broader public also needs to be engaged, since these policies can affect their lives in many ways.

NOTES

1. James R. Killian Jr., *Sputnik, Scientists, and Eisenhower: A Memoir of the First Special Assistant to the President for Science and Technology* (Cambridge: MIT Press, 1977), xv.

2. Defense Advanced Research Projects Agency, *Powered by Ideas* (Arlington, VA: Defense Advanced Research Projects Agency, February 2005), 1. See also Mark Greenia, "ARPA and the ARPANET (Early History of the Internet)," in *The History of Computing: An Encyclopedia of the People and Machines That Made Computer History* (Antelope, CA: Lexikon Services, 2003), http://www.computermuseum.li/Testpage/99HISTORYCD-ARPA-History.HTM (accessed April 30, 2007).

3. National Science Foundation, "50th Anniversary Web Site: An Overview of the First 50 Years," http://www.nsf.gov/about/history/overview-50.jsp (accessed April 30, 2007).

4. Vannevar Bush, *Science—the Endless Frontier,* July 5, 1945, NSF 40th Anniversary Edition, NSF 90-8 (Arlington, VA: National Science Foundation, 1990).

5. See Harry Kreisler, "Conversations with History Blog: Neglecting Science Policy," interviews with Zhores Alferov, Charles M. Vest, David King, and Clyde Prestowitz, http://conversationswithhistory.typepad.com/conversations_with_histor/2005/10/neglecting_scie.html (accessed April 30, 2007).

6. Rep. Vern Ehlers (R-MI) at Yale University's Faculty of Engineering Sesquicentennial Forum, "Challenges to Innovation in the 21st Century," May 3, 2002, http://entity.eng.yale.edu/150yrs/ehlers.ppt (accessed April 30, 2007). See also Steve Lilienthal, "Where Is Sputnik When We Need It?" *Accuracy in the Media,* April 6, 2006, http://www.aim.org/guest_column/A4476_0_6_0_C/ (accessed April 30, 2007).

7. Todd Bishop, "Gates: Computer Science Education May Need Its Own 'Sputnik Moment,'" *Seattle Post-Intelligencer Reporter,* August 3, 2004.

8. Committee on Science, Engineering, and Public Policy, *Rising above the Gathering Storm: Energizing and Employing America for a Brighter Economic Future* (Washington, DC: National Academies Press, 2007).

9. Shirley A. Jackson, "The Quiet Crisis and the Future of American Competitiveness," Presidential Symposium, American Chemical Society Fall National Meeting, Washington, DC, August 29, 2005.

10. Andy Sullivan, "Lawmakers, Businesses Call for More R&D Funding," Reuters, February 16, 2005.

11. Thomas L. Friedman, *The World Is Flat: A Brief History of the Twenty-First Century* (New York: Farrar, Straus and Giroux, 2005), 253.

12. Thomas S. Kuhn, *The Structure of Scientific Revolutions,* 3rd ed. (Chicago: University of Chicago Press, 1996), 1. Other philosophers and historians of science have also attempted to explain what science is (or is not). See the works of Karl Popper, Imre Lakatos, or Paul R. Thagard, for example. See also Martin Curd and J. A. Cover, eds., *Philosophy of Science: The Central Issues* (New York: W. W. Norton, 1998).

13. Carl Sagan, *The Demon-Haunted World: Science as a Candle in the Dark* (New York: Ballantine, 1996), 25.

14. For a comprehensive discussion concerning the confusion that often takes place in distinguishing science from technology, see Joseph Agassi, "The Confusion between Science and Technology in the Standard Philosophies of Science," *Technology and Culture* 7, no. 3 (1966): 348–66.

15. Alan J. Friedman, "Science vs. Technology," *Directors Column,* New York Hall of Science Press Room, http://www.nyhallsci.org/nyhs-pressroom/nyhs-directorscolumn/dc-sciencevstech.html (accessed April 30, 2007).

16. Qijie Zhou, Zhihong Chu, and Xiaowei Wang, "The Changes of Modern Science and Technology Notion and New Economic and Social Mode," *Nature and Science* 2, no. 3 (2004): 66–69.

17. Definitions are taken from the National Science Foundation, *Survey of Research and Development Expenditure at Universities and Colleges, FY 2004,* NSF Form 411 (08-06) (Arlington VA: National Science Foundation, 2004).

18. See National Science Board, *Science and Engineering Indicators 2006,* NSB-06-01 (Arlington, VA: National Science Foundation, 2006), 4.8. *Science and Engineering Indicators* is published biennially in two volumes. In volume 2 are the appendix tables; all other material is in volume 1.

19. Donald E. Stokes, *Pasteur's Quadrant: Basic Science and Technological Innovation* (Washington, DC: Brookings Institution Press, 1997), 10. See also Dudley S. Childress, "Working in Pasteur's Quadrant," *Journal of Rehabilitation Research and Development* 36, no. 1 (1999): xi–xii.

20. For example, see National Academies Committee on Department of Defense Basic Research, *Assessment of Department of Defense Basic Research* (Washington, DC: National Academies Press, 2005), 8–14.

21. Stokes, *Pasteur's Quadrant.*

22. Stokes refers to his model as "a revised dynamic model" (*Pasteur's Quadrant,* 88).

23. The notion of science and technology as being "parallel streams of cumulative knowledge" is attributable to Harvey Brooks. Brooks described science and technology as "two strands of DNA which can exist independently, but cannot be truly functional until they are paired." See Harvey Brooks, "The Relationship between Science and Technology," *Research Policy* 23 (September 1994): 479.

24. Stokes, *Pasteur's Quadrant,* 89 and chaps. 4 and 5.

25. National Science Board, *Science and Engineering Indicators 2006,* chap. 3.

26. National Science Foundation, Division of Science Resources Statistics, *National Patterns of R&D Resources: 2004 Data Update,* NSF 06-327 (Arlington, VA: National Science Foundation, 2006).

27. Kei Koizumi, "Federal R&D in the FY 2007 Budget: An Introduction," in *AAAS Intersociety Working Group Report XXXI: Research Development FY 2007* (Washington, DC: American Association for the Advancement of Science, 2006), 11.

28. In stating that there is a lack of consensus on the definition of public policy, Birkland refers to noted political scientist Thomas Dye's argument that trying to find a precise definition of public policy can "degenerate into a word game." See Thomas A. Birkland, *An Introduction to the Policy Process* (New York: M. E. Sharpe, 2001), 19.

29. Different definitions of public policy include the following: "Public policy is 'a goal-directed or purposive course of action followed by an actor or a set of actors in an attempt to deal with a public problem'" (James E. Anderson); "Public policy consists of political decisions for implementing programs to achieve societal goals" (Charles L. Cochran and Eloise F. Malone); and "Stated most simply, public policy is the sum of government activities, whether acting directly or through agents, as it has an influence on the life of citizens" (B. Guy Peters). These definitions are taken from Birkland, *Introduction to Policy Process,* table 1.3.

30. See Richard H. W. Maloy, "Public Policy—Who Should Make It in America's Oligarchy?" *Detroit College of Law at Michigan State University Law Review* 4 (1998).

31. Richard Barke, *Science, Technology, and Public Policy* (Washington, DC: CQ Press, 1986), 8.

32. Barke defines science and technology policy as "a governmental course of action intended to support, apply, or regulate scientific knowledge or technological innovation" and specifically notes that it is "often impossible to separate 'science policy' and 'technology policy'" (ibid., 11–12).

33. John W. Kingdon, *Agendas, Alternatives, and Public Policies,* 2nd ed. (New York: Addison-Wesley Educational Publishers, 1995), 78–79.

34. Charles E. Lindblom, "The Science of Muddling Through," *Public Administration Review* 14 (Spring 1959): 79–88.

35. Phillip A. Griffiths, "Science and the Public Interest," *The Bridge* 23, no. 3 (1993): 4.

36. Laura Garwin and Tim Lincoln, eds., *A Century of Nature: Twenty-One Discoveries That Changed Science and the World* (Chicago: University of Chicago Press, 2003), 107–12.

37. Harvey Brooks, "The Scientific Advisor," in *Scientists and National Policymaking,* ed. Robert Gilpin and Christopher Wright (New York: Columbia University Press, 1964), 76–77.

38. Atul Wad, "Science and Technology Policy," in *The Uncertain Quest: Science, Technology, and Development,* ed. Jean-Jacques Salomon (Tokyo: United Nations University Press, 1994), chap. 10, http://www.unu.edu/unupress/unupbooks/uu09ue/uu09ue00.htm (accessed April 30, 2007).

39. Richard Barke has noted that in some instances, science—just like economic data, political pressures, or threats abroad—can be used as an input to shape government policies in several areas, for example, health, energy, or environmental policy. This represents *science for policy.* In other instances, science is the output of government policies, or *policy for science,* for example, funding for research into pesticide accumulation in the environment or regulations on animal use in scientific research. See Barke, *Science, Technology and Public Policy,* 4.

40. In his *Endless Frontier* report, Vannevar Bush stated, "We have no national science policy for science. The Government has only begun to utilize science in the Nation's welfare. There is no body within the Government charged with formulating or executing a national science policy. There are no standing committees of the Congress devoted to this important subject. Science has been in the wings. It should now be brought to the center of the stage—for in it lies much of our hope for the future" (12).

41. Ibid., 11.

42. The Office of Management and Budget defines technology transfer as "efforts and activities intended to result in the application or commercialization of Federal laboratory-developed innovations by the private sector, State and local governments, and other domestic users. These activities may include, but are not limited to: technical/cooperative interactions (direct technical assistance to private sector users and developers; personnel exchanges; resource sharing; and cooperative research

Beyond Sputnik:U.S. Science Policy in the Twenty-First Century
Homer A. Neal, Tobin L. Smith, and Jennifer B. McCormick

and development agreements); commercialization activities (patenting and licensing of innovations and identifying markets and users); and information exchange (dissemination to potential technology users of technical information; papers, articles, reports, seminars, etc)." See Office of Management and Budget, Circular A-11, 1994.

43. This statement has it origins in work originally done by economist Robert Solow. See Robert Solow, "Technical Change and the Aggregate Production Function," *Review of Economics and Statistics* 39, no. 3 (1957): 312–20; Edwin Mansfield, "Academic Research and Industrial Innovation," *Research Policy* 20, no. 1 (1991): 1–12; Gregory Tassey, *R&D Trends in the U.S. Economy: Strategies and Policy Implications,* 99-2 Planning Report (Washington, DC: National Institute of Standards and Technology, U.S. Department of Commerce, April 1999); and Al Gore, The White House, Office of the Vice President, remarks, Microsoft CEO Summit, Seattle, May 8, 1997.

44. Telecommunications Industry Association, *Telecommunications Market Review and Forecast* (2006), 3–8; Reed E. Hundt, Chairman, Federal Communications Commission, "From Buenos Aires to Geneva and Beyond," speech before the World Affairs Councils, Philadelphia, October 22, 1997, http://www.fcc.gov/Speeches/Hundt/spreh759.html (accessed April 30, 2007).

45. See, for example, "MIT, the Federal Government, and the Biotechnology Industry: A Successful Partnership," Massachusetts Institute of Technology, December 1995; Biotechnology Industry Organization, *BIO 2005–2006 Guide to Biotechnology* (Washington, DC, June 2005), http://www.bio.org/speeches/pubs/er/ (accessed April 30, 2007); European Biopharmaceutical Enterprises, *History of Healthcare Biotechnology: Milestones of Discovery Leading to Concrete Benefits for Society,* http://www.ebe-biopharma.org/index.php?option=com_publications&task=section&Itemid=115 (accessed May 2, 2007).

46. For background information on the history of the Internet, see Barry M. Leiner, Vinton G. Cerf, David D. Clark, Robert E. Kahn, Leonard Kleinrock, Daniel C. Lynch, Jon Postel, Larry G. Roberts, and Stephen Wolff, *A Brief History of the Internet,* found at Internet Society, "All about the Internet, Histories of the Internet," http://www.isoc.org/internet/history/brief.shtml (accessed April 30, 2007); Richard T. Griffiths, "History of the Internet, Internet for Historians (and just about everyone else)," Leiden University, History Department, http://www.let.leidenuniv.nl/history/ivh/frame_theorie.html (accessed April 30, 2007); and Computer History Museum, "Exhibits, Internet History 1962–1992," http://www.computerhistory.org/exhibits/internet_history/ (accessed April 30, 2007).

47. Bush, *Science—the Endless Frontier;* see also House Committee on Science*, Unlocking Our Future: Towards a New National Science Policy,* 105th Cong., September 1998, Committee Print 105-B, 9, http://www.access.gpo.gov/congress/house/science/cp105-b/science105b.pdf (accessed May 5, 2007).

48. James C. McGroddy, before the House Committee on Science, "National Science Policy Part II: Defining Successful Partnerships and Collaborations in Scientific Research," 105th Congress, 2nd sess., March 11, 1998.

49. Bruce L. R. Smith, *American Science Policy since World War II* (Washington, DC: Brookings Institution Press, 1990), 12; see also Don K. Price, *The Scientific Estate* (Cambridge: Belknap Press of Harvard University Press, 1965).

50. Sherwood Boehlert, "Science: A View from the Hill," keynote address, EPA Science Forum 2002: Meeting the Challenges, May 1, 2002.

51. Therapeutic cloning is also called somatic cell nuclear transfer, research cloning, and cell nuclear replacement.