Weinberg, Alvin M. (1967). "The Choices of Big Science." Chap. 3 in *Reflections on Big Science*. Cambridge, MA: MIT Press.

SCIENCE POLICY

Science policy involves considerations of two fundamental human activities: science and policy. People make decisions in pursuit of valued outcomes, so thinking about science policy necessarily implicates science, its close associate science-based technology, and ethics. Although science policy is a topic central to all societies, particularly developed countries that devote significant public resources to science, for two reasons the focus here is on the United States. First, the United States is responsible for the largest share of global spending on science and technology. Second, for better or worse, the budgetary leadership role of the United States in science and technology since World War II has shaped how people around the world think about science, policy, and politics.

To place United States science and technology expenditures into context, consider that according to the Organisation for Economic Co-operation and Development (OECD) in 2003 the United States provided 38 percent of the approximately $740 billion world total (public and private) investment in research and development. The next largest funders were Japan with 15 percent, China with 8 percent, and Germany with 7 percent of the world total. Measured as a fraction of national economic activities, in 2001 total (public and private) expenditures on research and development varied from more than 4 percent in Sweden to 1.93 percent for the European Union (EU) to 2.82 percent in the United States. No country invests more than 1 percent of public funds in research and development, with Sweden investing 0.90 percent, the EU 0.65 percent, and the United States 0.81 percent.

Of course science policy is more than science budgets. The institutional structures and purposes of science are also issues of science policy. If science refers to the systematic pursuit of knowledge, and policy refers to a particular type of decision making, then the phrase science policy involves all decision making related to the systematic pursuit of knowledge. Harvey Brooks (1964) characterized this relation as twofold: *Science for policy* refers to the use of knowledge to facilitate or improve decision making; *policy for science* refers to decision making about how to fund or structure the systematic pursuit of knowledge.

Brooks's characterization of science policy as including both policy for science and science for policy has shaped thinking about science policy ever since, reinforcing a perception that science and policy are separate activities subject to multiple relations. But while Brooks's distinction has proved useful, reality is more complex, because the way society views science policy itself shapes the sorts of questions that arise in science policy debates. Science for policy and policy for science are each activities that shape the other—in academic jargon they are *coproduced*. Policy for science decisions about the structure, functions, and priorities of science directly influence the kind of science that will be available in science for policy applications, and the ways science is used in policy formation will influence in turn the policies formulated for science. Policy for science and science for policy are subsets of what might be more accurately described as a *policy for science for policy* (Pielke and Betsill 1997). To the extent that thinking about science policy separates decisions about knowledge from the role of knowledge in decision making, it reinforces a practical separation of science from policy.

From such a perspective, David Guston (2000) has argued the need to develop a new language to talk about science policy, one that recognizes how science and policy are in important respects inextricably intertwined; separation is impossible. Instead, however, the artificial separation of science from policy is frequently reinforced with calls for a new *social contract* between science and society. As Guston notes, "Based on a misapprehension of the recent history of science policy and on a failed model of the interaction between politics and science, such evocations insist on a pious rededication of the polity to science, a numbing rearticulation of the rationale for the public support of research, or an obscurantist resystemization of research nomenclature" (Guston 2000 Internet site)

The present analysis of science policy in the United States, with a particular focus on federally-funded science, thus begins by examining the value structure that underlies science and its relationship to decision making, and focuses on how science and policy have come to be viewed as separate enterprises in need of connection. This will set the stage for a discussion of an ongoing revolution in science policy that challenges conventional understandings of science in society. In the early years of the twenty-first century it is unclear how this revolution will play out. But a few trends seem well established. First, the science policies that have shaped thinking and action over the past fifty years are unlikely to continue for the next fifty years. Second, decision makers and society more generally have elevated expectations about the role that science ought to play in contributing to the challenges facing the world. Third, the scientific community nevertheless struggles to manage and meet these expectations. Together these trends suggest that more than ever society needs systematic thinking about science policy—that is research on science policy itself. And such research should center on issues of ethics and values.

Axiology of Science

A value structure is part of any culture, and the culture of science is no different. Alvin Weinberg (1970) suggests four explicitly normative *axiological attitudes*—statements of value—which scientists hold about their profession. Whereas Weinberg's concern was the physical sciences, such perspectives are broadly applicable to all aspects of science:

- Pure is better than applied.
- General is better than particular.
- Search is better than codification.
- Paradigm breaking is better than spectroscopy.

For Weinberg, these attitudes are "so deeply a part of the scientist's prejudices as hardly to be recognized as implying" a theory of value (Weinberg 1970, p. 613). But these values are critical factors for understanding both thinking about and the practice of science policy in the United States. And understanding why science policy is currently undergoing dramatic change requires an understanding of how Weinberg's theory of value, if not breaking down, is currently being challenged by an alternative axiology of science.

Understanding the contemporary context of science in the United States requires a brief sojourn into the history of science. In the latter part of the 1800s, scientists began to resent "dependence on values extraneous to science," (Daniels 1967, p. 1699) in what has been called "the rise of the pure science ideal" (Daniels 1967, p. 1703). The period saw such resentment come to a head.

> The decade, in a word, witnessed the development, as a generally shared ideology, of the notion of science for science's sake. Science was no longer to be pursued as a means of solving some material problem or illustrating some Biblical text; it was to be pursued simply because the truth—which was what science was thought to be uniquely about—was lovely in itself, and because it was praiseworthy to add what one could to the always developing cathedral of knowledge. (Daniels 1967, p. 1699)

Like many other groups during this era, the scientific community began to organize in ways that would facilitate making demands on the federal government for public resources. Science had become an interest group. Scientists who approached the federal government for support of research activities clashed with a federal government expressing the need for any such investments to be associated with practical benefits to society.

Expressing a value structure that goes back at least to Aristotle, U.S. scientists of the late-nineteenth century believed that the pursuit of knowledge associated with the pursuit of unfettered curiosity represented a higher calling than the development of tools and techniques associated with the use of knowledge. Hence, the phrase *pure research* came to refer to this higher calling with *purity* serving as a euphemism for the lack of attention to practical, real-world concerns (Daniels 1967). The first editorial published in *Science* magazine in 1883 clearly expressed a value structure:

> Research is none the less genuine, investigation none the less worthy, because the truth it discovers is utilizable for the benefit of mankind. Granting, even, that the discovery of truth for its own sake is a nobler pursuit. It may readily be conceded that the man who discovers nothing himself, but only applies to useful purposes the principle which others have discovered, stands upon a lower plane than the investigator (Editorial 1883, p. 1).

Some scientists of the period, including Thomas Henry Huxley and Louis Pasteur, resisted what they saw as a false distinction between *pure* and *applied* science (Huxley 1882, Stokes 1995). Some policy makers of the period also rejected such a distinction. For them, utility was the ultimate test of the value of science (Dupree 1957). The late 1800s saw different perspectives on the role of science and society coexisting simultaneously. But Weinberg's axiology of science emerged from the period as the value structure that would shape the further development of U.S. science policies in the first half of the twentieth century.

From Pure to Basic Research

In a well-documented transition, Weinberg's axiology of science stressed the primacy not so much of pure as of *basic* research. The term basic research was not in frequent use prior to the 1930s. But after World War II the concept became so fundamental to science policy that it is difficult to discuss the subject without invoking the corresponding axiology. The notion of basic research arose in parallel with both the growing significance of science in policy and the growing sophistication of scientists in politics. By the end of World War II and the detonation of the first nuclear weapons the acceleration of the development of science-based technology was inescapable. Throughout society science was recognized as a source of change and progress whose benefits, even if not always equally shared, were hard to dismiss.

The new context of science in society provided both opportunity and challenge. Members of the scientific community, often valuing the pursuit of pure science for itself alone, found themselves in a bind. The government valued science almost exclusively for the practical benefits that were somehow connected to research and development. Policymakers had little interest in funding science simply for the sake of knowledge production at a level desired by the scientific community, which itself had become considerably larger as a result of wartime investments. Support for pure research was unthinkable.

Congressional reticence to invest in pure science frustrated those in the scientific community who believed that, historically, advances in knowledge had been important, if not determining, factors in many practical advances. Therefore the scientific community began to develop a two-birds-with-one-stone argument to justify its desire to pursue truth and the demands of politics for practical benefits. The argument held that pure research was the basis for many practical benefits, but that those benefits (expected or realized) ought not to be the standard for evaluating scientific work. Because if practical benefits were used as the standard of scientific accountability under the U.S. system of government, then science could easily be steered away from its ideal—the pursuit of knowledge.

The scientific community took advantage of the window of opportunity presented by the demonstrable contributions of science to the war effort and successfully altered science policy perspectives. The effect was to replace the view held by most policymakers that science for knowledge's sake was of no use, and replaced it with the idea that *all research* could potentially lead to practical benefits. In the words of Vannevar Bush, the leading formulator of this postwar science policy perspective: "Statistically it is certain that important and highly useful discoveries will result from some fraction of the work undertaken [by pure scientists]; but the results of any one particular investigation cannot be predicted with accuracy" (Bush 1945, p. 81).

Central to this change in perspective was acceptance of the phrase basic research and, at least in policy and political settings, the gradual obsolescence of the term pure research. The term basic came without the pejorative notion associated with lack of purity imputed to practically focused work. More importantly, the term basic means in a dictionary-definition sense *fundamental, essential,* or *a starting point*. Research that was basic could easily be interpreted by a policymaker as being fundamental to practical benefits.

The Linear/Reservoir Model

Basic research would be connected to societal benefits through what has become frequently called the *linear model* of science. The linear model holds that basic research leads to applied research, which in turn leads to development and application (Pielke and Byerly 1998). To increase the output (that is, societal benefits) of the linear model, it is necessary to increase the input (support for science).

Bush's seminal report *Science—The Endless Frontier* (1945) "implied that in return for the privilege of receiving federal support, the researcher was obligated to produce and share knowledge freely to benefit—in mostly unspecified and long-term ways—the public good" (Office of Technology Assessment 1991, p. 4). One of the fundamental assumptions of postwar science policy is that science provides a reservoir or fund of knowledge that can be tapped and applied to national needs. According to Bush:

> The centers of basic research ... are the wellsprings of knowledge and understanding. As long as they are vigorous and healthy and their scientists are free to pursue the truth wherever it may lead, there will be a flow of new scientific knowledge to those who can apply it to practical problems in Government, in industry, or elsewhere. (Bush 1945, p. 12)

Implicit in Bush's metaphor is a linear model of the relationship between science and the rest of society: basic-applied-development-societal benefit. This model posits that societal benefits are to be found *downstream* from the reservoir of knowledge. Others have described the liner model as a *ladder*, an *assembly line*, and a *linked-chain* (Gomory 1990, Wise 1985, Kline 1985).

The linear/reservoir model is a metaphor explaining the relationship of science and technology to societal needs. It is used *descriptively* to explain how the relation actually works and *normatively* to argue how the relation ought to work. The linear model appears in discussions of both science policy, where it is used to describe the relation of research and societal needs (Brown 1992), and in technology policy, where it is used to describe the relation of research and innovation (Branscomb 1992). The linear model was based on assumptions of efficacy, and not comparisons with possible alternatives. In 1974 Congressman Emilio Daddario (D-CT), a member of the Science Committee of the U.S. House of Representatives (Science Committee), observed that members of Congress defer to the claims of scientists that basic research is fundamental to societal benefits "and *for that reason, if for no other*, they have supported basic research in the past" (Daddario 1974, p. 140; emphasis added). So long as policymakers and scientists felt that science was meeting social needs, the linear model was unquestioned.

The notion of basic research and the linear model of which it was a part has been tremendously successful from the standpoint of the values of the scientific community. Indeed the terms basic and applied have thus become fundamental to discussions of science and society. For example, the National Science Foundation (NSF) in its annual report *Science and Engineering Indicators* uses precisely these terms to structure its taxonomy of science. Not only did the basic-applied distinction present a compelling, utilitarian case for government support of the pursuit of knowledge, it also explicitly justified why pure research "deserves and requires special protection and specially assured support" (Bush 1945, p. 83). The special protections included relative autonomy from political control and standards of accountability determined through the internal criteria of science. In a classic piece, Michael Polanyi (1962) sketched in idealized fashion how a *republic of science* structured according to the values of pure science provides an *invisible hand* pushing scientific progress toward discovering knowledge which would have inevitable benefits for society.

TABLE 1

Four Definitions of Basic Research

By product:	Basic research refers to those activities that *produce* new data and theories, representing an increase in our understanding and knowledge of nature generally rather than particularly (National Science Board 1996, Armstrong 1994).
By motive:	Basic research is conducted by an investigator with a *desire* to know and understand nature generally, to explain a wide range of observations, with no thought of practical application (National Science Board 1996).
By goal:	Basic research *aims* at greater knowledge and mastery of nature (White 1967, Bode 1964).
By standard of accountability:	Basic researchers are free to follow their own intellectual interests in order to gain a deeper understanding of nature, and are *accountable* to scientific peers (Polanyi 1962, Bozeman 1977).

SOURCE: Courtesy of Roger A. Pielke, Jr.

Seeds of Conflict: Freedom versus Accountability

From the perspective of the scientific community, from the prewar to postwar periods, the concepts of pure research and basic research remained one and the same: the unfettered pursuit of knowledge. For the community of policymakers, however, there was an important distinction—pure research had little to do with practical benefits but basic research representing the "fund from which the practical applications of knowledge must be drawn" (Bush 1945, p. 19). From the perspective of policymakers, there was little reason to be concerned about science for the sale of knowledge alone; they had faith that just about all science would prove useful.

The different interpretations by scientists and policymakers of the meaning of the term basic research have always been somewhat troubling (Kidd 1959). A brief review of the use of the term basic research by the scientific community finds at least four interrelated definitions of the phrase, as summarized in Table 1.

From the standpoint of policymakers, basic research is defined through what it enables, rather than by any particular characteristic of the researcher or research process. These different interpretations of basic research by policymakers and scientists have coexisted largely unreconciled for much of the postwar era, even as for decades observers of science policy have documented the logical and practical inconsistencies. René Dubos (1961) identified a *schizophrenic attitude* among scientists, succinctly described as follows: "while scientists claim among themselves that their primary interest is in the conceptual aspects of their subject, they continue to publicly justify basic research by asserting that it always leads to 'useful' results" (Daniels 1967, p. 1700) It is this schizophrenia that has allowed postwar science policy to operate successfully under the paradigm of the linear model, apparently satisfying the ends of both scientists and politicians. *Basic research* was the term used to describe the work conducted in that overlap. The situation worked so long as both parties—society (patron) and scientists (recipient of funds)—were largely satisfied with the relationship.

The Changing Context

In the 1990s both scientists and politicians began to express dissatisfaction with the science policy of the post-World War II era. For instance, in 1998 the Science Committee undertook a major study of U.S. science policy under the following charge:

> The United States has been operating under a model developed by Vannevar Bush in his 1945 report to the President entitled *Science: The Endless Frontier*. It continues to operate under that model with little change. This approach served us very well during the Cold War, because Bush's science policy was predicated upon serving the military needs of our nation, ensuring national pride in our scientific and technological accomplishments, and developing a strong scientific, technological, and manufacturing enterprise that would serve us well not only in peace but also would be essential for this country in both the Cold War and potential hot wars. With the collapse of the Soviet Union, and the de facto end of the Cold War, the Vannevar Bush approach is no longer valid. (U.S. Congress 1998)

While the congressional report acknowledged the need for a new science policy, it did not address what that new policy might entail. However an understanding of the tensions leading to calls for change point in various directions.

These tensions have been long recognized. George Daniels (1967) sketches those underlying contemporary science policy: "The pure science ideal demands that science be as thoroughly separated from the political as it is from the religious or utilitarian. Democratic politics demands that no expenditure of public funds be separated from political ... accountability. With such diametrically opposed assumptions, a conflict is inevitable" (Daniels 1967, p. 1704) Such tensions were recognized even earlier, in 1960, by the Committee on Science in the Promotion of Human Welfare of the American Association for the Advancement of Science (AAAS): "Science is inseparably bound up with many troublesome questions of public policy. That science is more valued for these uses than for its fundamental purpose—the free inquiry into nature—leads to pressures which have begun to threaten the integrity of science itself" (AAAS 1960, p. 69). For many years under growing budgets in the context of the Cold War, postwar science policy successfully and parsimoniously evaded this conflict. Given pressures for accountability and more return on federal spending, conflict is unavoidable.

Why, more specifically, did postwar science policy remain largely unchallenged for a half century? From the point of view of society, it solved problems. First, science and technology were key contributors to victory in World War II. Infectious diseases were *conquered*. Nuclear technology ended the war and promised power *too cheap to meter*. From the point of view of the scientific community, most good ideas received federal funding. The U.S. economy dominated the world. In such contexts, there was less pressure from the public and its representatives on scientists for demonstrable results; there was less accountability. Scientists, policymakers, and the broader public were largely satisfied with national science policies.

But at the beginning of the twenty-first century new challenges arose. Some infectious diseases rebounded through resistance to antibiotics, and new diseases, such as severe acute respiratory syndrome (SARS), threatened health. For many, the cost of healthcare made world-leading medical technologies unaffordable. The events of September 11, 2001, demonstrated the risks to modern society at the intersection of fanaticism and technology. The availability of weapons of mass destruction makes these risks even more significant. New technologies, in areas such as biotechnology and nanotechnology, created new opportunities but also threatened people and the environment. Many problems of the past have been solved, but new ones are emerging, and science and technology are often part of both the problem and possible solutions. The question of how to govern science and technology to realize their benefits is thus increasingly important.

In addition, many scientists were unhappy as budgets failed to keep pace with research opportunities: As the scientific community has grown and as knowledge has expanded, more research ideas are proposed than there is funding to support. Strong global competition and demands for political accountability create incentives for policymakers to support research with measurable payoffs on relatively short timescales, while within the scientific community competition for tenure and other forms of professional recognition demand rigorous, long-term fundamental research. As the context of science changes, scientists share anxieties with others disrupted by global economic and social changes.

New Science Policy Debates

While scientists perceive their abilities to conduct pure research constrained by increasing demands for practical benefits, policymakers simultaneously worry that basic research may not address practical needs. Insofar as postwar science policy has weakened, discussion of science policy has moved beyond the partial overlap of motives that helped sustain postwar science policy. Scientists now speak of their expectation of support for pure research, and policymakers increasingly ask for direct contributions to the solution of pressing social problems.

In this situation the differing views of scientist and policymaker can create conflict as the shared misunderstanding of the term basic research threatens to become pathological. In the words of Donald Stokes:

> The policy community easily hears requests for research funding as claims to entitlement to support for pure research by a scientific community that can sound like most other interest groups. Equally, the scientific community easily hears requests by the policy community for the conduct of "strategic research" as calls for a purely applied research that is narrowly targeted on short-term goals. (Stokes 1995, p. 26)

For their part, scientists seek to demonstrate the value of research to the public, often through increasing skill in public relations and contracting with consultants to provide cost-benefit studies that show the positive benefits of research investments. With few exceptions, the result of such concerns has not been constructive change, but rather defense of the status quo. In 1994 the National Research Council (NRC) convened scientists and informed members of the broader community to begin a constructive dialogue on the changing environment for science. The group found the public policy problem to be primarily the amount of federal funds devoted to research. A later National Academy report, *Allocating Federal Funds for Science and Technology* (1995), recommended that U.S. science should be at least world-class in all major fields, in effect recommending an entitlement for research. Similarly the 1998 "Science Policy Study" of the Science Committee similarly concluded, "The United States of America must maintain and improve its pre-eminent position in science and technology in order to advance human understanding of the universe and all it contains, and to improve the lives, health, and freedom of all peoples" (U.S. Congress 1998 Internet site)

Other approaches relate research and national needs. The Government Performance and Results Act of 1993 legislates formal accountability by requiring all government programs, including research, to quantitatively measure progress against established goals. Yet experience shows that asking for performance measures and actually developing and applying meaningful measures can be difficult. Daniel Sarewitz offers a penetrating critique of current policy and general steps that would pull research closer to society without sacrificing critical values of science. In particular he recommends research on research: "how it can be directed in a manner most consistent with social and cultural norms and goals, and how it actually influences society" (Sarewitz 1996, p. 180). Donald Stokes (1995) resolves the dichotomy between research driven by purely scientific criteria and research responsive to societal needs by changing the single basic-versus-applied axis into a two-dimensional plane, with one dimension indicating the degree to which research is guided by a desire to understand nature, and the other indicating the degree it is guided by practical considerations. This conceptual advance demonstrates that *good science* can be compatible with practical application, but does not point to specific policy-relevant steps.

There is great potential for nations that have followed the Bush model, such as the United States, to learn from the experiences of those nations that have implemented differing science policies. What change will entail is not entirely clear, however, some trends are apparent. First, overall investments in science and technology show no signs of stagnation. If anything the world is investing more in science and technology, an amount that will in the near future exceed $1 trillion per year. These substantial investments are accompanied by increasing demands for accountability, relevance, and practicality. Such demands increasingly shape the context and practice of science in society. How science will shape and be shaped by these trends will undoubtedly mark a critical transition in science policy in the United States, and perhaps in the world.

ROGER A. PIELKE, JR.

SEE ALSO *Lasswell, Harold D.; Public Policy Centers; Social Theory of Science and Technology.*

BIBLIOGRAPHY

American Association for the Advancement of Science (AAAS). (1960). "Science and Human Welfare: The AAAS Committee on Science in the Promotion of Human Welfare States the Issues and Calls for Action." *Science* 132: 68–73.

Armstrong, John A. (1994). "Is Basic Research a Luxury Our Society Can No Longer Afford? *The Bridge* 24(2): 9–16.

Bode, Hendrik W. (1965). "Reflections on the Relation between Science and Technology." *Basic Research and National Goals: A Report to the Committee on Science and Astronautics, U.S. House of Representatives by the National Academy of Sciences*, pp. 71–76. Washington, DC.: Government Printing Office.

Bozeman, Barry. (1977). "A Governed Science and a Self-governing Science: The Conflicting Values of Autonomy and Accountability." Chapter 6 in *Science and Technology*

Policy, ed. Joseph Haberer. Lexington, MA: Lexington Books.

Branscomb, Lewis. (1992). "Does America Need a Technology Policy." *Harvard Business Review* 70: 24–31.

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

Brown, George E. (1992). "The Objectivity Crisis." *American Journal of Physics* 60(9): 776–863.

Bush, Vannavar. (1945). *Science—The Endless Frontier*. Washington, DC: Government Printing Office. Although its institutional recommendations were never fully adopted, this report is often referred to as setting the intellectual framework for thinking about science and its relationship to society for the post-World War II era.

Daddario, Emilio. (1974). "Science Policy: Relationships Are the Key." *Daedelus* 103: 135–142.

Daniels, George H. (1967). "The Pure-Science Ideal and Democratic Culture." *Science* 156: 1699–1706.

Dubos, René. (1961). "Scientist and Public: Why is the Scientist, Once a 'Natural Philosopher,' Now Considered a Barbarian by Many Educated Laymen?" *Science* 133: 1207–1211.

Dupree, A. Hunter. (1957). *Science in the Federal Government: A History of Policies and Activities to 1940*. Cambridge MA: Belknap Press of Harvard University Press.

"The Future of American Science." (1883). *Science* 1(1): 1–3. This is the first editorial that appeared in the journal *Science*, which in the early twenty-first century is one of the leading scientific journals in the world.

Gomory, Ralph. (1990). "Essay of Ladders, Cycles and Economic Growth." *Scientific American* June: 140.

Huxley, Thomas H. (1882). *Science and Culture, and Other Essays*. New York: D. Appleton and Company.

Kidd, Charles V. (1959). "Basic Research—Description versus Definition." *Science* 129: 368–371.

Kline, Stephen J. (1985). "Innovation Is Not a Linear Process." *Research Management* 28(4): 36–45.

National Science Board. (1996). *Science and Engineering Indicators*. Document NSB 96-21.Washington, DC: Government Printing Office. The U.S. National Science Board publishes data on a wide range of characteristics of science and engineering (e.g., funding, employment, disciplinary distributions of students, etc.) and as such provides an invaluable resource for characterizing the science and engineering communities and how they change over time.

Office of Technology Assessment. (1991). *Federally Funded Research: Decisions for a Decade*. OTA-SET-490. Washington, DC: Government Printing Office.

Pielke, Jr., Roger A., and Michele M. Betsill. (1997). "Policy for Science for Policy: Ozone Depletion and Acid Rain Revisited." *Research Policy* 26: 157–168.

Pielke, Jr., Roger A., and Radford Byerly, Jr. (1998). "Beyond Basic and Applied." *Physics Today* 51(2): 42–46.

Polanyi, Michael. (1962). "The Republic of Science." *Minerva* 1: 54–73. A classic piece that describes how the world would look if it operated under the norms of science.

Sarewitz, Daniel. (1996). *Frontiers of Illusion: Science, Technology and Politics of Progress*. Philadelphia: Temple University Press.

Stokes, Donald. (1995). "Sigma XI." In *Vannevar Bush II: Science for the 21st Century: Why Should Federal Dollars Be Spent to Support Scientific Research? Forum Proceedings, March 2–3*, ed. Kate Miller. Research Triangle Park, NC: Sigma XI Publications.

Stokes, Donald. (1997). *Pasteur's Quadrant: Basic Science and Technological Innovation*. Washington, DC: Brookings Institution Press. Offers a penetrating critique of post-World War II science policy and offers a clear conceptual alternative.

Weinberg, Alvin. M. (1970). "The Axiology of Science." *American Scientist* 58(6): 612–617.

White, Jr., Lynn. (1967). "The Historical Roots of Our Ecologic Crisis." *Science* 155: 103–1207.

Wise, George. (1985). "Science and Technology." *Osiris*, 2nd series 1: 229–246.

INTERNET RESOURCES

Guston, David H. (2000). "Retiring the Social Contract for Science." *Issues in Science and Technology Online* (Summer). A publication of the National Academy of Sciences, National Academy of Engineering, and Ida and Cecil Green Center for the Study of Science and Society. Available from http://www.nap.edu/issues/16.4/p_guston.htm.

U.S. Congress. (1998). Unlocking Our Future: Toward a New National Science Policy: A Report to Congress by the House Committee on Science, September 24, 1998. Available from http://www.house.gov/science/science_policy_report.htm.

SCIENCE SHOPS

Science shops provide independent, participatory research support in response to concerns experienced by civil society (Gnaiger and Martin 2001). Science in this context refers to all organized investigation, including the social and human sciences and arts, as well as the natural, physical, engineering, and technological sciences.

The concept of science shops was developed by students at universities in the Netherlands during the 1970s. This development was assisted by faculty and staff seeking to *democratize* the disciplinary hierarchies of the traditional university system. But arguably science shops are a manifestation of a movement stemming at least as far back as Thomas Jefferson's defense of the principle that "ideas should freely spread from one to another over the globe" (Jefferson 1813, Internet page).