The Changing Ecology of United States Science

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Organisms can be understood fully only in terms of their interactions with the environment, and to thrive they must adapt to their environment—even if the organisms of interest are scientists in a changing world. In this essay we address the "ecology of science" (*1*), that is, the relation of the world-leading institution of science in the United States—scientists, organizations, and culture—to its societal environment. Interaction between science and the rest of society has followed a paradigm, a social contract (*2*), codified in Vannevar Bush's seminal 1945 report, "Science: The Endless Frontier" (*3*). The contract provided that in return for federal support and relative autonomy, "the researcher was obligated to produce and share knowledge freely to benefit—in mostly unspecified and long-term ways—the public good" (*4*, p. 4).

A major ecological function of the social contract is to shape the expectations of both science and society. Science expects autonomy and support. Society expects substantial benefits based on the justifications scientists offer for federal support.

Changes in the ecology of science may render the contract unsustainable; with the Cold War ended, science is adapted to an obsolete environment. Other environmental changes include (i) a dissatisfied public ready to reduce the federal government's size and reach; (ii) deficit-reduction strains on funding, leading to many program reductions; (iii) increasing public awareness of problems that neither science nor government has resolved, including racism, drug abuse, breakdown of community, and crime; and (iv) two decades of decay in real wages, leading to politics focused on the grievances of the middle class. Science competes for funds that otherwise might address such problems directly. Problem resolution will become increasingly important in justifying support for science. Legislatures challenge research universities to contribute more to society, to better educate undergraduates, and to study practical problems.

To many scientists the situation seems perilous (*5*). Although some scientists observe that the changing environment necessitates fundamental change (*6*), others think that science just needs to tell its story better (*2*), and still others address symptoms—for example, finding temporary jobs for new Ph.D.'s. But many hunker down, waiting for the storm to pass. Scientists discuss change, but with little critical examination of the social contract in today's environment.

Science policy must be examined at a fundamental level because the environment for science is changing fundamentally and ineluctably. Our main point is that the social contract currently governing U.S. science is an obstacle to needed changes in science policy. This policy cannot realistically justify large science budgets. The situation demands more than defense of the status quo—if faced constructively, it is an opportunity to develop a sounder social contract, to develop an ecology in which science can thrive.

Science's Ecological Crisis

Since the nation's founding, "the federal government has rendered honor to science and profited from it" (*7*, p. 1). Before World War II, government policy, the "doctrine of useful knowledge," generally supported only science that could demonstrate efficacy with respect to a societal goal (*8*). In the postwar ecology of science, where science enabled critical military and commercial technologies and drew commensurate political attention, this doctrine gave way to Vannevar Bush's "social contract." The issue was not whether to reorganize science, but how to reorganize it (*9*, *10*).

Vannevar Bush's social contract. In 1945, Bush proposed a new relation between science and society. Through the metaphor of the frontier, he associated abstract and mysterious science with a comfortable view of American history (*10*, p. 107).

Bush's metaphor won the minds of the public and their elected representatives because it seemed that the old "doctrine of useful knowledge" no longer matched what was happening in the real world: The atomic bomb was most visible, but radar, jet engines, rockets, and medical innovations also seemed to validate Bush's thesis that new scientific knowledge was intrinsically useful. No longer did science need to pass a test of practicality in order to receive federal funds. In effect, the "social contract" was signed.

Three related assumptions underlie Bush's social contract. First, scientific progress is essential to the national welfare. Bush formally avoided promising too much by noting that science "by itself, provides no panacea for individual, social, and economic ills," but instead serves the national welfare "as a member of a team" (*3*, p. 11). In practice, however, science and society soon forgot this disclaimer and assumed that benefits would automatically follow research.

The second assumption is that science provides a reservoir of knowledge that can be applied to national needs (*3*, p. 12). The image of flow into a fund or reservoir is another critical metaphor of the report. "Basic research . . . provides scientific capital. It creates the fund from which the practical applications of knowledge must be drawn" (*3*, p. 19). Implicit in the reservoir-flow metaphor is a linear model of the relation between science and society in which social benefits occur "downstream" from the reservoir of knowledge.

The third assumption is that "scientific progress on a broad front results from the free play of free intellects, working on subjects of their own choice, in the manner dictated by their curiosity" (*3*, p. 12). For knowledge to flow freely, science must proceed unfettered by political or other constraints. Bush argued that because scientists can best judge science, the direction of research should be their responsibility. The reservoir isolates science from society, keeping it "pure."

On the basis of these assumptions "science is a proper concern of government" (*3*, p. 11) and "federal funds should be made available" (*3*, p. 31); that is, government should sustain the "wellspring" of knowledge.

Metaphors are important because they make some alternatives seem natural and obscure others (*11*). Bush's metaphors lead to a paradigm of research isolated from societal problem-solving: If science steadily refills the reservoir there is no need to worry about how the knowledge is used. Good science alone justifies support from society.

The social contract and the culture of science. Weinberg describes a largely unexamined norm at the core of the culture of science—"pure is better than applied"—which reinforces the social contract (*12*). Pure science arises "from the logic immanent in science itself; applied science arises from needs that lie outside science" (*12*, p. 613). Thus, as the culture values pure over applied science, it devalues the connection of science to its environment. In the culture of the social contract, a scientist following the canon of science is automatically a societal benefactor regardless of what research is done or what

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society needs. Societal benefits result not in spite of isolation from the broader environment, but rather because isolation, as autonomy, is a necessary element of the scientist's ecology.

The postwar ecology of science isolates research from both practical applications and the very environment which today presses it to demonstrate efficacy with respect to the solution of practical problems. This pressure stresses the structure of postwar science policy, creating the crisis.

Political ecology of science in the 1990s. The election of the Republican 104th Congress further changed science's environment. Some members of Congress encourage scientists to address more practical problems (*13*), whereas others would focus science funding in support of agency missions (*14*). The Clinton Administration supports science, but partly as a means to programmatic ends (*15*). These different, and sometimes opposing, positions leave the future of science uncertain (*14*).

The Republican ascendancy does not presage a golden age for science. Given their commitment to reduce federal spending, an increasing science budget is unlikely. Also, Congress supports the National Aeronautics and Space Administration's space station and shuttle which, though not science, are counted as science funds in the budget—for over $5 billion in fiscal year 1996. Furthermore, Republican leaders expect measurable results from research (*16*).

Because under the social contract simply filling the "reservoir" guarantees societal benefits, politicians can claim action on societal problems by funding science. To make such a claim may be a temptation for this Congress. On the other hand, pressure for solutions to chronic, frustrating societal problems; program cuts; and general dissatisfaction with government could create greater incentives for research accountability. In either case, science best serves itself and society if it can demonstrate a mutually beneficial relation, as Vannevar Bush's social contract once seemed to do.

Renegotiating the Social Contract

The ecology of science is changing so radically that science itself must change and should lead the change. The Bush contract is postwar public policy, not natural law. Its assumptions, internalized over the years, must be explicitly identified and critically examined to avoid unconscious limits on change. To guide the change, the nation needs a vision of an institution of science sustainable in a democratic culture. To be sustainable, science must meet two related external conditions: (i) democratic accountability, including accountability to societal goals (*17*), and (ii) sustained political support. (Of course, science must meet its own internal standards.)

Under democratic accountability, science is consciously guided by society's goals rather than scientific serendipity. Good science is necessary but not sufficient; association with a societal goal is required. The Bush paradigm discourages explicit association with goals that are not those of science. Social accountability leaves to scientists a broad scope of scientific choice. Denial of accountability encourages elitist isolation.

Improved justifications will sustain political support for science because support is strengthened by performance commensurate with expectations (*18*), and expectations of science are a function of justifications made in the process of securing funding. By assuming the automatic generation of benefits, Bush's social contract precludes realistic expectations of science, implying that science can solve some problems that, in fact, alone it cannot. Reliance on an outdated social contract leads to a loss of faith in science and a subsequent loss of political support.

To achieve the vision, we recommend a national debate on the future of science, eschewing defense of the status quo and putting aside current budget issues. The debate should address, with empirical evidence, the following two questions: (i) In what ways does science contribute to the national welfare? and (ii) How can science best be marshaled to assist in addressing specific societal problems? Because science affects all of society, debate should not be limited to scientists. Each forum should give equal voice to informed outsiders, seeking and answering sober critics, and welcoming growth in perspective. The academies and professional societies should lead the debates; Congress, universities, laboratories, industry, nongovernmental organizations, and individuals should participate.

Once the debate is engaged, we recommend that the same organizations take steps to make justifications for science funding more realistic and increase full-time participation of scientists in the policy process to facilitate mutual learning. To learn how best to accomplish these recommendations, they should conduct trials and propagate successes.

How might the assumptions underlying a renegotiated social contract compare with those of the Bush contract? First, the new contract would agree that science is essential to the national welfare. Second, it would require a more robust and responsive relation with its environment than that of the misleading, isolating reservoir metaphor. Third, under the renegotiated contract, science would be driven by internal and external problems, not just curiosity. Unsolved problems pique curiosity, and external problems naturally connect science to its environment.

Almost 30 years ago White recognized the following (*1*, p. 105)

> The continuation of civilization as we know it depends on science, and the continuance of science would seem to depend on our ability to examine this sphere of human activity objectively and relate it to its human context. Those responsible for the statesmanship of science must . . . become increasingly aware of the intricacy of the ecology of the scientist. We must learn to think about science in new ways unless we intend to leave the future of science to chance.

An ecologically robust science, adapted to its environment and governed by a renegotiated social contract, can thrive.

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1. L. White Jr., *Dynamo and Virgin Reconsidered* (MIT Press, Cambridge, MA, 1968).
2. D. Guston and K. Kenniston, *Tech. Rev.* **6**, 61 (1994).
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