BEYOND BASIC AND APPLIED

The separation of science from society is today seen as artificial and unsustainable. The scientific community needs to negotiate a new contract with the society that funds it.

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Science policy implements a social contract. In the US since World War II, this arrangement has amounted to society—through government—giving science both money and relative autonomy while, in return, reaping the practical benefits that inevitably result. The arrangement once may have been appropriate, but it no longer is; we now need a new understanding of how science serves national needs.

Recent changes in the context for science have revealed an underlying policy problem. Such changes include tighter funding, demands for more accountable government, emergence of increasingly complex policy problems associated with global economic and environmental issues and the end of the cold war—which replaced an overarching justification for research with a question mark. Such changes mean that research funders—including not only those who award grants, but also the legislators who set budgets and ultimately the public—now need and expect both more and different practical benefits from science.

Since World War II, neither policymakers nor scientists have believed they need to demonstrate a mechanism or model of how science benefits society. Both groups have simply assumed that benefits flow from research. Therein lies the policy problem, as we have discussed elsewhere.[1] Neither policymakers nor scientists can say which research is most likely to lead to benefits, nor how research can be planned, justified or appraised in terms of benefits. Since even pessimistic budget scenarios still call for billions of dollars for research, the critical issue from society's point of view is not small changes in research funding, but the lack of a transparent understanding of how research benefits society.

The current contract critiqued

The current social contract underlying US science policy is based on the concepts articulated in Vannevar Bush's famous 1945 report, *Science—The Endless Frontier*.[2] (For more on the context of science policy back then, see the article by William Blanpied beginning on page 34.) This contract is based on three fundamental assumptions:

▷ *Scientific knowledge is essential to meeting national needs.* The overriding justification for Federal support of research is the expected contribution to broader national needs in areas such as defense, health, environment and technology.

▷ *A simple linear/reservoir model describes how science meets national needs.* In the model, knowledge generated in basic research flows into a reservoir from which society then draws to create benefits.

▷ The scientific community requires relative autonomy from political and other societal concerns to successfully fill this reservoir. Autonomy is implicit in the model because the reservoir isolates science from society; science assumes no responsibility to apply the knowledge it puts into the reservoir, and society does not set scientific priorities.

Whether or not the model accurately describes how science actually meets national needs, the nation has prospered under the Bush contract. But one could also argue that US prosperity financed its world-class science and that the model was largely irrelevant. The model misrepresents and oversimplifies a more complex science/society relationship, and the widespread acceptance of this misrepresentation hinders productive debate on science.[3]

In the linear/reservoir model, which we'll just call linear, information flows in only one direction: from basic research, to applied research, to development, and finally, inevitably, to practical benefits (see the figure on page 43). But that sequence represents only part of the picture.[4] Technology often leads to basic research; the development of space technology, for example, led to high-energy astronomy and astrophysics. (An alternative to the linear model was presented by Burton Richter in PHYSICS TODAY, September 1995, page 43.)

The Bush social contract further assumes that societal benefits are proportional to the support of basic research. Bush argued that basic research is the limiting factor for innovation and its benefits to society, and that the payoff from basic research is random: "Statistically it is certain that important and highly useful discoveries will result from some fraction of the [basic research] undertaken; but the results of any one particular investigation cannot be predicted with accuracy."[2] Implicitly, all good science has the same chance of leading to practical benefits, so the more basic research, the more benefit. However, Bush's own linear model vitiates this argument because the benefits crucially depend on society finding what is needed in the reservoir and taking it out, not on research putting it in.

Bush supposedly developed his model from wartime experience, but wartime research was manifestly "applied." There was no isolating reservoir: Military needs pulled research directly; scientists "were hired to hit an assigned target."[5] The scientific successes of World War II created enough political momentum to install Bush's model in national science policy, but wartime scientific practice differed dramatically from the linear model.

The linear model presents an essentially random process of using research with the implication that society goes where science leads it. The Bush contract would exclude societal concerns from setting research paths and priorities.[6] Indeed, science is accountable through the paradox that research done to advance science—without any consideration of practical benefits—is justified by the

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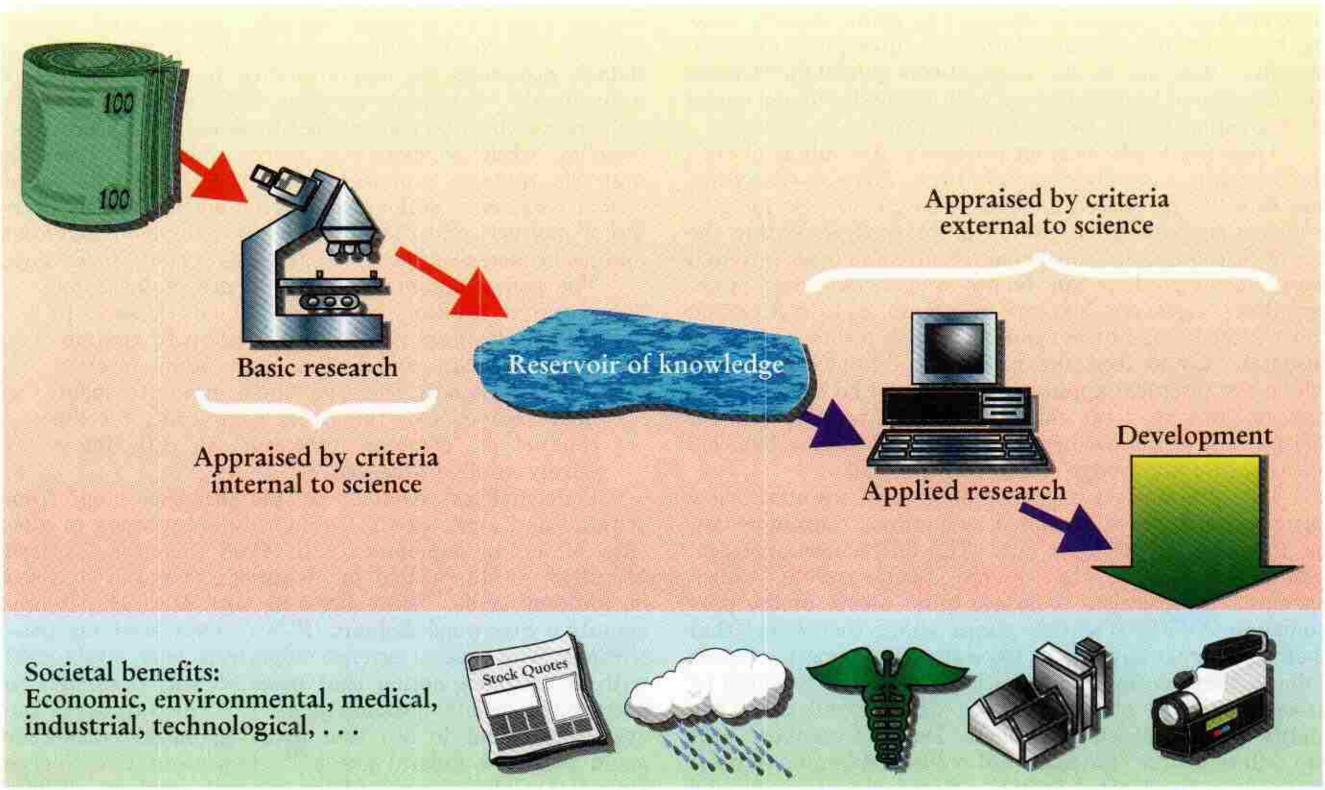

THE LINEAR/RESERVOIR MODEL of how government-funded basic research results in societal benefits. Though widely accepted, this model is too inaccurate to serve either science or society in today's rapidly changing world.

practical benefits that ultimately result. Most scientists, relying on their faith that basic research always yields useful results, live comfortably with the paradox. But their position is flawed because scientific curiosity and criteria will not necessarily fill the reservoir with information that society needs. Even if all information were eventually useful, all *needed* information may not be available at a particular time. The logic of the social contract is backwards because it starts with research and tries to prove it useful, rather than starting with national needs and proving that research addresses them.

In sum, neither experience nor logic prove that the longstanding system of research management and utilization is the best, the only or the desirable system. The fact that society has benefited greatly in the Bush era and many national needs have been met does not prove that his contract was valid, nor ensure that it will work in today's environment.

A problem of terminology

The terminology of the social contract, and specifically the phrase "basic research," hinders productive debate on science policy. "Basic research" descends from the 19th-century ideal of "pure science." In the 1870s, scientists rebelled against "values extraneous to science" and fostered "the rise of the pure science ideal" as a "generally shared ideology . . . the notion of science for science's sake." Science was not pursued to solve "some material problem [but rather] because it was praiseworthy to add what one could to the always developing cathedral of knowledge."[7] *Science*'s first editorial (in 1883) poignantly expressed this ideology: "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." The contrast with "pure" implies that applied research is somehow tainted, and leads to a central tenet of Alvin Weinberg's axiology of science, that "pure is better than applied."[8] A few scientists of that early period, including T. H. Huxley and Louis Pasteur, resisted what they saw as a false distinction between pure and applied research, and few policymakers made such a distinction. For them, utility was the ultimate test of all science.[6,9]

Scientists adopting the "pure science" ideal found themselves in a bind. It was unthinkable for government, representing a society that valued science largely for its practical benefits, to fund pure research at the level desired by the scientific community.[6] This situation frustrated scientists, who understood that advances in knowledge had led to many practical benefits. They developed a rudimentary two-birds-with-one-stone justification for both their desire to pursue truth and society's desire for practical benefits: They argued that pure science was the basis for many practical benefits. But those benefits, whether expected or realized, ought not to be the standard for evaluating scientific work, because that would steer science away from its ideal—the pursuit of knowledge. The argument failed to sway policymakers who remained skeptical of a scientific community they saw as trying to escape democratic accountability. As one congressman quipped, "The scientists claim it is all practical, do they not?"[9]

The US government did not substantially support pure research until the mid-20th century, when Bush improved the two-birds-with-one-stone argument, and presented it to policymakers who were impressed by scientific successes in World War II and challenged by a technology race with the USSR. Bush replaced the phrase "pure science" with "basic research"; thus scientists could call their work "basic" without casting aspersions on more practical work. In this critical change, "basic" meant fundamental, essential or the starting point, thereby making basic research the foundation for subsequent practical benefits. With one stroke, support was gained for "science for the sake of knowledge" as well as for the linear model of innovation in the Bush social contract.

Thus the Bush contract preserved the values of both the scientific and policy communities. *Science—The Endless Frontier* presented a strong, utilitarian case for government support of the pursuit of knowledge. Within the scientific community, the canons of pure and basic research were unchanged between the pre- and postwar eras. Policymakers, however, had an important new distinction: "pure science" had little connection with utility, but "basic research" would feed the reservoir of knowledge "from which the practical applications . . . must be drawn."[2] As policymakers read the contract, it contained no term for the pursuit of knowledge for its own sake; they believed all scientific knowledge would prove useful.

The different ways policymakers and scientists view basic research have coexisted, sometimes uncomfortably, for much of the postwar era. The difference causes an intellectual tension, what George Daniels calls a "schizophrenia," in scientists (who are quite aware of the phenomenon): "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."[7] They justify basic research as applied. Daniel Greenberg calls the difference the "fundamental political dilemma of basic research in the United States." Basic research is funded for many reasons, but the strongest "is a belief that utilizable results may ensue"[10]—the policy community values basic research for what it enables, rather than in terms of the scientist's motives or the research process. Therefore the researchers' motives "only partially overlap with the utilitarian motives of the patrons."[10]

That partial overlap has made the social contract workable. With different values and motives, science and society have kept their contract because it has served, adequately if imperfectly, both sets of expectations—the pursuit of knowledge and practical benefits. More specifically, from the point of view of society, the contract solved problems. The US won the cold war. Various diseases were "conquered." Nuclear technology promised power "too cheap to meter." From the point of view of science, most good ideas got funded. Because of our economic dominance, there wasn't too much pressure for practical results. Both parties to the contract were happy. The schizophrenia of the social contract did not become pathological as long as it satisfied both parties. But times have changed. Now neither party is satisfied.

Breakdown of the social contract

We are beginning to see that few problems have purely scientific solutions. Infectious diseases develop resistance to antibiotics. Proliferation of wastes and weapons mars the nuclear option. Scientists are unhappy as research opportunities outstrip budgets and many good ideas go unfunded. Global competition pushes funding toward short-term applied research and its quick payoffs, while competition for tenure demands rigorous, disciplinary research. Daniels explains a fundamental policy contradiction inherent in the social contract:

> 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.[7]

During years of growing budgets, science and society ignored the contradiction and avoided conflict. Given today's pressures for accountability, however, conflict is unavoidable. Scientists perceive their ability to conduct pure research to be constrained by demands for practical benefits, while policymakers worry that basic research may not address practical needs.[1] Faith in the social contract weakens, dialogue moves outside the partial overlap of motives, and the difference in motives of scientist and policymaker becomes harmful. As Donald Stokes says:

> 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.[11]

Policymakers' reactions to this situation range from critique and exhortation, through different ways to allocate funds, to legislation. In 1993, Senator Barbara Mikulski (D-Md.) called for "strategic research" focused on national goals. After agreeing with Mikulski, Representative Sherwood Bohlert (R-N.Y.) expressed his frustration: "The federal science apparatus was established with the explicit notion that research was necessary to accomplish specific national goals. . . . The purpose of the system was not to see that every potential researcher could receive a federal grant."[12] Representative George Brown (D-Calif.) diagnosed the general problem: "While science has been quick to take credit for societal advance, the path from scientific discovery to . . . benefit is neither certain nor straight."[13]

Various other proposals have tried to relate research to national needs. The Government Performance and Results Act of 1993 (GPRA, PL 103-62), requires all government programs, including research, to quantitatively measure performance against established goals. Yet, as noted by the chair of a National Research Council committee that studied the issue, "a large chasm exists between asking for performance measures . . . and getting ones that are reliable and usable."[14] Daniel Sarewitz recommends research on research, to determine "how it can be directed in a manner most consistent with social and cultural norms and goals, and how it actually influences society."[3] Stokes eliminates 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—one dimension indicating the degree to which research is guided by a desire to understand nature, the other indicating the degree it is guided by practical considerations.[6] This approach shows that good science can be conceptually compatible with practical application, but it does not point to specific policy steps.

Typically, the scientific community parries proposals such as these by requesting more funding for the status quo. For example, in 1994 the National Research Council began a constructive dialogue with scientists and others on the changing environment for science, but in the end its report narrowly defined the public policy problem as "the appropriate level and allocation of federal investment" in research.[15] A later National Academy of Sciences report[16] similarly recommended that US science should be at least world class in all major fields, effectively recommending a funding entitlement for research.

Toward a renegotiated contract

A renegotiated social contract will recognize that policy decisions about the Federal research portfolio are political decisions with scientific input and consequences, not scientific decisions implemented through politics.

Everyone agrees that publicly funded science should serve the national interest, but thereafter most science policy debate faces in the wrong direction. Because the linear model obscures our understanding and because we don't recognize the political nature of policy making, we ask the wrong question: What is the proper role of the Federal government in funding science? That question implies that science is entitled to support independent of any societal concerns, that the nation should be concerned with the support of science, but not vice versa. We ought instead to ask: What research will support the Federal government in meeting national needs? This question leads to appropriate criteria for planning, justifying and appraising research.

Since science policy is inherently political, its broader social context is critical. The salient characteristic of today's context is change. Science policy is already in transition from the Bush contract, but the new one is yet unformed, as outlined in the chart on page 45. The new contract will be flexible, recognizing that the context for science will continue to change.

We recommend that the science community take four beginning steps to develop an improved understanding of the science/society relationship and to renegotiate the social contract. We envision a process of acceptance, learning and change, involving parties both within and outside of the scientific establishment. The first two steps call for a new perspective that is a precondition to success. The last two call for actions, and can proceed in parallel.

	Bush Contract	Transition Period	Renegotiated Contract
Science for National Needs	Science essential, basic research meets national needs.	Science believed essential, but not clear *how* it meets national needs.	Science essential, needs met using what is known and what is learned from research.
Model	Linear/reservoir model.	Confusion. Many hold old model, often unconsciously. Alternative new models compete.	To be determined: model transparent and workable for formulating policy.
Accountability	Autonomy with respect to societal concerns. Formal accountability, i.e., "good science," determined by peer review.	Struggling with accountability, societal metrics incorporated through traditional, blunt political means.	Accountability in terms of "good science" *and* societal metrics, using the mechanisms of the new model.

Step 1: Accept change; eschew defense of the status quo

Scientists must accept that their world is changing and seek to help shape it. They must realize that science policy decisions are necessarily political; scientists could easily be excluded from the process. A new contract will threaten scientific leaders who are comfortable with the status quo, but if the scientific community does not participate vigorously and constructively, others with less concern for science will take its place.

Step 2: Decouple debate from short-term funding concerns

Revising the social contract cannot be done on a schedule driven by the need to address any particular budget problem. Evidence of scientists trying to become more democratically accountable to the broader society will argue powerfully for continued support of science.

Step 3: Pursue data and test hypotheses; eschew revealed wisdom

We have little systematic data to help us appraise the efficacy of research in meeting national needs. The few studies that attempt to correlate research expenditures and benefits do not provide a mechanism to explain the correlation.[17] Rather than continuing to rely on Bush's revealed wisdom, the scientific community should critically examine all assumptions and answer two sets of questions using specific, systematic, empirical evidence. The first set examines how science *now* relates to society. The second set would build on answers to the first to determine how science could relate to society in an even more beneficial way. See the box on page 46. The answers should lead both to an improved model of how science benefits society and to a new contract.

An effective model for this understanding would satisfy criteria of content and procedure. First, the model should focus on goals such as those set forth broadly in the US Constitution (for example, to "provide for the common defense") and more specifically in agency mandates (like the Environmental Protection Agency's goal to understand the health effects of air pollution, or the National Science Foundation's to support the advancement of knowledge). Second, the model must accurately represent the mechanisms of how research affects society; a science policy decision based on the model should have the intended effect. Third, the model should reflect the policy context in which it will be implemented, which includes consideration of national problems, resources and alternative uses for them, political and technical feasibility, societal goals and values, and finally, justifications, expectations, appraisal and accountability. The new model must be functional, not merely metaphorical. We already have some examples in agriculture and defense, among other areas, of how research can effectively meet national needs.

Step 4: Begin to negotiate a new contract

In some ways the new contract could look like the old one, but research should be less isolated in the new contract, reflecting the broader scope of considerations relevant to practical problems. For example, the Bush contract justifies funding for climate models of greenhouse warming by arguing that the predictive power of the models will facilitate efforts to make policy regarding anthropogenic climate change. However, policy efforts based on theoretical climate predictions are likely to founder on political realities.[18] In the new contract, climate change research might play the smaller role—still important and difficult, but more realistic—of calling attention to potential problems and promoting them onto the policy

How does science relate to society?

▷ In what ways does science contribute to the national welfare?
▷ With regard to particular national needs, what are the relative costs and benefits to society of the application of existing knowledge versus generating new knowledge?
▷ How does science interact with other parts of society to generate benefits?
▷ What important problems are not addressed by scientific research?
▷ To which important problems can science contribute only little?
▷ Is support of research on societal problems commensurate with the problems' importance?
▷ How are national needs communicated to scientists?
▷ How is science appraised?

How can science improve its relation to society?

▷ How can scientists better know and understand national needs?
▷ How can science better address needs that are not stable over time, internally consistent or coherent?
▷ How can science better address societal problems? Or, how can societal problems be translated into researchable scientific questions?
▷ How can problems be addressed without political bias (for example, without precluding controversial approaches from study)?
▷ How can science avoid harm to itself if it delivers an unpopular result?
▷ Throughout, how can scientific quality be maintained?
▷ How can science be appraised in terms of national needs?
▷ Can we better model the delivery of benefits?
▷ How do we assess whether one portfolio of research is likely to lead to greater societal benefits than another?
▷ Using new approaches, can science meet new standards of accountability, such as the GPRA?
▷ How can institutions adopt incentives for constructive change?

agenda, while the policy community debates, tests and appraises a range of policy alternatives. In the new model, research—physical, biological, social and policy—would play an explicit role in global change policy development, ranging from contributing the knowledge necessary to design policy alternatives, to appraising the policies' performance. Science would not promise a policy solution arising from basic research; rather, it would play a role in policy development and appraisal.

Clearly this will not be a negotiation with scientists on one side of a table and society on the other, but the concept of a new contract is useful. Scientists must develop trial elements of a new contract and test them broadly, for example, in their research practice, in testimony, in socializing new PhDs. The renegotiation is under way now, but tentatively, incoherently and largely unconsciously. It should be explicit, coherent and committed, but also flexible, incremental and self-correcting, with many parallel trials. The process must offer participation to all scientists and solicit constructive input from outside the scientific community.

A part of, not apart from

We cannot foresee the outcome of this process—neither the new model of how science benefits society, nor the new social contract—because we have relied for 50 years on the revealed wisdom of Bush. This is reason to proceed carefully, and to start now.

We do foresee opportunities for growth in understanding, for more societal benefits, for better appreciation of science and perhaps even for more funding: It is conceivable that we could learn how to capture some of the economic benefits of science, so that some research could become self-supporting. If the scientific community can provide clear, persuasive answers to the above questions and tend to its interface with the rest of society, we can approach what Representative Brown (in PHYSICS TODAY, September 1994, page 31) has called "a research system that arches, bends and evolves with society's goals" to the greater benefit of science and society.

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