

NEEDS FOR A NATIONAL POLICY

Among shortcomings to be faced are projects that burden the National Science Foundation, rising costs of graduate science education, lack of coordination in attacks on social problems, and the poor flow of information from scientists to Congress.

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THIRTY YEARS AGO research in physics in the United States was a remote concern of government. Graduate students in this then pure science were the original do-it-yourself leaders and had to become as adept at begging and borrowing as they were in making equipment. Then came the discovery of fission, the second world war and the nuclear chain reaction. You well know the rest of the story. Congress was so impressed with the enormous new power derived from the science of physics that it enacted one of the most extraordinary laws in our history—the Atomic Energy Act of 1946.

Trends in funding

The decades following the war saw Congress loosen the drawstrings of the public purse to pour out unstinting financial support for research and development. So generous was this support that the annual increase in the level of funding averaged 15% during the Eisenhower years and 16.5% during the Kennedy years. It slowed to 3-4% during President Johnson's administration. However, keep in mind that 3-4% of this enlarged science budget still represented a substantial number of dollars each year.

For many years scientists have assumed that the federal support for science would continue its exponential growth. Only four years ago Harvey Brooks, in responding to questions posed to the Committee on Science and Astronautics,¹ observed that university requirements rise at a minimal rate of 13-15% a year. The economist Carl Kaysen likewise called for continued growth of federal funds for research. We heard similar testimony in hearings that preceded rewriting the National Science Foundation Act.

How large has this funding become? The latest NSF report on federal funding for science-related activities in universities and colleges estimates some \$3.3 billion for 1967. Of this amount \$2.3 billion was for academic science and \$1.3 billion, or about 40% of the total, was for research and development as such.

I see signs that federal funding for university research is following the familiar S-shaped logistic or growth curve. Figure 1 illustrates the point with data on federal obligations for research in the physical and environmental sciences. Table 1 gives the details. I found it refreshing last year to see this recognized by the National Research Council's Committee on Support of Research in the Mathematical Sciences, which observed that growth of federal financial support can not go on forever. Speaking of its recommendation of increased support for research in mathematics, the committee said:

An 18-percent-a-year increase means doubling every four years. A 10-percent annual increase means doubling in less than 10 years. Such doubling cannot continue indefinitely. Not only mathematical science, but all science and all technologies with growing research sectors must face the need for an ultimate tapering off. Neither the fraction of gross national product that can be devoted to research nor the number of people potentially capable of becoming research investigators can increase indefinitely.

Compounding the funding problem is the increasing cost of research that has approximately doubled in the past decade. This doubling is due to an annual cost-increase rate of about 7%,

which includes the efforts of inflation at approximately 3% plus the higher costs from increasing complexity in research processes. The impact of this factor is all too apparent in figure 2.

This question of funding is one that my Subcommittee on Science, Research and Development has followed ever since it was established.

How does the situation for scientific research, for university research, look from Capitol Hill?

I see storm signals flying. The pressures of rising expectations affect scientists and engineers as well as ghetto dwellers. Our people's commitment to science is an act of faith that carries with it the dangers of disappointed expectations. Don Price recently wrote in *Science*²:

I suspect that the current attacks on science come less from those



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who have always feared it than from those who were frustrated when they tried to put too much faith in it. To them, it was another God that failed.

I conceive as one responsibility of my subcommittee the effort to keep expectations in balance with the potentialities of science.

Four policy issues

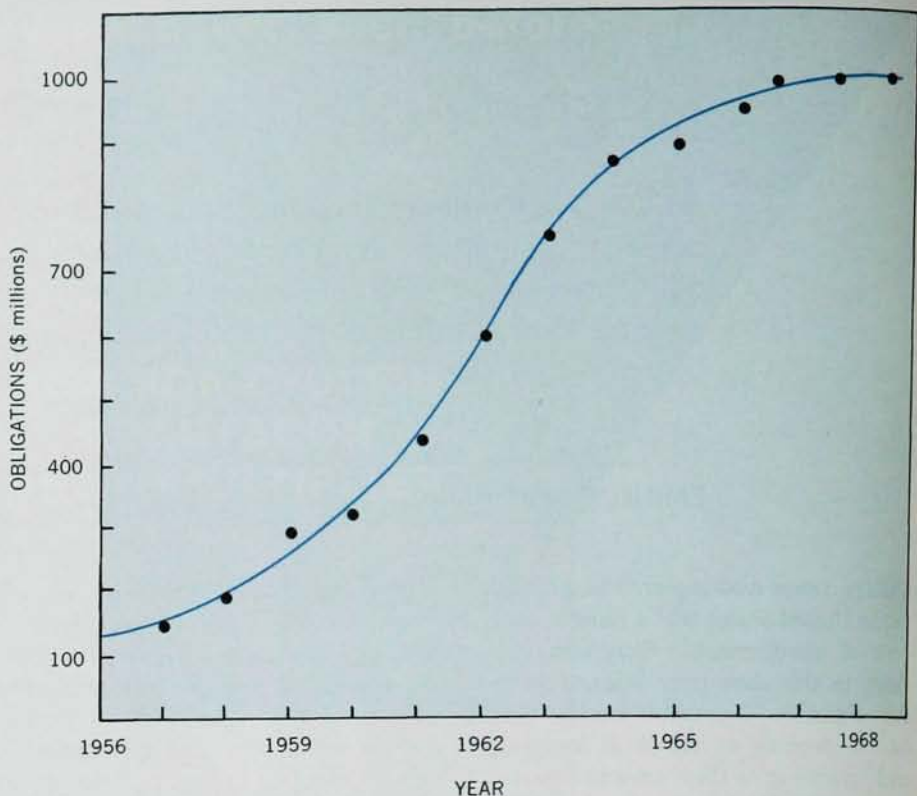
Now I will discuss four matters of priority in shaping public policy for science. Each poses subordinate questions that merit the attention of our scientific organizations. Each raises questions of priorities for use of limited national resources.

The issues are:

- Are mission agencies abdicating their responsibility for academic research?
- How shall the nation sustain its institutions of higher education in science and technology?
- How should multidisciplinary research on the problems of society be fostered?
- How can Congress obtain an improved input of information and ideas from the scientific community?

Are mission agencies abdicating their responsibility for academic science?

After the second world war many federal agencies began to substantially support scientific research in colleges and universities. Many a scientist owes a long-standing debt of gratitude to the Office of Naval Research for its support of academic research after the wartime Office of Scientific Research and Development was terminated and during the legislative effort that finally led to the formation of NSF in 1950. During the four years it took to establish NSF, other mission agencies also moved into the vacuum. The Atomic Energy Commission, the Air Force and the Army, all began to put money into research on campus. Later the Advanced Research Projects Agency and the National Aeronautics and Space Administration did likewise. So it happened that a de facto science policy came about through which individual mission-oriented agencies assumed a responsibility to replenish the pool of scientific knowledge and understanding upon which they drew in implementing their mis-



FEDERAL OBLIGATIONS for university research in the physical and environmental sciences. These data for 1956-68 follow the S-shaped growth curve. —FIG. 1

sions. The consequent pluralism in federal support for academic research in the sciences has become one of the strengths of our nation's science, and many attribute to it our leadership in many fields of science.

ONR money paid for the research of the Fermi Institute in nuclear physics at the University of Chicago after the second world war. ONR support made the Nevis Laboratory of Columbia University a leader in meson phys-

ics. ONR money established the nuclear-physics group at Notre Dame as a national center of excellence. More recently, ARPA funds paid for construction and operation of the radio-astronomy installation at Arecibo and installed the finest world-wide network of seismographs ever known.

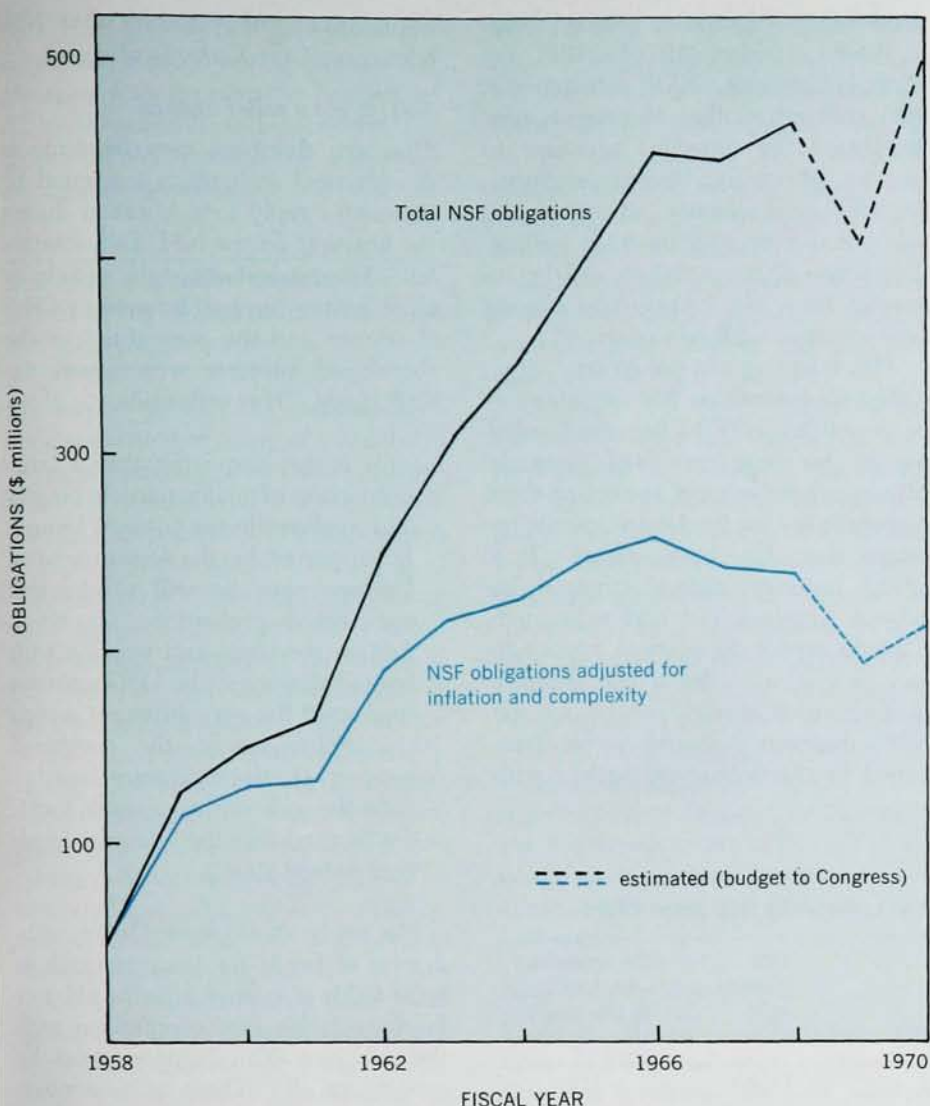
The pluralistic system that supported such excellence worked well as long as there were regular increases in federal funding for research and de-

Table 1. Federal Obligations for Basic Research in Physical and Environmental Sciences, 1956-1969*

Year	Obligations (\$ millions)	Year	Obligations (\$ millions)
1956	120	1963	767
1957	147	1964	874
1958	192	1965	902
1959	291	1966	962
1960	319	1967	1034
1961	443	1968	1087
1962	604	1969	1116†

*Before 1967 no distinction was made between obligations for physical-science research and that for environmental sciences. Thus one should add to the figures for 1967 and afterward those for environmental sciences to make them comparable to the preceding data. The source is *Federal Funds for Research, Development, and Other Scientific Activities, Fiscal Years 1967, 1968, and 1969*, National Science Foundation report 68-27, vol. 17, table C-92, p. 225.

† This 1969 figure is still an estimate.



INFLATION AND INCREASING COMPLEXITY. Total NSF obligations (black) are compared with the same data adjusted for increasing costs during 1958-70. —FIG. 2

velopment. This enabled the mission agencies to extend their interests to new fields of academic research, sometimes not immediately related to agency interests, and to support continuing projects as well. These were the days when we were treated to the sight of much of the nation's most fundamental work in high-energy physics riding on the coattails of an essentially military atomic-energy program. Parenthetically, I have read Craig Hosmer's remarks at the recent particle-accelerator conference, in which he proposed that the funding for AEC's high-energy physics be set off separately from AEC's authorization, thus cutting off that coattail.

Now that funds for research and development are tighter and the growth rate is not much ahead of inflation, we are seeing signs of strain. And with

this change has come what appears to me as a flight by some agencies from their long-standing de facto responsibility for academic research. Federal agencies now appear to be redirecting their support for basic research into fields that they apparently believe are more visibly related to their missions and thus are more easily defensible. Some appear to be retreating from support of basic research they once initiated with the lame excuse that this is now the function of NSF.

Dumping onto NSF

Think back to the examples I just mentioned. Each of these projects was dropped or so severely curtailed by the originating agency that NSF has felt impelled to pick them up. Every project so supported by NSF has preempted funds that otherwise

could have gone to new investigators with new ideas, with new experiments to try. What we are seeing in my opinion, approaches a cynical dumping of well established, productive research groups onto NSF. One reason is that this is an easy alternative for the mission agencies that are now feeling budget pressures. Another is that this is easier than making the case for continued support to those members and committees of Congress who may have questioned such mission-agency support. I am very much concerned about this flight from responsibility by the mission agencies. And I am sure that their budget requests have not been reduced by the amounts shifted to NSF. Moreover, what assurance have we that projects of less quality, less productivity do not continue to receive mission-agency support while first-rate ones are cast adrift.

Recently Leland Haworth, then director of NSF, summed up for our committee his work with the foundation. He spoke of NSF as providing the basis for science upon which mission agencies should build, rather than acting to fill gaps between areas of research supported by mission agencies. And as this dedicated man spoke his hopes for NSF, I could not help thinking how different its situation might be today. What if the scientific community had been less adamant about the organization of NSF as first proposed in Congress? What if there had been compromise so that President Truman would not have felt compelled to veto the first NSF Act of 1947? Those three years until the act was passed in 1950 cost NSF and academic science dearly. In that interim the mission agencies moved in with big money, and NSF never caught up. Now some of these same agencies are looking towards NSF and saying, "Here, catch!" as they have second thoughts about the nature and extent of their responsibilities for academic research. In this time of financial constraint, NSF finds real obstacles in getting funds not for new research but to take care of orphans of the fiscal storms.

If ever there was a matter that requires national policy, this is it.

Now that we have dragged this unmentionable subject out into the open, let us look at it more closely.

Since 1965 NSF has chosen to pick up the support of 20 large research groups, mainly from the physical sci-

ences, whose support was reduced or ended by mission agencies. The cost of this research for fiscal year 1970 is estimated at \$11.8 million. Now this may not sound much to the big spenders, where a single project may spend that and more in a single year. But compare this with the total of \$195 million requested for *all* NSF project support and with the \$29 million for all physics project grants for fiscal 1970. For the current fiscal year alone NSF has picked up seven large projects whose costs come to \$3.5 million. This includes \$1.6 million for Arecibo as the Department of Defense blithely withdraws much of its support for radio astronomy. And did you know that DoD, which puts only 3% of its research and development into universities, estimated their university spending at \$223 million for fiscal 1968? Compare that with NSF's total of \$170.1 million for project grants for that same year! Table 2

gives the information since 1965.

What of fiscal 1970? Will the dumping go on? NSF anticipates it may pick up another 48 projects now supported by mission agencies in physics, chemistry, biology, engineering and social sciences. If it does, the additional cost will be \$2.9 million. Every one of those dollars will be removed from the competition among new scientists with new ideas.

This dumping can not go on.

My subcommittee has no intention of permitting NSF to become a relief agency for now unwanted research. Mission agencies must recognize their responsibility for funding academic research that they have begun. If a group becomes unproductive, if its subject is mined out and exhausted, I would expect the mission agency to end its support. But if the group is productive, it should not be left on NSF's doorstep; it should not be abandoned by the delinquent agency with

a plaintive note pleading that NSF take care of the agency's offspring.

NSF is not a relief agency

That this dumping may be acute in the physical sciences is suggested by Haworth's reply to a question during the hearings on the NSF authorization bill. I had asked about the withdrawal of agency support in various fields of science and the competition of the abandoned projects with others for NSF funds. Haworth said:

It is not surprising that a large proportion of major particle-physics and nuclear-physics projects formerly supported by the Department of Defense agencies will survive this competitive evaluation . . . Being first on the scene and working with limited resources, the DoD agencies supported the very strongest groups . . . Subsequently, the continued support of these groups together with the superiority of their facilities insured that the scientific faculty remained strong. . .

His reply shows how DoD's withdrawal of funds for basic research in some fields of science puts the old pros in those fields into competition with the rookies. The outcome must be evident to all. There is no contest. Perhaps we will have to learn from horse racers how to handicap the well established, winning groups in the competition for funds so that the newcomers will not be lost in the dust.

There is a corollary to the idea I have just outlined. Pluralism in funding of academic research implies that some such support will continue to come from the defense agencies. In turn this means that the academic community may have to forego the intellectual luxury of condemning defense-supported research simply because it disagrees with certain of the nation's defense policies.

On this matter, I note that the President's science adviser, Lee DuBridge, has spoken twice, at the University of Chicago and in a letter to the *New York Times*, to make the point that DoD support of basic research of the sort that universities themselves think appropriate and educationally valuable should be continued.

Returning to our theme, it seems to me that one matter of immediate priority is to reestablish agency responsibility for support of academic research and thus to sustain our pluralis-

Table 2. Projects Taken Over from Other Agencies by NSF since 1965*

<i>Institution</i>	<i>Former support agency</i>	<i>Year taken over</i>	<i>NSF expenditure fiscal 1969 (\$ thousands)</i>
ATOMIC AND MOLECULAR PHYSICS			
Stanford	NASA	1968	112
ELEMENTARY-PARTICLE PHYSICS			
Johns Hopkins	AFOSR	1967	269
Chicago	AFOSR	1969	110
California, Berkeley	ONR	1966	125
Syracuse	ONR	1969	170
Cornell	ONR	1965	2800
Stanford	ONR	1969	1630
Michigan	ONR	1969	305
Princeton	ONR	1969	130
NUCLEAR PHYSICS			
Chicago	ONR	1966	1560
Columbia	ONR	1966	1262
Cal Tech	ONR	1968	880
Notre Dame	ONR	1968	310
Illinois	ONR	1969	260
Indiana	ONR	1965	358
RADIO ASTRONOMY			
Illinois	ONR	1968	120
California, Berkeley	ONR	1968	180
Michigan	ONR	1968	120
RADIO ASTRONOMY AND IONOSPHERIC PHYSICS			
Arecibo Ionospheric Observatory	ARPA	1969	900
GEOPHYSICS			
Worldwide seismic network	ARPA	1968	283

* Source. 1970 National Science Foundation Authorization. Hearings before the House Committee on Science and Astronautics, Subcommittee on Science, Research, and Development, 91st Congress, first session, 1969, vol. 1, pp. 524-5.

tic system. If we do not do so, the only alternative may be to create a single agency to oversee the funding of all basic research and to assure the proper implementation of national—not agency—priorities.

How shall the nation sustain its institutions of higher education in science and technology?

My second issue is the precarious financial position of many of our centers of excellence for education and research in science and the absence of coordinated federal policy and action to cope with the situation.

American science and engineering have achieved great strength, which we believe to be vital for the future of our country. Yet our institutions of graduate education, one major source of this strength, have had to make financial decisions and commitments without the guidance of an explicit national policy. Some even now are risking their financial health to give us time to shape and apply such a policy, and, I should add, we are not yet shaping and applying one.

This is a future-oriented issue. Responding to the new responsibility put upon it by Congress last year, the National Science Board has advised us that graduate education will soon be the fastest growing and most expensive part of the educational process. The number of graduate students is expected to double and reach 1.3 million by 1980. The cost of their education is expected to quadruple to an annual rate of \$20 thousand million by then. At present some 200 000 graduate students are in science and engineering. This number is expected to exceed 400 000 by 1980.

These figures take on special pertinence when we look at the high unit cost of graduate education in the sciences. Philip Handler testified before my subcommittee last February³ that the expenditures per graduate student in the natural sciences "very substantially exceed those for the graduate student in mathematics or the humanities, with the expenditures for social sciences somewhere in between." Northwestern University estimates that a graduate student in the physical sciences costs about \$21 000 a year in comparison with \$4000 a year in the humanities. Moreover, records show that a doctoral student in chemistry there can cost

\$40 000 a year. If we subtract those costs recouped from federal sources, we find that a university such as Northwestern may be putting in \$11 000 a year for each graduate science student in comparison with about \$3700 a year per graduate student in the humanities.

How long can a university afford so disproportionate an allocation of its resources among fields of graduate education?

Consider the predicament of US universities that are caught between their desire to respond to the American dream of education for each person to the limits of his intellectual ability on one hand and the spiraling costs of graduate education and research on the other. Some universities are dipping into their capital endowment funds, robbing their future to pay for the present. This year Duke is about \$2.5 million in deficit. Within a few years an annual deficit of \$10 million is projected at one major university in the Northeast, while a \$2 million annual deficit is expected shortly at another major university in the near Midwest.

Real and urgent problems

Early in March I visited the West Coast with some other members of Congress to obtain firsthand information about effects on universities there of constraints on federal funds. I returned to Washington convinced there is a real and urgent problem. Part of it stems from the response by the universities to federal policies that called for establishing new centers of excellence. Just as these new centers began to take off, just as they were recruiting graduate students and faculty, there came the NSF cut, the cutback on the National Defense Education Act, NASA, AEC and National Institute of Health fellowships, and the belt tightening on mission research support. The final crunch came with the Expenditure Control Act of last year.

I saw visible evidence of real injury to our scientific enterprises on campus. People were being fired. Major equipment purchases were delayed or canceled. Institutions such as the Scripps Institution of Oceanography were tying up their oceanographic boats and firing the specially trained crews—which will be expensive and difficult to replace in the future.

How long can deficit financing by universities continue before they are

inescapably caught in the downward spiral leading to reduced enrollments, reduced quality and even bankruptcy? What is the future for those universities that in good faith responded to the need for new centers of excellence, centers that we will need very much in the coming years, only to suddenly find to their sorrow that federal policy and federal funding were different things? How much longer can our universities wait for concerted national policy and action? Are we by default abandoning the American dream that each citizen be educated to the limits of his intellect rather than to the size of his purse?

Deficit spending by universities is not their only financial problem. Financial support for graduate education comes in part from academic research funded by mission agencies. But the narrow interpretations of their missions has led to incomplete coverage of graduate science education and science, both by discipline and among institutions. Although mission agencies have strengthened specific fields of science and technology, they have not correlated their support with long-range national needs for graduate scientists and engineers. I submit that it is poor policy to hope for an accidental confluence of mission-agency interests in academic research and education that will produce the kinds of manpower we will need. This is not to say I favor total state planning and control, which is just as bad at the other extreme. It is time to think much harder about the responsibilities of mission agencies in relation to our institutions of graduate education. My Subcommittee on Science, Research and Development has good reason to consider carefully the recommendation of the National Science Board that the federal government accept a continuing responsibility for a significant share of the total cost of graduate education and to assist in the implementation of a national policy to this end.

To deal with these issues in graduate science education Chairman George P. Miller of the House of Representatives Committee on Science and Astronautics and I introduced H. R. 35, a bill to provide institutional grants to our universities. This would authorize the appropriation of \$400 million for fiscal 1970 to supplement other forms of financial support to universities and to provide stable, long-range funding for research and instruction in the sciences. I will not go

into that bill in detail, but I hope many readers of *PHYSICS TODAY* will give it careful attention. You can write to my office for a copy of the bill and of the hearings on it. It is enough for now to say that H. R. 35, if enacted, will be an important step towards meeting the grave financial threat to the future of our universities and their ability to produce the educated men and women whom we will so urgently need in the years to come.

How should multidisciplinary research on the problems of society be fostered?

A third priority matter for national science policy has to do with multidisciplinary research on the problems of society. By this I mean research that combines the intellectual and informational resources of the life, physical and social sciences and engineering. Multidisciplinary research holds out the hope of better—note I do not say complete—understanding of the complex issues that perplex us today. We must further experiment with ways to marshal the interests and talents of our scientists and graduate students. At the moment, such multidisciplinary research is still a novelty. NSF estimates there are only about 40 such groups in existence or coming into existence at universities. The International Biological Program and the NSF weather-modification programs are good examples of an approach that is both multidisciplinary and multi-institutional. How well such groups can adapt to the highly individualistic traditions of university science remains to be seen. Whether the scientific community itself will accord multidisciplinary research full recognition is also an open item. These questions will remain moot, however, if we do not encourage such groups to show what they can do and to recognize there will be disappointments as well as successes.

I bring up multidisciplinary research for another reason. Multidisciplinary research offers to our young science faculty and their graduate students, who are intensely concerned about social problems of the day, an opportunity to connect, to tie their professional development to resolving problems of the real world. It can bring the rigorous criticism of science to bear upon the often emotionally loaded questions we face.

Given these reasons for multidisciplinary research, what is being done about it?

My answer has to be, "Precious little." Agencies with specific functions naturally concentrate upon the short-term, applied problems, often to the exclusion of longer-range anticipation of and preparation for the future. They have little authority, time, funds and inclination to develop a basis for understanding the ever changing complex questions of our day that demand solution. I would hope that federal policy could set out a responsibility for mission agencies to invest in some interdisciplinary research that may solve some problems.

Consider for a moment the International Biological Program. This international, interdisciplinary scientific venture seeks to obtain the baseline information so urgently needed to assess the effect of man's excesses upon his environment—upon the air *you* breathe, the water *you* drink and swim in, the foods *you* eat and the land that *you* would enjoy. With prodding and urging by Congress, the Executive is slowly responding. If this response is what we hope it will be, the program will be an outstanding example of large-scale multidisciplinary research that will include systems analysts, meteorologists, land-management scientists, geneticists, pathologists, nutritionists and professionals of many other disciplines.

We also have before us the proposal from NSF for a new program of multidisciplinary research with an initial budget of \$10 million for fiscal 1970. It is interesting to me that NSF included this item upon the recommendation of its Engineering Advisory Committee. Part of this money would help existing, or forming, multidisciplinary groups to firm up their thinking and plan the kind of research they would propose. Part would fund multidisciplinary ventures that are ready to move off. Some examples mentioned by NSF include research into cultural and social consequences of changes in technology, structure of urban environment, and environmental quality of modern society.

We are interested in this proposal. One thought that occurs to us is that perhaps other institutions with a proven ability in multidisciplinary research should be permitted to share in this effort. For example, Oak Ridge National Laboratory already has included political and other social scientists in

some of its research projects. We should be thinking about ways to bring that expertise residing in our federal laboratories to bear on this multidisciplinary approach to the problems of our society.

How can Congress obtain an improved input of information and ideas from the scientific community?

My fourth item for immediate priority in national science policy is the question of improved communications with the Congress by the scientific community. We do have some advisory groups now. Our experience, however, convinces me that much remains to be done to improve the content, timing and targeting of advice on scientific matters. Now let me be clear. I am not suggesting a science lobby. Rather I am calling for legitimate and needed inputs in their fields of expertise from the societies and individual scientists who make up our scientific community. In particular we need inputs that look beyond the needs of one particular specialty and compare the needs and opportunities of various fields of science. The Committee on Science and Public Policy (COSPP) report to the Committee on Science and Astronautics by George B. Kistiakowsky's panel is a good beginning in addressing some of these thorny questions. This would help us in Congress to substitute reasoned advice for hunches and off-the-cuff responses.

I realize full well that we in this country would be the poorer were we to forget that science has become a prime means of enriching our lives through the generation of knowledge. Man has an inborn desire to know, a curiosity that propelled him up the chain of evolution. I think we need this intellectual stimulation just as much as we need food, shelter and health.

References

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2. D. K. Price, *Science* 163, 27 (1969).
3. P. Handler, Hearings before the House Committee on Science, Research and Development, 91st Cong., 1st sess., 1969, p. 181. □