Steps toward a National Policy for Academic Science

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Two topics that could serve as the basis of a long-range plan for a national policy on academic science in the United States are dealt with here: (i) the stabilization of that portion of the federal budget devoted to the support of research and development (R&D) in the universities and colleges, and (ii) the problem of direct federal support of graduate students. Both of these topics would attempt to stabilize the federal support of academic science after a decade of enormous growth in certain areas followed by a substantial shift of emphasis to new fields of interest.

It is necessary to begin by defining as clearly as possible the terms "science," "technology," "basic research," "applied research," and "development." In a speech Sir Brian Flowers (*1*) has said:

> . . . the analytic development of knowledge that is science, the synthetic development of knowledge that is engineering, and the technological activities that make both possible are all interdependent and inextricably mixed into the pattern that is the fabric of science.

Although this description of the multiple relationships between the substance of science and its closely related activities is accurate, it does not lend itself as easily to statistical analysis as does a somewhat simpler conception. In the United States, the National Science Foundation (NSF) has collected and published data on the funding of federal R&D programs since 1952 (*2*). Because this data base is the most consistent and because it has been maintained over the longest period of time, the definitions of the NSF will be used in this article.

The data compiled in these studies have been separated into three principal categories: (i) "Basic research is concerned with exploration of the unknown. It is primarily motivated by the desire to pursue knowledge for its own sake"; (ii) "Applied research is concerned with finding the means for meeting a recognized need. It draws upon the general principles established by basic research investigations and in turn creates additional knowledge"; and (iii) "Development is the systematic use of knowledge and understanding gained from research and directed to the production of useful materials, devices, systems, and methods; such work includes the design, testing, and improvement of prototypes and processes. Development is directed to generally predictable and very specific ends. . . ."

These three definitions describe a spectrum of activities that can be visualized as shown in Fig. 1. The boundaries of separation are poorly defined, as indicated by the crosshatched lines. However, in analyzing federal expenditures, the staff of NSF has been able to resolve most of the individual cases and to assign them consistently to one category or another. If basic research, applied research, and development are used to describe the total range of the spectrum, then science and technology might be viewed as a dual separation of the same activities, as indicated schematically in the middle part of Fig. 1. Such a separation is at variance with the definitions given by Flowers, but it arises from the fact that a simply connected, linear description of these activities is used for simplicity of data analysis, while the reality is a mesh of strongly interacting entities. Because the data base uses the linear spectrum of Fig. 1, I use that description also.

Finally, the term "academic science" will be used to include that portion of the entire spectrum of activities which is carried out on the campuses of universities and colleges throughout the country. Academic science emphasizes basic or fundamental research most heavily, but does include appreciable activity in applied research and some few projects that can only be described as development. In Fig. 1, this variation in emphasis is indicated by the degree of shading.

Having defined the terms of reference, the next task is to consider how the support of these R & D activities might be justified. The areas of applied research and development, as well as technology, are characterized by having clearly defined goals for each of the projects undertaken. The degree of financial support that might be needed to achieve a specified goal can be weighed against the estimated value of the outcome to determine whether or not one should proceed. This type of cost-benefit analysis has been widely used when the Department of Defense has undertaken the development of a new weapons system, when the National Aeronautics and Space Administration (NASA) has considered a new project in space, or when an environmental agency has undertaken the development of a new kind of pollution control technology.

On the other hand, basic research cannot be treated in this way. Although it is not possible to put a dollar value on the extension of knowledge, history has demonstrated that the advance of scientific knowledge has been of enormous benefit to mankind and has been an extremely profitable investment. Unfortunately, we cannot predict which area of scientific research will yield a given kind of knowledge or what applications that knowledge might have. It is this element of unpredictability that causes basic research to depend upon long periods of uninterrupted effort to achieve its purposes. The randomly distributed times of delivery of results, plus the long periods between discovery and utilization, make it extremely difficult to apply the usual cost-benefit analyses to basic research. However, it is possible to manage the flow of funds, to judge the quality of work on a periodic basis, and to measure the rate of progress on a given project in a completely satisfactory way.

The funding of a group of these projects, which are aggregated into a coherent program, requires some criteria in addition to cost-effectiveness for establishing the proper amount of support. To determine the appropriate mechanism for the funding of long-term programs of basic research, several of the nation's leading technological industries have adopted a "level-of-effort" philosophy. According

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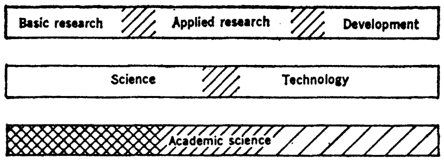

Fig. 1. A representation of the ranges of activities covered by the terms "basic research," "applied research," "development," "science," "technology," and "academic science."

to this rationale, an industry that deals in technological goods or services must maintain research activities in order to generate new products and innovations because the company would otherwise lose its ability to compete in the marketplace. It is then necessary for the management of such an enterprise to determine how much research activity can be sustained. In practice, each individual research project is justified and coordinated into an overall program, and the larger companies frequently have many diverse programs on an assortment of topics. These programs must be implemented and coordinated in such a way that the long-range objectives of the company can be achieved. The overall level of funding for such programs is often determined by the gross income of the company. It is common practice to use a fixed percentage of the gross income as a guide to setting the overall level of effort. This total is then used as a reference point in the internal allocation of resources to the various programs. The priority and amount of support assigned to each program reflects its importance and relevance to the stated goals of the company.

The level-of-effort concept of funding projects with long-term payoffs can be applied to the programs of the federal government. This article explores the means by which this philosophy can be applied to a specific segment of the federal budget and evaluates the implications of such a plan.

Federal Support for Academic Science

The federal government supports scientific research in academic institutions, industrial laboratories, nonprofit organizations, and its own in-house laboratories. Almost two-thirds of these research expenditures go to institutions of higher education, which produce both research results and trained manpower. Because the universities play such a dominant role in the national picture of research, let us discuss the application of the level-of-effort concept to academic science. Although academic science encompasses some development and considerable applied research, as indicated in Fig. 1, the primary motivation for these activities centers around the training of students. Because the average training period for a Ph.D. student in the sciences is approximately 7 years, it is appropriate to identify all of the activities of academic science with the long times

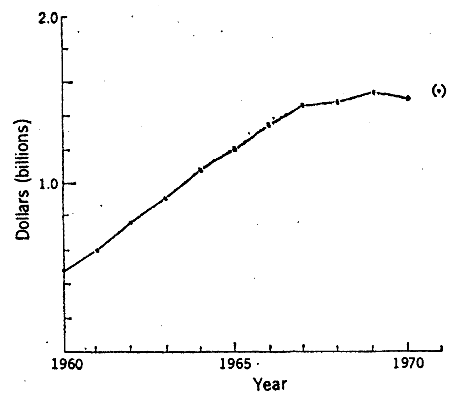

Fig. 2. Federal obligations for R & D by universities (*2*).

(periods of 3 to 5 years) characteristic of basic research, in spite of the applied or directed nature of some of the work.

The growth of federal funding for R & D carried out in the colleges and universities of the country is shown in Fig. 2. This curve is based on data found in Table 1 (*2*). These funds do not include federal money spent to improve the physical facilities of the institutions or funds provided for the support of students by federal fellowships and traineeships.

Figure 2 indicates the rapid growth of federal allocations, expressed in current dollars for university research during the early 1960's, and the marked leveling off that began to occur in 1967. The period of growth had a profound effect upon higher education and re-

Table 1. Federal R & D obligations to universities and colleges 1960–1971, by agency. Table Q-3 in Special Analysis Q of the 1971 budget covering federal funding of universities and colleges differs from *Federal Funds* (*2*) because the former is prepared earlier in the budget year. This table contains the latest modifications to the data available from NSF.

Agency	Dollars (millions)											
	1960	1961	1962	1963	1964	1965	1966	1967	1968	1969	1970*	1971*
Department of Health, Education, and Welfare	157.8	220.7	309.8	350.4	418.6	472.6	534.4	619.8	671.3	695.0	656.2	711.6
Department of Defense	154.5	191.1	200.2	237.5	292.0	291.0	295.3	279.9	244.4	252.8	217.9	216.3
National Science Foundation	59.9	68.4	89.3	115.3	127.4	142.1	187.4	207.8	221.0	212.6	228.8	278.0
National Aeronautics and Space Administration	10.4	17.7	53.5	78.2	105.6	124.1	133.2	124.1	130.6	125.1	109.8	88.0
Atomic Energy Commission	39.3	49.4	54.9	67.4	69.4	74.4	82.2	89.5	92.6	101.4	100.3	96.4
Department of Agriculture	31.6	32.9	38.6	40.6	48.6	58.4	61.6	64.2	61.1	61.5	63.6	73.3
Office of Economic Opportunity						7.1	20.9	15.5	13.8	25.4	23.0	25.0
Department of the Interior	1.5	2.2	2.8	3.7	5.5	9.8	19.7	23.4	25.7	23.8	25.4	27.3
Department of Transportation†	0.3	0.7	0.7	0.8	0.6	0.4	1.4	11.1	11.9	12.8	18.4	21.8
Agency for International Development	0.1	0.3	2.7	1.3	3.9	6.0	3.7	3.2	3.5	5.0	6.4	12.9
Department of Labor			0.1	0.5	1.1	2.2	3.1	3.0	3.2	3.0	3.1	3.1
Department of Housing and Urban Development							0.4	2.5	1.1	1.0	0.9	1.3
Department of Commerce	0.9	0.8	1.6	2.8	2.9	3.7	3.7	6.0	7.4	1.8	2.7	3.2
All other	2.3	0.7	0.8	1.0	1.7	2.0	3.5	3.5	2.7	4.6	7.8	12.5
Total, all agencies	458.6	584.9	755.0	899.5	1077.3	1193.8	1350.5	1454.5	1490.3	1525.8	1464.3	1570.7

* Figures for 1970 and 1971 are estimates. † Federal Aviation Administration only, prior to 1966.

flected the public dedication to our national goals in the areas of health, defense, and outer space. During this period, the universities expanded their physical plants, faculties, and student enrollments in these areas of national concern. The expansion was facilitated by federal grants, often with matching-fund financing, for buildings which, under the terms of the agreements, had to be used for specified purposes for long periods of time. Similar long-term commitments, in the form of full academic tenure, were made to the faculty members who were recruited for these research programs. These long-term requirements, which were imposed by the federal agencies or implicit in the agreements, may have confused some university administrators with regard to the long-range intentions of the federal government.

The trend in Fig. 2 for the years following 1968 has dispelled any illusions they might have had, but it has also left many of our largest institutions in an extremely precarious financial situation. Not only have the dollar expenditures of the federal government been roughly constant since 1968, but the cumulative effects of inflation and research sophistication have caused a sharp effective decrease in the level of support for the universities. This has added to their financial distress, as well as to their sense of uncertainty in planning for the future.

To establish a clear set of guidelines for future planning, an attempt will be made to evolve an appropriate level of effort for the federal funding for academic science. Two factors are required in such a program: First, establishing the dollar amount of support in a given budgetary year; and second, providing a prescription for the annual rate of growth in each succeeding year. In discussing this latter topic, care must be used to distinguish between "real" growth and inflationary increases in the dollar costs. This distinction is made in each of the three methods for determining the level of support and rate of growth.

Method 1

In 1968, the federal support to universities for research had increased by only a small amount over the previous year, but it was generally agreed by all concerned that the condition of academic science in the United States was

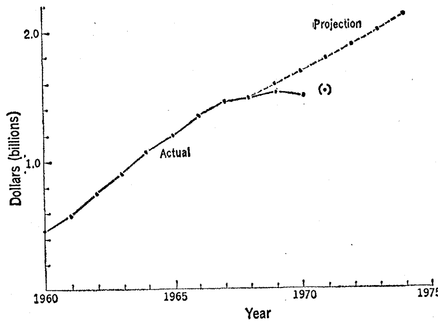

Fig. 3. A projection of federal R & D by universities at an annual rate of increase of 6 percent per year.

excellent. By 1969, the decreased funding had produced significant strains within the system, and a general retrenchment in research programs and plans for graduate student enrollment had begun. The continued decreases in the fiscal year (FY) 1970 appropriations have now created a serious problem for the future. There are clear indications that an appreciable erosion of the base for the technology of the nation has begun. It has been widely acknowledged that certain fields of science in this country will be unable to compete with the work done in other nations. Lee DuBridge (*3*) has suggested that, if the United States is to maintain its position of leadership in world science, a base level of funding of $1.5 billion, as in 1968, should be assumed as an appropriate starting point.

In establishing a growth rate, DuBridge recognized that the rapid rate of increase which took place in the early 1960's had to decrease. He proposed minimal real growth of no less than 1 percent per year to provide for flexibility and some growth in the program. Although this real growth is substantially less than the recent average annual increase of the gross national product (GNP), it would permit limited growth and help to offset the increased costs of performing research due to the increasing complexity of our technology. A widely accepted estimate of the rate of increase in the cost of living is 5 percent per year (*4*), and a total rate of 6 percent per year was chosen as a minimal rate of growth to maintain the level of effort in academic science. A 6 percent per year rate of growth of the current dollar amount for research in the universities has been plotted in Fig. 3, starting with $1.5 billion in 1968. The resultant gap between the actual appropriations and this projection is apparent. The budgetary request of the President for FY 1971 indicates that the appropriate minimum rate of growth has been requested for the current year, although the delay of 3 years causes a substantial funding gap of about $250 million when compared with the desired extrapolation from the 1968 base.

Method 2

Eugene Fubini (*5*) has suggested a somewhat different approach to this problem of setting the level of effort and then calculating an annual rate of increase.

> In determining a suitable level of support for academic science two factors are critical, first, the output of trained scientists and engineers which is required to support the continued growth of our economic base, and second, the amount of research which is required to produce sufficient new knowledge for continued growth.

He then goes on to consider the rate of growth.

> Federal Support for Academic Science should grow at a rate intermediate between that of the number of students and that of the GNP. For FY 72–74, the average rate of growth of GNP (in constant dollars) is estimated to be 5.5 per cent and for the number of full time equivalent graduate students in science and engineering the rate is 7.0 per cent. On the basis of this, the proposed support levels (using the 1970 totals from Table 1 and a 6.5 per cent annual increase) are:
>
> (in constant dollars)
> FY 72: $1.712 billion
> FY 73: $1.823 billion
> FY 74: $1.942 billion

If this rate is converted to current dollars by the addition of 5 percent per year, then Fubini's method requires a total annual growth of 11.5 percent, which is almost twice that suggested by DuBridge.

Method 3

Derek Price (*6*) has proposed a somewhat different approach to the problem, based upon his well-known treatment of growth governed by a "logistic" curve. He chooses the level of support to be the value in FY 1969. Then, having recognized that the rate of growth is in that portion of the logistic which is changing from an exponential to a more moderate linear rate, he fixes the rate and its time variation. He notes that in FY 1969 the support for science was a fixed fraction of the GNP, and he accepts this fraction as "appropriate." He then assumes that the academic science population should continue to grow at its present linear rate and that support for this, expressed as a percentage of the real GNP, should grow proportionately and at a linear rate. Because the manpower grows at about 6 percent per year, the prescription by Price is stated as follows:

The support for academic science for any fiscal year relative to the preceding year's GNP should equal that ratio for FY 69 increased by a factor of $(1 + 0.6t)$, where t is the number of years elapsed from FY 69.

The similarity between this result and that of Fubini is evident, although Price has used a smaller rate of growth. Again, to transform the results into current dollars, one must add 5 percent per year for inflation. In Table 2, a comparison of the three methods for making budgetary requests is made in terms of *current* dollars.

Implementation of the Level-of-Effort Concept

The choice of an overall level of funding and a prescription for its rate of growth does not solve the problem of the internal distribution of these resources, nor does it provide a mechanism to insure the maintenance of the level in succeeding years. Although the natural analog of the level-of-effort concept in industry would require the use of the GNP as a reference point, several objections led DuBridge to use the segment of the budget contained in Table 1. These are the funds that are under the direct control of the President, while the GNP is not. The initial allocation of these funds among agencies is a dual activity of the executive and legislative branches of government. Once the budget has been transmitted to the Congress by the President, it is divided up among a multitude of congressional committees for further action.

After the series of authorization and appropriation bills streams back to the President to be signed into law, the Office of Management and Budget has the task of reassembling the budget and comparing it to the original document. By setting a projected level of expenditure for a budgetary segment such as that contained in Table 1, the Executive Office could only make a corrective budget request in the succeeding fiscal year. In some extraordinary cases, the Administration might request Congress to supply a supplemental appropriation for one of the agencies in the same fiscal year, but this type of correction is too politically complex to be made every year. If a policy were to be adopted to correct the budget request after 1-year time lag, it would greatly stabilize the financial relationship between the federal government and the academic world.

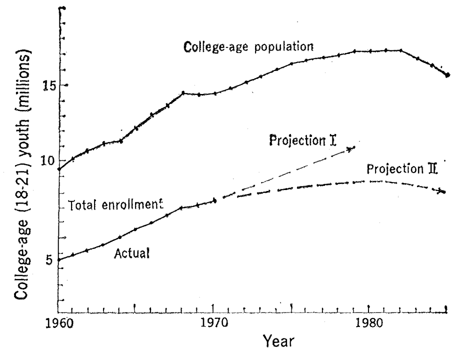

Fig. 4. The college-age population (18 through 21 years of age) and the total enrollment in higher education.

The flexibility of such a policy with regard to changes in national goals can be seen in Table 1. The rise and fall of NASA's budgets during the 1960's clearly demonstrates the adoption of the goal "to land a man on the surface of the moon in this decade." After the achievement of that goal in 1969, a steady decline in budgets is seen. However, the growing national concerns of the mid-1960's with civil rights and social objectives are reflected in the budget of the Office of Economic Opportunity; other agencies dealing with housing, transportation, ecology, and urban development have been slower to develop their use of the talent in the universities.

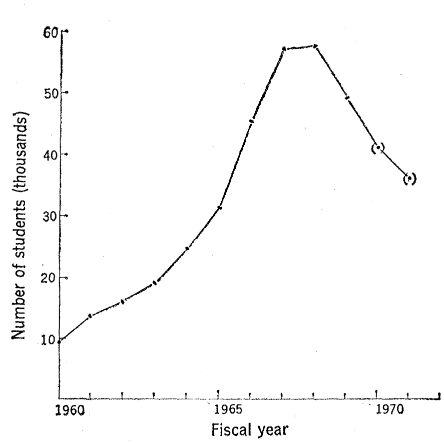

Fig. 5. Federally supported predoctoral fellows and trainees.

A policy to provide a deliberate financial correction to the academic science portion of the federal budget not only would give the financial stability that is needed by the academic world, but also would provide the Administration with an important means of implementing its stated objectives. The budgetary increment could be used to start new programs of research or to expand and modify the emphasis placed on others. Such a system would contain most of the benefits of a "pluralistic" system of support, and at the same time supply the long-term stability which some people believe can only be provided by a single source of federal funds for academic science.

Training Scientific and Technical Manpower

Although many studies on the production of advanced degrees have been carried out within recent years (*7–10*), almost none of them considers the important influence of the declining national birthrate. This decline has been clearly evident since 1962, and it has already been noticed in terms of unfilled elementary school facilities in areas where demographic migrations have not obscured the decline in numbers of children. The top curve of Fig. 4 shows the population of college-age youths (18 through 21 years of age), plotted through 1985 (*11*). The lower curve shows the total enrollment in higher education through 1970, with two different projections (I and II) for the next 15 years. Projection I is that used by the Office of Education (*12*) and, later, by the National Science Board (*13*) in their reports. Because the total enrollment in colleges reached 50 percent of the college-age population between 1969 and 1970, projection II is simply a continuation of 50 percent of the college-age population. One possible rationale for the 50 percent projection as a limit on the number of students enrolled in collegiate higher education can be based on their intellectual abilities. By definition, 50 percent of any given age group has an IQ or Army General Classification Test score less than 100. No matter how the intellectual attainment of an individual is measured, most people would agree that the same verbal skills required for successfully pursuing a

Table 2. Current dollars that would be spent in each method, from FY 1971 to FY 1974.

Method	Current dollars (billions)		
	FY 1972	FY 1973	FY 1974
Method 1	1.893	2.007	2.127
Method 2	1.798	1.914	2.039
Method 3	2.048	2.289	2.594

liberal arts degree are required for a score of 100 or more on such a test. Thus, projection II gives an indication of how future enrollment in collegiate higher education might develop. The Office of Education projection, on the other hand, can serve as an indicator of how much the nation ought to provide for post-secondary school educational opportunities for young people. The Higher Education Act of 1970 has already called for a shift in emphasis from the liberal arts education toward more junior college and paraprofessional training. Even these requirements will not continue to grow after 1982, when the population curve for 18- to 21-year-olds begins to drop; and future plans for post-secondary school education will undoubtedly take this into account.

Supply and Demand of Doctorates in Science and Engineering

I next explore the implications of this population limit, or demographic saturation, in its relation to the future supply of scientists and engineers. If the collegiate undergraduate enrollment is limited to 50 percent of the population, there are well-established relationships that can be used to predict the number of Ph.D. degrees to be awarded. The calculation is made by first converting the total enrollment into the number of full-time equivalent (FTE) students. The graduate enrollment had been about 12 percent of the total FTE enrollment, but it has been steadily rising for the past decade. In the projections presented here, this fraction was allowed to increase from 13.5 percent in 1971 to 15.0 percent in 1985. The Ph.D. degrees granted in each year in science and engineering have been about 2.2 percent of the total graduate enrollment, and this fraction has been taken as constant from 1971 through 1980. The calculations are summarized in Table 3 and show that we can anticipate a total of 229,600 Ph.D. degrees to be produced in the period from 1968 to 1980. This is about 15 percent smaller than the number predicted by the NSF (*7*), which estimated that 264,300 would be produced. After applying all of the NSF corrections (*7*) to these numbers, the total supply of Ph.D.'s is estimated to be 317,400 in 1980. It should be emphasized that this estimate of production is an upper limit to the number that can be produced. If the graduate schools change their emphasis on the Ph.D. by introducing new degrees, or if the fraction of the student population going into science and technology is smaller than it has been in the past decade (*10*), then the true number of Ph.D.'s in 1980 will be smaller than this upper limit.

A number of projections of the job market for Ph.D.'s in 1980 have been made (*7, 9, 10*), and one of the most sophisticated estimates has been carried out by the Bureau of Labor Statistics (*14*). This study starts with a model of the nation's economy in 1980 and a fairly complete set of assumptions about how the country will change in the intervening years. It concludes that there will be an oversupply of elementary and secondary school teachers during the coming decade, and this conclusion is consistent with the declining birthrate mentioned above. It predicts that, in higher education as a whole, a substantial oversupply of full-time teachers will be available as the result of increased Ph.D. production. This conclusion is in agreement with the analysis done for scientists and engineers (*7*). In the teaching profession, as well as in industry, an overabundance of Ph.D.'s would cause an appreciable decrease in the number of non-Ph.D.'s employed in the same kind of work. Most educators would agree that this upgrading of the qualifications of their teaching staff would be desirable, if somewhat more expensive in terms of salaries. It is not clear that industry would respond to this projected overabundance of Ph.D.'s in as positive a manner.

In spite of the general agreement that there will be an excess of Ph.D.'s in 1980 if present trends continue, openings in certain fields will be in short supply over the next decade. The Bureau of Labor Statistics predicts that the fields of physics, chemistry, and, to some extent, engineering will have shortages. Since the Bureau's trend analysis includes a long-term decrease in federal expenditures for the defense and space programs, the present unemployment in the aerospace industry can be interpreted as a transient phenomenon that will not affect the long-range demand for physical scientists and engineers.

Table 3. Projected supply of science doctorates in 1980, adapted from table B1 (*7*, p. 13).

Doctorates	Number (thousands)	
	NSF 69-37	Corrected for saturation
Supply in 1968	147.0	147.0
New awards, 1968 to 1980	264.3	229.6
Immigration, 1968 to 1980	5.0	5.0
Subtotal	416.3	381.6
Attrition of 1968 base	−27.2	−27.2
Attrition of 1968 to 1980	−10.6	−10.6
Emigration	−26.4	−26.4
Subtotal	−64.2	−64.2
Net	352.1	317.4

Federal Support of Graduate Students

The recent history of direct federal support to graduate students can be seen in Table 4 and in Fig. 5, which plots the number of full-time, predoctoral fellows and trainees supported by the federal government for the past decade (*15*). The funds to be budgeted and appropriated in FY 1972 will reach the universities in the beginning of FY 1973, if no undue delays in the appropriation process are incurred. The students who receive this support will be graduated with a doctoral degree from 3 to 7 years later—that is, in the period from 1976 to 1980. Thus, it is difficult to argue that students should not be supported now because there is temporary unemployment of scientists and engineers now. These students will not be

Table 4. Federally supported predoctoral fellows and trainees.

Fiscal year	Students (No.)	Dollars ($\times 10^6$)
1960	9,395	36.5
1961	13,716	53.8
1962	15,974	65.8
1963	19,037	92.8
1964	24,413	120.2
1965	31,185	158.3
1966	45,265	232.9
1967	56,945	279.3
1968	57,586	286.6
1969	48,986	248.4
1970*	41,000*	201.0*
1971*	36,000*	182.1*

* Contributions to these numbers from the National Institutes of Health are based upon estimates for these 2 years.

entering the job market until the end of this decade.

In spite of the careful analyses described above, at the end of this decade no exact picture of the number of Ph.D.'s needed at the end of the decade has been generated to date. However, as our society becomes more and more dependent upon technology, it would be unwise to reduce significantly the technical manpower that will be available at the end of this decade. One course of action might be to maintain the level of fellowships and traineeships at some predetermined level for the next several years. The problem is somewhat complicated by the fact that direct support of graduate students by traineeships and fellowships is provided to only one-sixth of all the students supported. Hence, the funding of this one channel of support does not determine the entire picture. Nevertheless, during a period of financial stability for both the universities and the graduate students, several important changes could take place. The adjustment of the new federal agencies to their roles in solving societal problems will become more clearly defined, and their programs for achieving these goals will become better developed. The universities, on the other hand, need time to focus on the solutions to their own internal problems of organization. The difficulties of establishing interdisciplinary degree programs to provide broad training in the techniques of synthesizing practical solutions to real problems must be surmounted. This will be especially difficult for institutions that have used the traditional approach of analytic and theoretical solutions to idealized situations as their prime standard of excellence. It will take time to reeducate and reorient significant portions of the university community to a new set of operational techniques and methods.

Conclusion

In the discussion above, two steps toward a national policy for academic science have been proposed. The first suggests a budgetary policy that would stabilize the total amount of federal money made available to the universities and colleges for R & D. The second suggests a temporary freeze on the level of direct support for graduate students in science and engineering.

References and Notes

1. B. Flowers, public lecture delivered at Nottingham University, Nottingham, England, 6 March 1970.
2. *Federal Funds for Research, Development and Other Scientific Activites, NSF 69-31* (National Science Foundation, Government Printing Office, Washington, D.C., 1969), vol. 18, table C-97, p. 255. This table contains only the "totals" presented in Table 1 of this article. The author is indebted to the Office of Education and Manpower Studies group of NSF for supplying Table 1. Updated information on agency obligations explains the differences between the "totals" given in *NSF 69-31* and Table 1, dated 30 September 1970.
3. L. A. DuBridge, personal communication, July 1970.
4. The assumption of a constant rate of inflation of 5 percent per year has been made for simplicity in estimating future values. In fact, this rate changes every year, and the current rate could be used in any given year to improve the estimates, without changing the general line of argument. See *Economic Report of the President* (Government Printing Office, Washington, D.C., 1970), table 13, p. 79.
5. E. Fubini, personal communication, July 1970.
6. D. J. De S. Price, "Principles for projecting funding of academic science in the 1970's," unpublished paper, 1970. Also see the discussion by Price [*Little Science, Big Science* (Columbia Univ. Press, New York, 1963)].
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Ecosystems of National Parks

National parks are unique in seeking to limit man to nonconsumptive uses of the land.

Douglas B. Houston

The primary purpose of the National Park Service in administering natural areas is to maintain an area's ecosystem in as nearly pristine a condition as possible (*1*). This means that ecological processes, including plant succession and the natural regulation of animal numbers, should be permitted to proceed as they did under pristine conditions, and that modern man must be restricted to generally nonconsumptive uses of these areas.

These deceptively simple, and seemingly naive, ideas require explanation. Few of our parks are completely self-contained ecological units, and their problems have been repeatedly cataloged (*2–5*). These areas have obviously been affected by modern man's overall disturbance of the biosphere, as well as by his more specific disturbances, including elimination and introduction of species, designation of artificial park boundaries, and suppression of natural biotic processes. I will not minimize these problems: an Everglades without water or with a jetport would be a travesty. I contend that, despite man's intrusions into the ecology of national parks, the pristine ecosystem relations in many of them are comparatively intact or have some reasonable potential for being restored. This sounds incongruous, since visitors to several of these areas number in the millions annually. However, it is necessary to recognize that the uses

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