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National Science Foundation: A Ten-Year Résumé

Its obligations in support of research and training and in evaluating national science policy have multiplied.

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The National Science Foundation's first 6 years were analyzed with scholarly thoroughness by Dael Wolfle in *Science* in 1957 (*1*). I shall not attempt to review the factual data concerning the organization and operations of the foundation that are given in detail in his article. I shall take up the narrative essentially where he left it, at the beginning of fiscal year 1958. Whatever I have to say concerning the earlier period will be from the special point of view of one who has been intimately involved in shaping the foundation's policies and operations during its formative years.

As visualized by Vannevar Bush in *Science, the Endless Frontier*, and as defined by Congress in the National Science Foundation Act of 1950, the foundation has two distinct sets of functions; one relates to the support of research and education through grants, fellowships, and other means, and the second involves the development of national science policy and the evaluation and correlation of the research activities of the federal government, as well as the correlation of its own program with those of other agencies, both public and private. There is a degree of difficulty in reconciling these two functions, because in planning and operating a research-support program the foundation becomes to some extent an interested party with respect to the policy prescribed. Congress obviated this situation somewhat by denying the foundation authority to perform research or to establish its own research laboratories.

In the first or operational category, planning and execution have been reasonably straightforward. Early in its history the foundation adopted the grant as being the most flexible and effective means of support for basic scientific research. In the field of education it was decided that the graduate fellowship was the device that would produce the most immediate results in terms of trained manpower. Within the budgetary limits imposed by Congress, the foundation immediately launched a graduate fellowship program and a research-support program which embraced all the natural sciences and, later, selected areas in the social sciences.

The policy-making functions, as well as the evaluation functions prescribed in the act were less susceptible of immediate and specific action, for reasons Wolfle pointed out.

In *Science, the Endless Frontier*, Bush had visualized that a National Research Foundation would be the principal, if not, indeed, the sole, point of reference for federal support of basic or uncommitted research in the postwar period. In view of the brilliant success of the wartime Office of Scientific Research and Development, this was a logical plan for taking care of the nation's research needs in science. So urgent were these needs, however, particularly in the mathematics, science, and engineering departments of universities, and so urgent was the nation's need for scientific research that the provision of federal support could not await the outcome of the 5-year congressional debate over legislation to establish the National Science Foundation.

The foresight of Secretary of the Navy Forrestal in establishing the Office of Research and Inventions—which in 1946 became the statutory Office of Naval Research—made it possible for the Navy to provide critically needed support for basic research at universities. This program was followed in short order by the programs of the Federal Security Agency, notably those of the U.S. Public Health Service and the National Institutes of Health, and those of the Atomic Energy Commission. When the National Science Foundation began to operate in 1951, initial policy had been formulated and active support of science was under way, and as a result there was pressing demand for (i) impartial support of basic research and training unrelated to such practical missions as defense and health and (ii) supervision, coordination, and policy determination among the growing and splintered research-support programs of the federal government.

Equipped with a broad charter, a limited but growing staff, and an operating budget of $3.5 million, the new foundation found itself under pressure almost immediately to start performing policy-making and evaluation functions. In addition, of course, it was expected to launch, as early as possible, programs in support of basic research and education in the sciences.

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Development of National Science Policy

In this situation, the National Science Board and the director sought to define more specifically the role of the National Science Foundation in relation to other agencies. After extensive conferences between National Science Foundation staff members and the Bureau of the Budget and other agencies, the foundation made a series of recommendations which were incorporated in Executive Order 10521 of 17 March 1954 (*2*). The order states that the foundation "shall . . . recommend to the President policies for the promotion and support of basic research and education in the sciences, including policies with respect to furnishing guidance toward defining the responsibilities of the Federal Government in the conduct and support of basic scientific research."

The order further directs that the foundation shall be increasingly responsible for the support of general-purpose basic research but recognizes also the importance and desirability of having other agencies conduct their special basic research in fields closely related to their missions. The foundation is not expected to have responsibility for the applied research and development program of other agencies; each agency is accountable for the scope and quality of its development efforts.

The Executive Order of 13 March 1959 [section 6(*b*)] further clarified the foundation's role as applying only to *basic* research. Within this more specialized framework, the foundation has been steadily formulating national science policy in the course of day-to-day operations, frequently on the basis of agreement and understanding with other agencies. Those who insist that policy must be handed down "ready made" in the form of a proclamation or edict do not understand the nature of policy in the realm of science. To be workable, policy must evolve on the basis of experience; further, it must take fully into account the fundamental principles essential to the effective performance of research in science.

In carrying out its obligations regarding the development of national science policy, the foundation started from the premise that, in its broadest sense, national policy for science is a matter primarily to be determined by the scientists themselves. The scientists of the country are unquestionably the ones most capable of deciding what is best for progress in science, in the true meaning of the word. Policy in this sense should not be "master-minded" by the federal government or any single agency.

The foundation has advocated, and has itself adopted, the fairly general federal policy of providing support to basic research after consultation with leading scientists in their respective fields. This would appear to be the most direct way in which progress in science in the country can be determined by the scientists themselves. It is the method that is favored by the majority of working research scientists. In carrying out this policy, a given federal agency interjects its own interests and priorities.

In further development of science policy, the foundation's approach has been to examine particular issues and to develop recommendations through a variety of techniques and devices, as follows.

1) The establishment of a special committee, followed by the issuance of a report. The principal example here is the foundation's study, through two different committees, of the problems of government-university relationships. This study availed itself of the assistance of outside individuals and groups, the foundation staff, members of the National Science Board, and representatives of other government agencies. Another example is the work of the foundation's Special Commission on Rubber Research, which made recommendations on the role of the government with respect to basic research in this field that were approved by both the President and Congress.

2) Preparation of special reports on particular subjects—for example, the foundation report on "Basic Research —A National Resource" (1957).

3) The use of experimental programs by the foundation as a means of acquiring information and experience to provide a basis for policy recommendations. The various experimental programs in science education, such as the Physical Sciences Study Committee, are examples of this approach.

4) Conduct of studies and issuance of reports upon request of the Executive Office of the President. The foundation's report on the role of the federal government in international science, its report on federal support of research facilities, and its recommendations regarding payment of indirect costs were prepared at the request of the Executive Office of the President.

5) Sponsorship of legislation on particular problems. An outstanding example is the successful foundation sponsorship of legislation to extend to all agencies of the government the authority to make grants for the support of basic research and the authority to vest title to research equipment with educational institutions. In this and other similar administrative policy matters the Interdepartmental Committee for Scientific Research and Development was helpful.

In 1959 the foundation compiled a list of some 50 science-policy items of a government-wide, national character that it has recommended or stressed. Drawn from a variety of public statements and published reports, these include: (i) the need for increased support of basic research; (ii) the need for increased opportunities and funds for basic research at federal laboratories; (iii) greater stability and continuity in federal support of basic research at universities; (iv) the need for diversity of sources of support of basic research in the federal government and need for basic research in support of development; (v) avoidance, to the extent possible, of large classified developmental undertakings by the government at colleges and universities; (vi) payment of full indirect costs of federally sponsored research at universities and colleges; (vii) reasons for questioning the advisability of establishing a Department of Science and Technology; (viii) policy concerning loyalty of investigators on basic research grants.

Studies in support of policy. As background data for its own research programs and for policy formulation concerning the role of the federal government in the support of science, the foundation established a continuing series of studies of the nature and extent of the national effort in research and development. Comprehensive surveys are made of the research and development effort of colleges and universities and other nonprofit institutions and of industry. Initiated for the year 1953–54, these surveys measure research and development in terms of (i) dollars expended, (ii) professional personnel employed, and (iii) apportionment of effort between basic research, applied research, and development. With 1953–54 as the base year, future surveys will afford data to indicate trends and for other analytical purposes. These surveys are in addition to the foundation's analyses of the support of research and development by federal agencies, published annually in *Federal*

Funds for Science. The whole series carries out the executive order "to make comprehensive studies and recommendations regarding the Nation's research effort and its resources for scientific activities. . . ."

Questions are sometimes raised concerning the value of attempting a breakdown of research and development activities in this way. The objection is made that in the pursuit of specific objectives—as, for example, by technical industries—the planning and execution involve all three categories in close coordination. Furthermore, individuals are often found who can participate effectively in all three areas. The latter are in much demand as project leaders and administrators of government and industrial research and development.

The foundation believes that study of these categories is warranted for a number of reasons. Leaders in science and technology feel generally that more basic research could profitably be performed by government and by industrial laboratories. Similarly, scientists and educators have questioned the extent to which universities should engage in applied research and development, outside of certain areas such as engineering, medicine, and agriculture. Furthermore, it is desirable in any intelligent planning of science and technology to identify students with special aptitudes and to insure that such aptitudes are properly taken into account in the individuals' career plans. But by far the most important consideration is the need to emphasize the importance of basic research itself.

Under the increasing pressure to undertake and perfect critical developments in order to attain national or economic objectives, the emphasis is certain to be on the applications of science, particularly in view of budgetary and manpower limitations. Therefore, unless a determined effort is made to support basic research, developments will inevitably be undertaken prematurely, career incentives will gravitate strongly toward applied science, and opportunities for making major scientific discoveries will be lost. Unfortunately, pressures to emphasize new developments, without corresponding emphasis upon pure science—that is, basic research—tend to degrade the quality of the nation's technology in the long run, rather than to improve it.

Under these circumstances the need for study and analysis of the facts is obvious.

Evaluation of Research Programs

A problem that matches in complexity the policy function is that of evaluation. The National Science Foundation Act makes the foundation responsible for the evaluation of scientific research programs undertaken by agencies of the federal government and for a correlation of the foundation's scientific research programs with those undertaken by individuals and by public and private research groups. The foundation has consistently pointed out, however, that it is unrealistic to expect one federal agency to render judgment on the over-all performance of another agency or department.

The foundation has chosen, instead, to approach the problem through close liaison and exchange of information with other science agencies. The idea is to gain a comprehensive idea of the federal programs and over-all support of *fields* of science such as physics, mathematics, and biology. The adequacy of federal support in each field may thus be considered. This procedure is implemented by the general technique of basing research support upon selection among applications or proposals received. By these measures the foundation has endeavored to identify areas that are receiving inadequate support or which require attention for other reasons.

It was discovered, for example, that systematic biology and, more recently, inorganic chemistry were being inadequately supported. Word that the foundation would be receptive to proposals in the fields of systematic biology has resulted in the rescue of this field from comparative neglect, and in all likelihood the same results will obtain with respect to inorganic chemistry.

Another example will serve to illustrate this point. A few years after the close of World War II, both the Office of Naval Research and the Atomic Energy Commission were providing considerable support to research on low-temperature physics. When the time came that neither agency felt justified in continuing its support at the existing level, the foundation agreed to take over the major support of research in low-temperature physics.

Critical Areas of Science

A related matter that will call for increasing attention on the part of the federal government and other sources of support for research and development is the question of special emphasis on particular areas of science. The issue frequently arises in determining critical areas or, from another point of view, in identifying "gaps." In all developmental work, and in the search for areas of application, the importance of priorities of time and effort is an accepted fact. In pure science, the word *priorities* is inappropriate and misleading. No field of science can properly be said to have priority over other fields, *as science*. However, at a given time, in a particular field of science, it is common to find special lines of inquiry that for the moment are making rapid progress or other lines of inquiry that are meeting difficulty. These considerations can be, and indeed are, taken into account both by individual research scientists and by research agencies concerned in research support. Thus, at any time there may develop what might be termed "critical areas" that it is currently important to foster. If the urgency is great, a conference on the subject may be in order, or possibly a thorough study undertaken to ascertain what special facilities, equipment, or training may be needed to encourage progress in the field. These are well-known techniques, in common use. It seems evident that, in years to come, increasing attention will be required along these lines, since there will undoubtedly be a tendency for groups of scientists to present for support plans and programs that represent their collective thinking. Agencies that provide support will then have to evaluate the needs of different groups in the light of current available information and knowledge—and funds. However, the existence of special patterns for critical areas should not be allowed to alter the view that support of research, across all fields of science, should be carried on on a continuing basis.

New Mechanisms and Agencies

The tasks of policy-making, evaluation, and coordination have been further clarified by the establishment of new mechanisms and agencies that did not exist at the time Dael Wolfle's article appeared in 1957.

In the fall of 1958, after the launching of the first Russian sputnik, President Eisenhower called for redoubled efforts in science and technology, and

steps were taken to strengthen the government's leadership with respect both to science and technology and to education in the sciences. The position of Special Assistant to the President for Science and Technology was created. The President's Science Advisory Committee was expanded and strengthened and undertook at once a series of studies covering significant aspects of the government's relationships to science, technology, and education.

The science activities of the Department of State, which had been allowed to lapse, were revived. A Science Adviser to the Secretary of State was appointed, and science attachés were again placed in key diplomatic posts.

Finally, in response to recommendations of his Science Advisory Committee, the President signed an executive order, in March 1959, establishing the Federal Council for Science and Technology, to promote closer cooperation among federal agencies in planning their research and development programs and to recommend ways in which the federal government can assist in advancing and strengthening the nation's scientific efforts as a whole. Represented on the council are the Departments of Defense, Interior, Agriculture, Commerce, and Health, Education and Welfare; the National Science Foundation; the National Aeronautics and Space Administration; and the Atomic Energy Commission. Representatives of the Secretary of State and the Director of the Bureau of the Budget attend as observers.

Thus, at the present time we have the following pattern: the National Science Foundation, with its National Science Board, has the primary responsibility for dealing with policy concerning federal support of basic research throughout the country. The Federal Council for Science and Technology deliberates on matters of policy and program coordination and future planning among federal agencies and makes recommendations to the President. The President's Science Advisory Committee, comprising nongovernment scientists and engineers, considers important scientific and technical matters in relation to government policy, with special reference to national security. The Special Assistant to the President for Science and Technology is available to the President at all times for advice or counsel on a wide range of scientific and technical matters.

Rate of Over-All Growth

During the first phase of its operations the National Science Foundation was occupied with its own structure and staffing, with the definition of its functions and responsibilities, and with providing a firm foundation for its two major programs: research support and education in the sciences. From the beginning it has also been steadily involved in policy determination both for itself and in terms of federal support of science.

During its first 5 years the foundation's appropriation climbed slowly from an initial $3.5 million for the first year to $16 million for the fifth year, fiscal year 1956. In the second half of the decade there has been a marked upswing in appropriations, from $40 million in fiscal year 1957 to the current level of $152.773 million (see Table 1).

In connection with the growth of appropriations, note should be taken of the perspicacity of Congress in endeavoring to strengthen the programs in education in the sciences at least two years before launching of the Russian sputnik. In the summer of 1955 the foundation published a National

Table 1. Total appropriations and obligations of the National Science Foundation for fiscal years 1952–60 (to the nearest thousand dollars).

Field	1952	1953	1954	1955	1956	1957	1958	1959	1960
				Appropriations (thousands)					
	3,500	4,750	8,000	12,250	16,000	40,000	49,750	136,000*	154,773*
				Obligations (thousands) †					
Development of graduate laboratories									2,000
Biological and medical sciences									
Basic research	736	831	1,966	3,612	4,793	7,361	8,540	19,805	24,405
Research facilities					125	885	987	3,270	2,000
Math., phys., and engineering sciences									
Basic research	311	983	2,033	4,244	4,700	7,619	9,536	22,985	33,489
Research facilities									
University computing facilities							200	1,500	1,500
Major engineering-physics facilities						500	450	2,000	2,000
Oceanographic research vessel									3,000
Atmospheric sciences									500
National Radioastronomy Observatory				104	147	3,431	1,587	4,419	922
Kitt Peak National Observatory				50	250	545	3,100	4,391	3,749
Other							67‡		
Social sciences									
Basic research						289	554	853	1,925
Special international programs									
Antarctic research							446	2,306	7,248
Office of special studies									
Surveys and report	130	42	310	349	97	47	222	230	367
Office of Scientific Information Service									
Distribution of scientific information	87	119	174	303	395	905	1,938	3,848	5,392
Scientific personnel and education									
Training of scientific manpower	1,644	1,477	2,120	2,297	3,718	14,698	19,414	62,070	64,477
Operating costs	531	972	1,351	1,528	1,764	2,351	2,933	5,261	6,188
Total obligations	3,766	4,424	7,954	12,486	15,989	38,630	49,973	132,940	159,162

* Includes a $2 million appropriation transfer from AEC for nuclear research reactors. † 1960 obligations estimated. ‡ Feasibility study for astrograph.

Research Council study, *Soviet Professional Manpower,* which drew sobering comparisons between the rates at which the United States and the Soviet Union were training scientists and technical manpower. Largely as a result of these findings Congress markedly increased the foundation's funds for education in the sciences. The total appropriation for fiscal year 1957, $40 million, was more than double that for the preceding year.

During the 10-year period since it was established, the foundation has successively outgrown three locations in Washington: a private residence (901 16th Street, NW), a former school (2144 California Street), and the old Cosmos Club at H Street and Madison Place. Its present headquarters, 1951 Constitution Avenue, became overcrowded almost as soon as the foundation moved in. Additional space has recently been acquired at 528 23rd Street, NW, and it is expected that further expansion will be necessary.

Support of Research Facilities

With increased appropriations, the foundation has been able to expand its activities in areas that have long needed attention and for which it had previously lacked funds. One of the first areas to claim its attention was the need for basic research facilities. In response to a request from the Bureau of the Budget in 1956, the foundation undertook a study of the subject and published its findings in a report of June 1957, *Federal Support of Physical Facilities and Major Equipment for the Conduct of Scientific Research.* The study pointed out that basic research today increasingly requires the use of large, complex, and expensive research tools. Although government expenditures for research facilities since World War II have run into the hundreds of millions of dollars, for the most part these have been committed to practical research and hence have been available only to a small degree for purposes of basic research.

Traditionally, universities and other private research organizations have provided needed research tools from their own funds or from funds available from state or local sources. Now, however, the need for such major equipment as nuclear reactors, high-energy particle accelerators, high-speed computers, and radio and optical telescopes is too great to be met from such local resources or even from the combined resources of several institutions. The report concluded that if American science were to advance at a satisfactory rate, federal support of needed facilities would have to be provided.

In embarking upon a program in support of facilities, the foundation has recognized that each case must be judged on its individual merits. It is difficult to establish criteria that would be applicable in all cases. Factors taken into consideration include the urgency of the need, the national significance of the development, the availability of adequate personnel, and the degree and character of local backing. Recipient institutions are encouraged to participate financially to the extent possible. The foundation has also recognized that in some situations the federal government must continue to supply funds for operation and maintenance, in addition to funds for construction.

The foundation is presently supporting two major facilities in astronomy, the National Radio Astronomy Observatory at Green Bank, West Virginia, and the Kitt Peak National Observatory at Tucson, Arizona. Both of these projects were undertaken only after intensive studies by astronomers extending over a period of several years. Determination of the types of facilities and instruments needed was followed in each case by exhaustive search for suitable sites.

Other facilities being supported by the foundation include biological field stations, construction of an oceanographic research vessel, university computing facilities, university nuclear research equipment, and facilities needed to expand research in the atmospheric sciences.

Table 2. Comparison of research proposals considered and supported in the biological and medical sciences; mathematical, physical, and engineering sciences; and social sciences (weather modification and antarctic research not included).

Fiscal year	Proposals for research grants ($)		Percentage of support	Av. amount of grants awarded ($)	Av. life of grant (yr)
	Considered	Supported			
1952	13,300,000	1,074,000	8.0	11,156	1.9
1953	17,478,000	1,813,000	10.4	10,540	1.9
1954	27,159,000	3,999,000	14.7	11,100	2.5
1955	38,046,000	7,855,000	20.6	13,350	2.7
1956	54,133,000	9,493,000	17.5	13,641	2.1
1957	78,318,000	14,979,000	19.1	14,934	2.1
1958	126,500,000	18,630,000	14.7	17,000	2.1
1959	179,671,000	43,644,000	24.3	25,900	2.3
1960	221,118,000	57,819,000	26.1	30,500	2.3

Closely related to the facilities program is the recent Graduate Laboratory Development Program, under which the foundation provides funds on a matching basis for the modernization and equipment of research laboratories. Studies of the situation indicate that the graduate-level research laboratories of the nation's universities are obsolescent to a degree that is detrimental to the national basic research effort. The financial straits in which most of our institutions of higher learning find themselves make it impossible for them to provide modern, well-equipped laboratories entirely out of their own funds.

This program was initiated in a modest way in fiscal year 1960, in the amount of $2 million. The budget for fiscal year 1961 provides for a substantial increase in the support level for this area.

Research Support

The increases in the foundation's appropriation are reflected in the research support program in several ways. First, and most obvious, is the growth in the total number of grants awarded, growth in the percentage of proposals supported, and increases in the amount and duration of the average grant (see Table 2). In fiscal year 1952 the foundation was supporting 8 percent of all proposals received, for a total of $1.074 million. In the current fiscal year, support is provided for 26 percent of the proposals received, for a total value of $57.819 million. In 1953, the average grant was $10,300, for an average period of 1.9 years. In 1960, the average grant was $30,500, for an average period of 2.3 years. These figures indicate that the foundation, with its increased funds, is able to support

individual projects more fully than before and that greater stability in support is being achieved through a gradual increase in the life of the average grant. It should be noted, however, that if the funds available for the support of research have risen, so too has the demand. To date, the foundation has not been able to support more than one-third of all the meritorious proposals received.

Up to the present, support for basic research has been divided approximately equally between the mathematical, physical, and engineering sciences and the biological and medical sciences, but beginning with 1960, the balance is weighted somewhat on the side of the physical sciences.

Support for basic research in the social sciences, initially divided between the two natural science divisions, began at a very modest, experimental level below $50,000. In 1958, the program was given the status of a separate program, and support was at the level of $725,000. At the end of 1958, the National Science Board approved the establishment of an Office of Social Sciences, and in the current year support has risen to $1.6 million. Only those projects are supported that are susceptible to scientific approach and that are truly fundamental in character.

Thus, the foundation is prepared to support research of this type in such fields as archeology, economics, philosophy of science, linguistics, social anthropology, demography, history of science, and social psychology.

Methods of research support. The general pattern under which federal agencies support research at institutions outside the federal government, particularly universities, originated with the Office of Scientific Research and Development during the war and provided the means whereby the federal government could benefit from important research carried on outside its own laboratories. The principle was developed and expanded by the Office of Naval Research and the National Institutes of Health after the war and adopted by other agencies, such as the Army, Air Force, and Atomic Energy Commission.

Briefly, the method is this: The government encourages or invites research proposals from individuals or groups of scientists, submitted through their institutions. With the help of individual reviewers in the field involved and of advisory panels appointed by the agency for this purpose, the federal agency selects for support those that are judged to have the greatest scientific merit. The foundation also has statutory divisional committees for over-all review of programs in the three major areas of life sciences, physical sciences, and scientific personnel and education, and a recently appointed committee to operate in similar fashion for the social sciences.

Incidentally, the foundation's efficiency in acting upon grants has been considerably enhanced by the congressional action last year in amending the National Science Foundation Act to permit the Board to delegate authority to the director and its executive committee to approve grants and contracts in certain situations. The delegation of authority has since been implemented by Board action.

The so-called "project method" of research support has a number of advantages. Properly interpreted, the plan is flexible and may be applied to narrowly defined problems in science or to broad areas. It enables the government to move in freely with the support needed for promising and significant undertakings of current interest. It provides for a national program in the sciences, utilizes the advice of the scientists in each field, and is based upon the significance and merit of the research proposed and the competence of the investigators. Since each grant and contract requires the official indorsement of the investigator's institution, the plan has evolved with the concurrence of the nation's universities and has had a most important indirect effect in helping to strengthen such institutions. In fact, such aid has often been of critical importance, particularly for the smaller schools.

The chief drawbacks of this method of research support are its failure thus far to provide full indirect costs and the difficulties it creates in departmental administration. It has also been criticized on the grounds that the reviewing process is slow and that the resulting program is too conservative.

In reply to these criticisms it can only be said that the slowness of the process is the price one pays for operating on the basis of consultation and advice, rather than "master-minding" the system from Washington. Probably it is offset by the great advantage of having the nation's scientific research and development problems widely understood by scientists as they participate in the solution of these problems. If the final results are conservative, it is because groups in general tend to become conservative; but each agency, including the foundation, is responsible for guarding against the conservatism that is apt to result from too much committee advice.

Breadth in project support. With the increased sums available to it for support purposes, the foundation is now able to make more grants of the broader type, often cutting across two or more departments of a university.

Some of the recent grants in this category may be of interest. A $700,000 grant awarded to the University of Pennsylvania will further research being conducted by Britton Chance, director of the Johnson Foundation for Medical Physics, which applies concepts of chemistry and physics to the biological problem of regulation of metabolism within the cell.

A study of the slave-making behavior of ants and its populational consequences is one part of a broad program of "Thesis Research in Population Ecology" being directed by Thomas Park of the Department of Zoology of the University of Chicago. The foundation will contribute support to the extent of $46,700 for the 3-year period.

Scientists at the Massachusetts Institute of Technology will undertake a concerted attack upon the problem of the production and nature of plasmas. Included are studies on gaseous electronics processes, plasma statics, magnetohydrodynamics of compressible and incompressible fluids, ionospheric physics, and some branches of astrophysics. This program, which is under the direction of William P. Allis, is being supported by the foundation with a 3-year grant in the amount of $932,000.

In the field of solid-state physics, Massachusetts Institute of Technology has undertaken a large interdisciplinary program centered about a better understanding of the nature of low-temperature phase transitions. Several departments will participate in this project, which is being supported by the foundation at a level of approximately $400,000 for a 2-year period.

Two major projects in atmospheric physics will operate on similar lines. At Harvard the foundation is supporting a program of atmospheric studies in the general area of physics, applied physics, and applied mathematics. The purpose of the program is to build a

Table 3. Distribution of funds for education in the sciences by major program for the period 1952–60, inclusive.

Major program	Obligations ($1 million)	Percentage of total obligations
Institutes	89.8	51.2
Fellowships	43.3	24.9
Special projects in science education	21.2	12.1
Course content improvement	13.5	7.7
Scientific manpower	3.0	1.7
Other obligations	4.6	2.6
Total obligations (1952–60)	175.4	100.0

small, competent group of workers to engage in aspects of atmospheric study that can be advantageously treated by deductive scientific methods. The ultimate hope is that students trained in the disciplines of physical science will regularly enter the field. The work is under the direction of Richard M. Goody and is being supported by the foundation for a 3-year period at the level of $172,000. At the University of Chicago advantage is being taken of the presence of a group of cloud physicists to establish a program of cloud-physics research dealing with the water resources of clouds. The research covers all the factors believed to be important in precipitation mechanisms. The foundation grant for this program is $383,700 for a 3-year period.

Institutional grants for research. The fact that federal agencies have based their support of research at educational institutions on the principle of grant or contract for a particular research project judged primarily on its scientific merits has led to an increasing lack of flexibility among university science departments in the planning and administration of their own research. As an experimental approach toward a solution of this problem, the foundation is planning to initiate institutional grants to aid institutions in fulfilling their responsibilities for developing and maintaining sound, well-balanced programs of scientific research and research-training activities without precisely specifying what activities are to be undertaken with the funds. The amount of such grants allowable to a particular institution for a given year will be 5 percent of the payments to that institution through basic research grants from the foundation during the preceding year. Such institutional grants would be made on request and without requiring a prior statement regarding the use of the funds by the institution. A report on how the funds were used, however, would be requested. The proportion of research funds distributed by the foundation for research purposes among all types of institutions will not be changed by this plan; the plan is designed to allow each institution to exercise a greater degree of initiative with respect to its needs in scientific activities.

Programs for Education in the Sciences

Between the time of passage of the National Science Foundation Act of 1950 and the end of fiscal year 1960 the foundation's Division of Scientific Personnel and Education will have obligated an estimated $175 million for the support and administration of programs directly related to the improvement of education in the sciences.

These programs have been directed toward the solution of problems in the following four broad categories: (i) support of students of science, mathematics, and engineering, including support of students at graduate levels and above, and support of programs for students at the undergraduate level and below; (ii) aid to teachers of science, mathematics, and engineering, including teachers of science and mathematics at the secondary school level and below and teachers of science, mathematics, and engineering at the college level and above; (iii) the content of science courses; and (iv) public understanding of science.

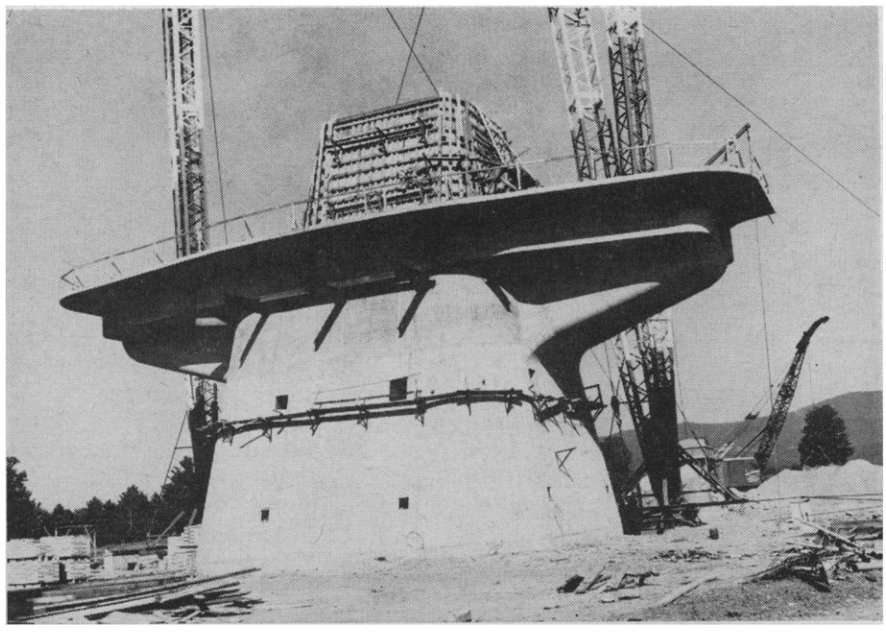
Approximately half of the available funds has been used for the training of secondary school teachers of science and mathematics. The next largest share—about one-fifth of the total—has been used in programs for the training of students at the graduate level and above, primarily in the fellowship programs. About one-fourth of the funds has been used in programs for students at the undergraduate level and below, for course content improvement, and for the training of college teachers.

The primary objective, toward which all the program activities in science education are directed, is to insure an adequate supply of competent scientists and engineers by maintaining a high level of excellence in science education in the face of expanding enrollments, rapid changes in science itself, and the growing need for the products of scientific research and development. The demands upon the educational system have been growing faster than they can be met through the traditional processes. Extraordinary methods, therefore, have had to be developed to assist the educational system in the solution of its problems.

In developing its various programs in education in the sciences, the foundation has been guided by certain broad principles. Its first responsibility has been to work with the ablest people concerned with improving education in the sciences in defining problems to be solved and in seeking solutions to these problems. All decisions with respect both to broad programs and to specific grants are made on the basis of continuous consultation with members of the scientific and educational community. The foundation is concerned with the substance of science, mathematics, and engineering, and its programs are designed to encourage the leading scholars in these fields to take an active part in seeking solutions to problems which bear on the improvement of subject-matter instruction. The foundation has had constantly before it the accepted American principle of local control of education and has observed this principle in its operations. Other federal agencies, universities, private foundations, and industrial organizations are also concerned with education in the sciences and are working toward the same goal. It is our hope and objective that the activities of these several groups may supplement each other in a constructive way.

Let us consider briefly the principal foundation programs under the Division of Scientific Personnel and Education. These include fellowships, institutes, special projects in science education, public understanding of science, course content improvement, and scientific manpower.

The fellowship program. The fellowship program is the oldest support pro-



Foundation for the 140-foot telescope at the National Radio Astronomy Observatory, Green Bank, West Virginia.

gram of the foundation. It was inaugurated in 1952 by the predoctoral and regular postdoctoral programs with a budget of $1.4 million—almost half the foundation's appropriation for that year. As new needs have become apparent, additional programs have been added: in 1956, the senior postdoctoral program; in 1957, the science faculty program; in 1959, the cooperative graduate, teaching assistants, and secondary school teachers programs. By the end of fiscal year 1960, approximately $43 million will have been used for support of graduate students and advanced scholars through these seven fellowship programs. After awards have been made for 1960, an approximate total of 13,000 graduate students and advanced scholars in science, mathematics, and engineering will have received awards, from among about 50,000 applications.

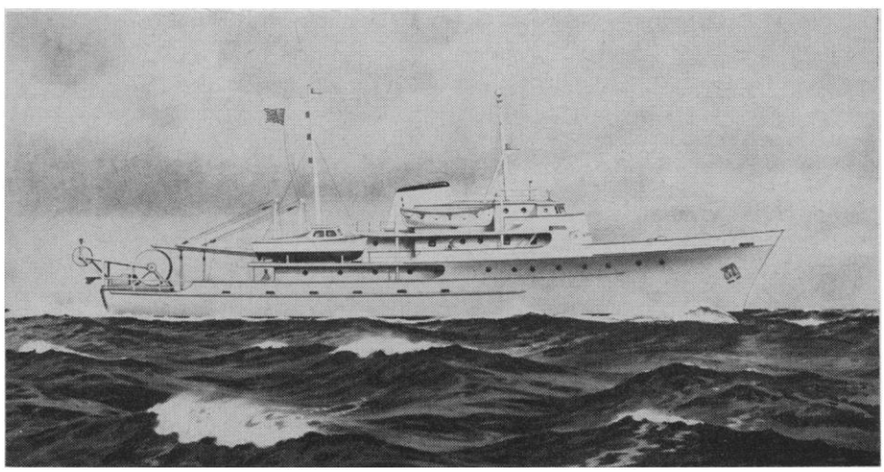
It should be noted, also, that the high standards of selection for foundation fellowships have resulted in wide-spread interest in the applicants, with the result that many of the unsuccessful applicants for foundation fellowships have received awards from other sources. This is particularly true in the case of applicants included in the honorable mention lists published by the foundation each year.

The institutes programs. The institutes programs were inaugurated in 1953 with two experimental projects for college teachers—one in mathematics at the University of Colorado and one in physics at the University of Minnesota. In 1954 the experiment was broadened somewhat to include high school teachers. In 1956 the academic-year institutes program for high school teachers started with two institutes—one at Oklahoma Agricultural and Mechanical College and one at the University of Wisconsin; and in 1959 a similarly limited and experimental program was started for college teachers. The in-service institutes were inaugurated in 1957 for high school teachers and in 1959 for elementary school teachers.

During this over-all period there has been rapid growth in the funds available for the institutes and subsequently in the number of institutes that could be provided. Because of the special interest of Congress in improvement opportunities for high school teachers of science and mathematics, in recent years a substantial percentage of the funds available for education in the sciences has been devoted to the institutes programs. The high point was in 1957, when the institutes accounted for 65.6 percent of the total program. With the large general increase in appropriations and the adjustment of program support, however, the share of total funds for institutes has declined currently to 51 percent, which brings it more nearly in balance with other programs. By the close of 1960 some 72,000 teachers will have participated in these programs.

It is still much too early to be able to make a valid assessment of these programs, but it is cause for some satisfaction that through this means a significant proportion of the secondary school teachers of science and mathematics will have had some opportunity to become informed about current trends in their fields, as well as an opportunity to become acquainted with new laboratory methods.

A fundamental and long-range problem, of course, is that of providing more adequate original training for such teachers. Clearly, we cannot expect to continue indefinitely "retraining" teachers whose preparatory training has been inadequate. This, however, is a problem that lies outside the foundation's purview and brings us back once more to the principle of local control of education; it is at the local level that the problem must be faced.



Artist's conception of the oceanographic research vessel to be built for the Woods Hole Oceanographic Institution under a $3 million grant from the National Science Foundation.

Special projects in science education. Programs included in this category are grouped generally as follows: (i) programs directed toward secondary school students; (ii) college programs and teacher-improvement programs; and (iii) public understanding of science.

Programs in the first category are designed to supplement the secondary school students' classroom training in science by providing visiting scientists, state academies of science, and summer training for students of special ability and aptitude. The program also makes available science materials, through the media of the traveling science libraries, and traveling science demonstration lectures. It supports cooperative college-school programs and school science clubs.

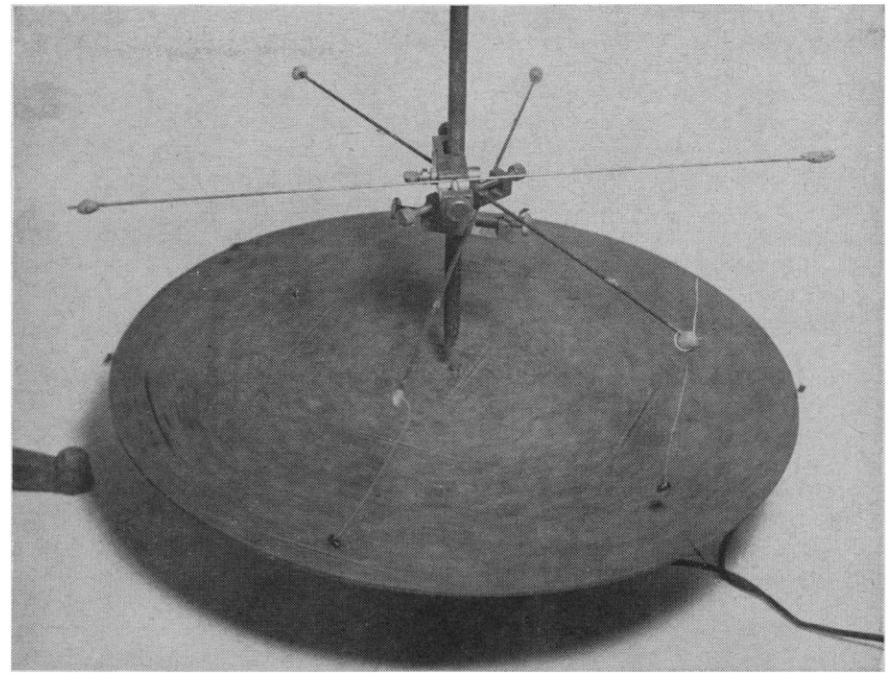
Under college and teacher-improvement programs, opportunities are provided for undergraduate students in science, mathematics, and engineering to obtain experience in research laboratories, through the undergraduate science education program. Students in small colleges are brought into contact with eminent scholars from other institutions through the visiting scientists program. To assist teachers, various experimental activities have been designed, such as conferences and special academic-year programs and the program for research participation.

From a small beginning of $20,000 in 1953, support for the special projects rose slowly to something over $8.5 million in 1959 and more than $10 million in 1960. Increased support is based upon the expansion of old programs that have proved their worth and the apparent success of some of the new ones launched last year.

Public understanding of science. Progress in science depends to a considerable extent on public understanding and support of a sustained program of science education and research. At the present time, science is generally mistakenly identified in the public mind with the results of applied research and technology—spectacular developments such as space vehicles and weapons systems; with the applications of research to the cure of disease; and with the bewildering array of modern machines and gadgets that are advertised on every side.

There is inadequate understanding of the role of basic research and its fundamental relationship to progress in engineering and technology.

The foundation has broadly construed "education in the sciences" to include, also, education of the public. The increasing significance of science and technology in relation to public policy, both national and international, has made it urgent that the level of scientific literacy on the part of the general public be markedly raised. In order to participate fully in the democratic process through intelligent voting, citizens must have at least a general knowledge and understanding of the nature of science and its implications for the national defense and welfare.



An interesting technique for studying the physiology of insect feeding, in a research project in the biological sciences, supported by the National Science Foundation. The turntable is used to "fly" flies to exhaustion in order to deplete the carbohydrate reserves. The flies are then fed a highly stimulating but nonnutritional sugar to test their hunger reactions.

This is a relatively new area, and there is little experience to guide us in the choice and methods and techniques that will serve the purpose. To date, the foundation has supported a limited number of conferences and institutes in which scientists and science writers have been brought together for the purpose of discussing the problems of communicating science to the layman. It is planned to expand these efforts and to enlist the support and advice of influential editors of the general-information media as well as the aid of the scientific community and such organizations as the AAAS and the professional scientific societies. The program was initiated in 1959 with a budget of $5000, but as much as $200,000 may be expended for these purposes by the end of 1960.

Course content improvement. Comparable in importance to the need for aid to students and to teachers of science is the need for improvements in curriculums and course content. As a result of early studies of the subject, the dimensions of the problem began to emerge. Science must not be poorly taught at any level or in any field. Attention must therefore be given to the content of science and mathematics courses, from the elementary courses in general science through graduate courses in highly specialized fields.

The foundation has approached this problem in a number of ways. Support has been given to relatively small projects in limited areas where useful results can be anticipated. For example, the American Meteorological Society has been awarded a grant to enable its editorial board to prepare a series of monographs on such subjects as "The Earth and the Sun," "High Atmosphere," "Climate and Man," "Oceans and Air Currents," and other subjects designed to interest high school and college students in the field of meteorology.

At the other end of the scale, a high level of support has been given out-

standing investigators to enable them to attack a major problem in force. The work done by the Physical Sciences Study Committee at Massachusetts Institute of Technology is an example. This project, which was initiated in November 1956, has produced an entirely new approach to the teaching of physics, with a new syllabus, new textbooks, and a wide variety of new teaching aids and new methods and techniques of demonstration. The course was tried out experimentally in the 1957–58 school year, with eight teachers presenting the entire course. The number of teachers using the course has increased in each succeeding year, and special summer institutes supported by the foundation have trained teachers in its use. In September of 1960 the materials developed by the committee will be made available to all interested schools through Educational Services, Inc., of Watertown, Massachusetts, a nonprofit organization founded in September 1958.

The success of the course revision work in physics prompted a similar large-scale effort in mathematics, guided by the School Mathematics Study Group, operating with headquarters at Yale University. The chemistry curriculum is being worked on by two groups, the Chemical Bond Approach Committee at Earlham College and the Chemical Educational Materials Study at Harvey Mudd College. The Biological Sciences Curriculum Study has its headquarters at the University of Colorado.

Here again we have the pattern of an experimental beginning of only a few thousands of dollars up until 1957–58 (when the figures climbed above the half-million mark) and a continuing increase to the current year, in which it has seemed wise to invest $6 million in these programs.

The comprehensive review and revision of the four major science courses—physics, mathematics, chemistry, and biology—is unquestionably one of the most significant developments in the teaching of science in this country. Courses that are out of date by as much as 30 to 40 years are being brought abreast of modern developments. In the process of working together on this task, university scientists and secondary school teachers and administrators have come to see each other's problems and points of view as they could have in no other way.

Scientific Manpower Program

Responsibility for the operation and maintenance of the National Register of Scientific and Technical Personnel was transferred to the National Science Foundation by the foundation's enabling legislation. The register provides records of location and of training, scientific specializations, and other qualifications of approximately 185,000 selected scientists and engineers and is designed to insure that timely information is available, in case of need, on the numbers and characteristics of scientists and other technically trained persons in the United States. The foundation's scientific manpower section is also engaged in continuing studies designed to provide basic data on scientific and technical personnel generally. This program is currently being supported at a level somewhat below $1 million.

Other sources of federal support for education. In addition to the programs of the National Science Foundation, major contributions to science education are made by a number of other agencies, including the National Institutes of Health, the U.S. Office of Education, and the Atomic Energy Commission. The National Defense Education Act, for example, provides significant help under the graduate fellowship program, the student loan program, and to some extent under titles III and VII.

International Programs in Science

The scope of the foundation's international activities in science broadened considerably during the second half of the decade. The International Geophysical Year marked the first time that the foundation had participated in international scientific activities on a large scale, and it also represented the foundation's first opportunity to coordinate a major activity being undertaken by a number of government agencies. The scientific and technical program for the United States was developed and directed by the U.S. National Committee for the IGY, under the National Academy of Sciences. At the request of the academy, the foundation initiated consideration of IGY support by the federal government and, upon affirmative decision, secured and administered federal funds totaling $43.5 million. The foundation also served as coordinator of government interests in the program; these involved not only direct participation by government agencies but also, quite often, matters of broad national policy that arise in an international program.

As an aftermath of the IGY, both individuals and government agencies have been encouraged to carry on research that extends certain aspects of the IGY work. Under the general label of International Geophysical Cooperation, the program is being coordinated at the international level by the Comité International Géophysique of ICSU. This special committee is composed of the four unions principally involved: the International Union of Geodesy and Geophysics, the International Scientific Radio Union, the International Union of Astronomers, and the International Union of Pure and Applied Physics. So far as administration is concerned, the IGC is not a "package program." Instead, the foundation accepts proposals in areas where coordinated global research is of special importance, and these are then appraised as part of the regular program of research grants.

Antarctic research. A major outgrowth of the IGY has been the continuing research programs in the Antarctic being carried on by the 12 nations who participated in the IGY antarctic program. General scientific recommendations for the area are made by the Special Committee on Antarctic Research (SCAR) of ICSU. The United States program is being developed, funded, and coordinated by the National Science Foundation. The latter looks primarily to the Committee on Polar Research of the National Academy of Sciences for program recommendations, and the foundation also considers proposals from qualified scientists interested in carrying out such research. The foundation works with the Interdepartmental Committee on the Antarctic to coordinate the research activities of other agencies, such as the National Bureau of Standards, the Weather Bureau, and the Geological Survey, and provides them with funds for their participation in antarctic research. Grants are also made to universities and various interested research organizations to complete the program of scientific activities in the Antarctic. To date, Congress has ap-

propriated $10 million for the post-IGY program in the Antarctic.

The Navy, which has from the beginning provided all logistic support for antarctic research, continues to do so with distinction under the new program and is in command of operations in the area. The cost of this logistic support is, of course, considerably greater than the cost of the actual scientific program.

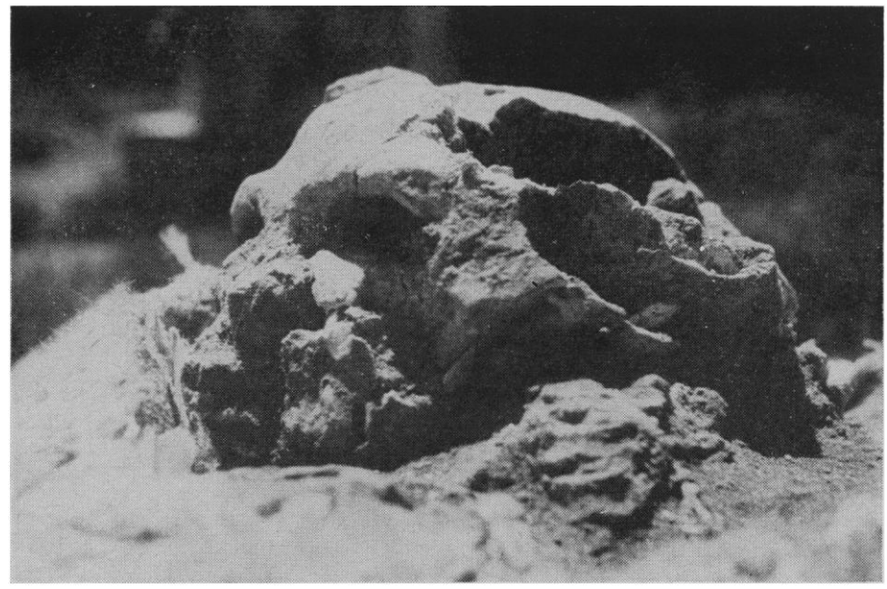
International science education. Beginning in 1959, the foundation undertook a modest program designed to foster international cooperation and improve communications among nations with respect to problems of science education and scientific manpower. Appropriate professional groups in the various disciplines were given support for a study and evaluation of science subject matter offered in foreign educational systems, with the objective of improving science curriculums in this country. Distinguished foreign scholars were brought here to visit the various institutes sponsored by the foundation. Advanced students and scientists have received foundation support to permit them to participate in international educational programs. For example, a grant was made to the University of Uppsala, Sweden, for American participation in an international summer institute in quantum chemistry.

These various small programs have furnished experience that will guide us in the development and enlargement of future programs in international science education.

Other international scientific activities. Amendments to the National Science Foundation Act which were passed by Congress last year permit the foundation to cooperate in international *scientific* activities, whereas previously it was limited to *research* activities. The amendments also permit the foundation, with the approval of the Secretary of State, to grant fellowships or make other arrangements with foreign nationals for scientific study or scientific work in the United States. Under its existing and extended authority, and with the concurrence of the Secretary of State, the foundation plans to expand its international activities on a modest scale.

The foundation hopes to place, later on, appropriately qualified persons at overseas locations to carry out short-term studies in limited areas of science that are of interest and importance to both the United States and the foreign country. Eventually, it is hoped, qualified persons can be placed overseas for longer periods for the purpose of conducting and maintaining continuous contact with the scientific communities of other countries.

As funds are made available, it may be possible, also, to afford greater support to certain appropriate types of research and research facilities abroad.



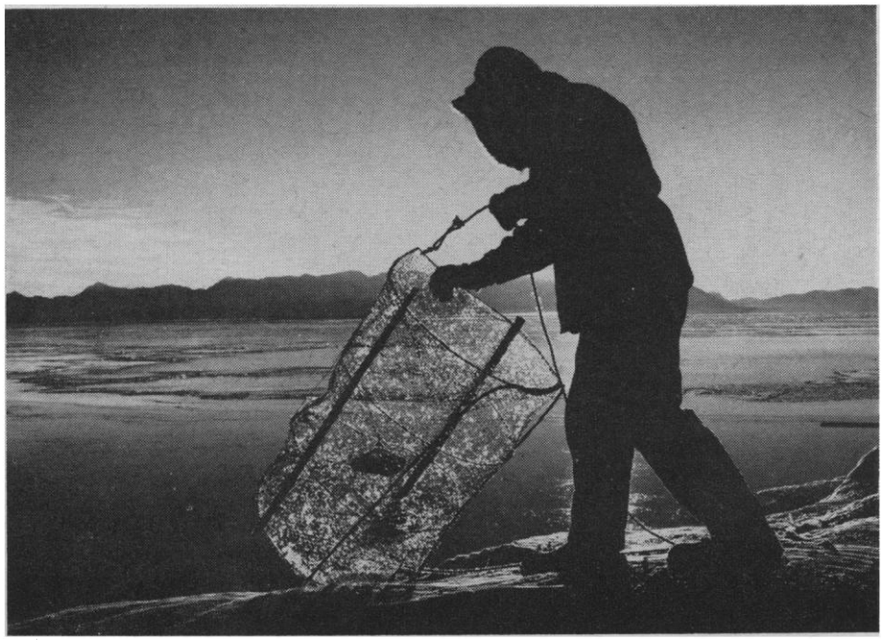
A 45,000-year-old skull uncovered during the excavation of Shanidar Cave in northern Iraq by an archeological expedition sponsored by the Smithsonian Institution and partially supported by the National Science Foundation. The skull is that of an adult Neanderthal man. The cranium had been struck by stones and displaced at the time of accidental death. The neck vertebrae are in the original position.

Science Information

The scope and importance of the scientific information problem is something of which the foundation has been aware since the beginning. Early attempts were made to study certain aspects of the problem, and, with the extremely limited funds available, support was given to small projects directed toward this end. This was increased as the over-all appropriation grew, but a really major effort in the field of scientific information was made possible by almost simultaneous action by the Executive and Legislative branches of government.

In December 1958 the White House released a special report of the President's Science Advisory Committee on "Improving the Availability of Scientific and Technical Information in the United States." After emphasizing the importance of the problem, the President's Committee recommended that the National Science Foundation expand its scientific information program to strengthen and coordinate existing governmental and private efforts in this field. This recommendation was later implemented by Executive Order No. 10807 of 13 March 1959. The National Defense Education Act of 1958, under title IX, directed the foundation to establish a science information service. The act also provided for the establishment of a 19-member Science Information Council whose members, government and nongovernment, would represent a broad range of skills and experience in the problems of the communications needs of scientists. The Office of Science Information Service was formally established in the foundation on 11 December 1958, and the Science Information Council first met in February 1959.

The program activities of the Office of Science Information Service fall generally in five categories: (i) storage and retrieval systems and mechanical translation; (ii) scientific publications; (iii) unpublished research information; (iv) scientific data and reference centers; and (v) foreign science information. Through these several programs the foundation seeks to increase the dissemination of existing materials by helping to provide for prompt publica-



A marine biologist currently working in the Antarctic under a National Science Foundation grant sets a wire fish trap at the ice edge near the McMurdo Sound Naval Air Facility. This is part of the U.S. Antarctic Research Program administered by the foundation.

tion of research results, for reference aids and information centers of various kinds, and for translations of significant scientific papers in languages not widely understood by American scientists.

Research on information problems. The foundation is supporting a slowly growing body of research on new approaches to the information problem. Most of the research is concerned with exploration of ways to use machines in information processing tasks, such as the organization, storage, and searching of scientific information and the translation of scientific publications from foreign languages into English. Before machines can process the texts of documents, however, for either mechanized information searching systems or mechanical translation systems, more precise knowledge of syntax and semantics is needed. Therefore, current research activities in these areas are extending our understanding of language in the expectation that ultimately machines will be able to handle linguistic data.

A Research Information Center and Advisory Service on Information Processing has been established jointly with the National Bureau of Standards, with some financial support from the Council on Library Resources. The purpose of the new center is to bring together research and development data on methods and equipment for the automatic processing of scientific information. The center will also endeavor to foster closer cooperation among the groups in industry, the private foundations, the universities, the professional societies, and the agencies of the federal government that are concerned with developing and improving methods for rapid and efficient handling of large volumes of information.

In this same area, the foundation is issuing regularly two publications designed to disseminate information on the scientific information field and foster cooperation among research workers in that field. *Current Research and Development in Scientific Documentation* is issued semiannually as a guide to current projects both here and abroad, while *Non-Conventional Technical Information Systems in Current Use* reports on information systems that embody new principles for the organization of subject matter or employ automatic equipment for storage and search.

In the support of scientific publications, temporary or emergency aid is given to primary journals and abstracting and indexing services; also, funds are provided for the preparation or publication of significant monographs, reviews, and reference works that could not be made generally available without subsidy.

Support of this kind is granted on the basis of the needs of the scientific community and sound economic planning for the publication.

Among the scientific journals partially supported by the foundation are two new experimental periodicals, *Physical Review Letters* and *Wildlife Disease*. The first is designed to provide rapid, low-cost publication of short, up-to-the-minute articles on physics research. The latter is the first journal to be published only in microform. The purpose of this journal is to explore author, reader, and librarian reaction to microform as a means of publishing research results at greatly reduced costs.

The foundation is also seeking to make unpublished research information more accessible. The principal sources of such information are research reports and memorandums of government and private institutions, theses and dissertations, and papers presented at scientific conferences. An example of foundation activities in this area is the recently initiated series of inventories of information activities of those federal agencies that operate major scientific information programs. Four surveys in this series, covering the Department of Agriculture, the Office of Naval Research, some programs of the Department of Commerce, and the Government Printing Office, have been published, and others are in various stages of preparation.

Two examples of data and reference centers supported by the foundation are the Office of Critical Tables (OCT) of the National Academy of Sciences and the Bio-Sciences Information Exchange (BSIE) of the Smithsonian Institution. The OCT, wholly supported by the foundation, is a coordinating and information center on projects engaged in developing critical physical data of all kinds. The BSIE, supported by the foundation and other interested agencies, functions as a repository of knowledge on "who is working on what" in the biological sciences.

Plans are now being developed, with the aid of the Federal Council on Science and Technology, for broadening the information exchange at the Smithsonian Institution to include the physical sciences and possibly, at a later date, the social sciences as well.

Foreign science information. The foundation is supporting the cover-to-cover translation of 35 key U.S.S.R. scientific journals. Support is also being given the Midwest Inter-Library Center

for the acquisition of approximately 2300 "hard-to-get" foreign biological and chemical journals.

A series of studies is being made that will provide information on the organization, characteristics, and generation of scientific information in every major geographic area of the world. Studies currently under way or planned concern the Soviet Union, Poland, Japan, Indonesia, mainland China, Czechoslovakia, Yugoslavia, and Hungary.

The foundation is coordinating a program, involving several federal agencies, whereby foreign currencies accruing to the U.S. Government through sales of surplus agricultural products will be used to support projects abroad for translating foreign-language publications into English.

In order to provide an effective means of exchanging information among groups working in the scientific information field, the foundation issues a bimonthly bulletin, *Science Information Notes*. This bulletin reports national and international developments and will, it is hoped, assist in promoting increased cooperation and coordination among scientific information services.

Conclusion

In any assessment of the role and accomplishments of the foundation during its first decade, it is necessary to consider the broader question of federal policy determination with respect to research support, research facilities, and the development and use of scientific manpower. Policy, in turn, must be evaluated in terms of (i) the general principles to be followed, (ii) the organization of the federal government for science and technology, and (iii) the effectiveness of the organization and operations in accomplishing the desired objectives. Let me summarize briefly the conclusions discussed above with respect to each of these points.

General principles. The first principle in national science policy, as interpreted by the foundation, is the critical importance of basic research for progress in science and technology. It is only through comprehensive support of basic research in all the fields of science that one can discover the potentialities for application that are so important in the competitive technology of today. Because basic research is an essential factor in the advanced training of scientists and engineers, and because the university is the natural home of basic research, it is clear that major attention must always be paid to the support of basic research in colleges and universities.

The support of basic research is relatively inexpensive. The significant costs of research and development arise out of expensive developmental programs, such as ballistic missiles, especially when these are undertaken on a "crash" basis. Since there is bound to be an upper limit to the amount of money available for science and technology, it is obvious that needed economies should be effected through careful selection of the developments to be undertaken. But it is false economy to curtail the basic research that uncovers leads for future developments.

In the support of basic research there are three important considerations: progress of science, development of the individual, and strengthening and development of the institutions where research is done.

By and large, the federal government has paid the most attention to the first two categories. The progress of science has been advanced by the so-called "research projects" system, which permits an individual or a group to pursue a scientific problem of its own choosing and which permits the agencies to support proposals selected from those submitted. The government has paid considerable attention to the development of the individual through fellowship and other educational programs and through special programs to improve science teaching and science courses.

A national problem to which the federal government has paid relatively little attention, however, is that of support for educational institutions to enable them to develop their own capabilities in science and engineering. Institutions have benefited greatly from government support of research projects and from awards, such as fellowships, to individuals, but they have received little aid of a sufficiently general type to enable them to carry out their own plans for growth in science and engineering and to maintain a proper balance between these activities and others in which they engage. The needs are great: Graduate research laboratories require modernization in terms of buildings, equipment, and space; the salary scale in many institutions urgently needs adjustment upward; there is a great and continuing shortage of maintenance and operating funds; in the secondary schools the salary problem is also acute, and although progress is being made, much still remains to be accomplished.

The federal government's policy with respect to the problems of the institutions is to point out the needs and to emphasize the importance of satisfying those needs, to the extent possible, from state and private sources in accordance with American traditions. But it is also the responsibility of the federal government to exercise leadership in meeting this problem. It is becoming increasingly clear that the inadequacy of the resources available to our educational institutions is a national problem and one which the federal government must help to meet. Another problem to which I have referred above is the growing need for evaluation and handling of competing claims in special areas of basic research which their supporters feel are critical. Atmospheric physics, oceanography, meteorology, and seismology are examples of areas that in recent years have been found to lack adequate support, trained personnel, facilities, and equipment. Special techniques may be required for handling such problem areas, but these special problems should not obscure the need for comprehensive support of basic research in all fields of science.

Organization of the federal government for greatest progress. In recent years there has been extensive discussion of the adequacy of the federal government's organization for dealing with matters of science and technology. At the present time, each government agency has its own organization for research and development. Over-all policy recommendations concerning the nation's effort and federal responsibilities for science in the strict meaning of the term are vested in the foundation and centered in its Presidentially-appointed National Science Board. The President's Science Advisory Committee considers critical scientific and technological matters relating to the national security and welfare; the Federal Council for Science and Technology is responsible for over-all long-range planning and matters of coordination in research and development activities among the federal agencies; science in foreign affairs is represented in the Department of

State by the Science Adviser to the Secretary; and finally, the Special Assistant to the President for Science and Technology makes immediately available to the President advice in any of those areas bearing upon critical questions of policy or action.

Effectiveness of organization and operations. In principle, the organization thus outlined should be able to deal with most fundamental issues involving science and technology with which the government is faced. On the record, many major issues have been met effectively, the cooperation of participating scientists has been outstanding, and progress along many lines has been noteworthy. However, part of this structure has not been operating long enough to evaluate its effectiveness.

In the meantime, suggestions have been made, especially in Congress, for a more radical type of organization—for example, a cabinet department for science and technology. If, by this, is meant a department that would assume complete responsibility for all research and development in the federal government, the suggestion can surely be dismissed as being completely impractical. Over-centralization of science in a department of this type would be strenuously opposed by all scientists and engineers as hostile to their basic philosophy, and by federal agencies as usurping their essential prerogatives and responsibilities.

If, on the other hand, the suggested department of science and technology were intended to provide supervision and control over the research and development activities of other federal agencies, it would encounter severe administrative difficulties as differences of opinion arose between it and the individual agencies. Under our form of government, no agency can be expected to exercise such a role, which properly belongs in the White House or in the Executive Office of the President.

A third suggestion, more limited in scope, is that there should be brought together in one department certain major research and development activities now operating as part of regular departments. Included would be such establishments as the United States Weather Bureau, the National Bureau of Standards, the Hydrographic Office, and the Geological Survey. Such a consolidation might well advance the research and development activities of these agencies but would leave the problem of what to do with their functions as service organizations to the departments in which they are presently located. It is to be hoped that inadequacies in the present situation that have given rise to this suggested plan can be remedied by constructive action of the departments concerned.

Admittedly there are problems of considerable magnitude to be solved in achieving maximum effectiveness in the organization and operations of the federal government with respect to science and technology. However, the greatest need at the moment, appears to be that of full support for the present organization, which is relatively new both in its over-all aspects and in the internal organization of individual agencies. In the charter for the Federal Council on Science and Technology, for example, it is provided that each member will speak authoritatively for his department or agency in matters pertaining to science and technology. A simple way of carrying out this provision would be for each department to appoint as its representative an Assistant Secretary for Research and Development, or someone in an equivalent position.

It must be remembered that the problem of large-scale government administration of science is recent, dating back only to World War II. We have had to feel our way into a whole new area of policy and operation. Scientists and engineers must be ready to accept full-time government posts and to acquire the training and background in administration that are essential to this new role. The agencies and departments, on the other hand, must accept the growing importance of science and technology and adapt their administrative structures to meet its needs. The problem is one that calls for great understanding as well as cooperation and good will on all sides.

A final word. Irrespective of individual opinions as to the manner in which the National Science Foundation is carrying out its assigned role, it cannot be denied that the importance of science in national affairs is such as to justify the establishment of an agency dedicated to the progress of basic research and education in the sciences. Nor will it be denied that the federal government should be increasingly concerned with the progress of science and technology, both in its own agencies and in the nation at large. The current estimated national expenditure of $12 billion on research and development would bear out this conclusion, even if more important considerations were not involved.

But it is also clear, that the whole responsibility cannot and should not rest with the federal government. It is essential that the citizens of the country understand and appreciate the importance of science and technology in all its phases, but especially the importance of basic research and education. Without the understanding and support of the people of the United States, the federal government will be unable to take proper measures for the adequate support of basic research and education in science. Individual voters, communities, and states must clearly recognize their responsibilities. The problems inherent in science and technology cannot be dismissed on the assumption that they can be met by the federal government without understanding, support, and local action by informed citizens.

References and Notes

1. D. Wolfle, *Science* **126**, 335 (1957).
2. This executive order was later amended by Executive Order 10807, 13 March 1959.