15th ANNUAL REPORT

1965

NATIONAL SCIENCE FOUNDATION

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National Science Foundation

Fifteenth Annual Report for the Fiscal Year Ended June 30, 1965

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LETTER OF TRANSMITTAL

WASHINGTON, D.C.,
January 10, 1966.

MY DEAR MR. PRESIDENT:

I have the honor to transmit herewith the Annual Report for Fiscal Year 1965 of the National Science Foundation for submission to the Congress as required by the National Science Foundation Act of 1950.

Respectfully,

LELAND J. HAWORTH,
Director, National Science Foundation.

The Honorable
The President of the United States.

CONTENTS

A listing of grants, contracts, and Fellowships awarded in fiscal year 1965 appears in a separate publication entitled National Science Foundation Grants and Awards, Fiscal Year 1965, NSF 66-2. It is available from the Superintendent of Documents, U.S. Government Printing Office, Washington, D.C.

THE DIRECTOR'S STATEMENT

The Foundation in Retrospect

This 15th annual report of the National Science Foundation seems to me a suitable point from which to look back across the years that have passed since the National Science Foundation Act was passed by the 81st Congress and signed by President Truman on May 10, 1950. The timeliness of such a look is enhanced by the review of Foundation activities initiated in fiscal year 1965 by the Subcommittee on Science, Research, and Development of the Committee on Science and Astronautics (U.S. House of Representatives, 89th Congress). Testimony presented to the Subcommittee by many individuals from within and outside the Government along with comments and observations by Subcommittee members combined to provide a well-rounded, objective picture of the Foundation and its relationship to national purposes.

Creation of the National Science Foundation as a unique agency of the Federal Government was the result of two factors directly related to the massive impact of World War II. The first of these was the explosive technological development that accompanied the war, and irrevocably altered for all time the tone and fabric of the American social structure. Second was the fact that the national store of unexploited fundamental scientific knowledge was virtually bankrupt as a result of technological pressure, a condition made even more parlous by the enforced interruption of the education of young scientists and engineers.

J. Robert Oppenheimer, wartime director of the Los Alamos Scientific Laboratory, later testified that "we learned a lot during the war," and his words might well have been echoed by many others. "But," he continued, "the things we learned (were) not very important. The real things were learned in 1890 and 1905 and 1920, in every year leading up to the war, and we took this tree with a lot of ripe fruit on it and shook it hard and out came radar and atomic bombs. . . . The whole spirit was one of frantic and rather ruthless exploitation of the known; it was not that of the sober, modest attempt to penetrate the unknown." Thus it may be said in a sense that technology was treading on the heels of science when the war ended.

Many of the dramatic technological developments of the war were the result of "crash" programs conducted in an atmosphere of urgency at some of our major universities, and as hostilities neared an end the implications for science and technology in the years of peace ahead were visible, if yet undefined.

In late 1944, President Roosevelt addressed a request to Dr. Vannevar Bush, director of the wartime Office of Scientific Research and Development, for advice as to how the lessons learned in war could be applied to the pursuits of peace. With the help and recommendations of four committees of scientists and other scholars, Dr. Bush set forth in clear and specific terms what he felt the relationships of government to science should be, and how they should be sustained. His imaginative and stimulating report, *Science, the Endless Frontier,* was to have a profound and lasting impact on the future of American science.

The Bush report pointed out that there was at the time no national policy with respect to science. Government interest in and patronage of the sciences dates back to the earliest days of the Republic, with varying degrees of emphasis in accordance with circumstances or requirements of the moment. But the war and its consequences brought both opportunity and responsibility for the Federal Government to utilize science in promoting the national welfare on a scale never before envisioned. "Science," wrote Dr. Bush, "has been in the wings. It should be brought to the center of the stage—for in it lies much of our hope for the future."

This call for a place in the sun for science was inspired by vision of the great potential for the future, and not in deprecation of the accomplishments of American science in the past. Rather it articulated a coming of age for science in this country, and a fuller appreciation of science as a viable and dynamic social force.

One of the most important recommendations of the Bush report was that there be established within the Government a unique agency to serve as a focal point for the support of scientific research and science education, but resembling in many respects some of the private foundations and organized in such a way as to be sensitively responsive to the general scientific community. This was the conceptual origin of the National Science Foundation, as described by Dr. Bush.

A Broad Congressional Mandate

Public Law 507, the implementing legislation passed by the 81st Congress in 1950, was described as an "act to promote the progress of science; to advance the national health, prosperity, and welfare; to secure the national defense; and for other purposes."

Specifically the act authorized and directed the Foundation to:

- develop and encourage the pursuit of a national policy for the promotion of basic research and education in the sciences;
- initiate and support basic scientific research in the mathematical, physical, medical, biological, engineering, and other sciences, by making contracts or other arrangements (including grants, loans, and other forms of assistance) for the conduct of such basic scientific research and to appraise the impact of research upon industrial development and upon the general welfare;

- at the request of the Secretary of Defense, to initiate and support specific scientific research activities in connection with matters related to the national defense . . .;
- to award scholarships and graduate fellowships . . .;
- to foster the interchange of scientific information among scientists in the United States and foreign countries;
- to evaluate scientific research programs undertaken by agencies of the Federal Government, and to correlate the Foundation's scientific research programs with those undertaken by individuals and by public and private research groups;
- establish special commissions . . . necessary for the purposes of this Act;
- to maintain a register of scientific and technical personnel and in other ways provide a central clearing house for information covering all scientific and technical personnel in the United States . . . .

Although some amendments to the legislation of 1950 have subsequently been enacted, notably in the policy-making area, the broad responsibilities and functions outlined in the original act have provided the framework within which the Foundation has developed to its current status. I believe that a statement made by Dr. James B. Conant, first chairman of the National Science Board, and published in the first annual report of the Foundation, is worthy of review from the distance of 15 years. It spells out a philosophical departure point, and establishes a sense of direction for operational doctrine of the Foundation which remains substantially valid to the present.

"Both types of research (basic and applied) are of the utmost importance—important for advancing industry, public health, national defense, and extending the boundaries of knowledge, but today in the United States it is the uncommitted investigator who stands in the greatest need of public support. He needs not only more money for his equipment and for helping hands but more public recognition for the significance of his work, for he is the scientific pioneer, the man who turns the unexpected corner, the laboratory man whose experiments mark the opening of a new era or the theorist whose ideas are so fruitful as to be revolutionary. By and large the United States has not yet produced its share of such scientific pioneers compared with Europe. One of the purposes of the National Science Foundation is surely to right this balance and provide in every section of the country educational and research facilities which will assist the development of such men.

"In the advance of science and its application to many practical problems there is no substitute for first-class men. Ten second-rate scientists or engineers cannot do the work of one who is in the first rank. Therefore, if the aims of Congress as set forth in the National Science Foundation Act are to be fulfilled, there must be all over the United States intensive effort to discover latent scientific talent and provide for its adequate development. This means strengthening many institutions which have not yet developed their full potentialities as scientific centers, it means assisting promising young men and women who have completed their college education but require postgraduate training in order to become leaders in science and engineering . . . . Given time, the expenditure of public funds in this enterprise, I feel certain, will prove to have been a most advantageous investment by the American people."

Organization of the Foundation

The organizational structure of the Foundation provides a form of dual authority and dual responsibility, one of the few examples of such an arrangement among nonregulatory agencies of the Government. On the one hand there is the National Science Board, a 25-member policy-making component of the Foundation as established by the original enabling legislation. The Board is composed, now as in the past, of distinguished individuals from outside the Government, drawn mostly but not entirely from the scientific disciplines, and all appointed by the President "with the advice and consent of the Senate." The Director is an ex officio member. In addition to its policy-making function, the Board constitutes one of the Foundation's most important avenues of communication with the scientific and educational community.

The Director of the Foundation, on the other hand, is a salaried Presidential appointee who serves as chief executive officer of the Foundation, with specific statutory responsibility assigned within the broader framework of policy established by the Board. A close and harmonious partnership between these two organizational elements has characterized the operation of the Foundation from the beginning. During recent years, however, with a substantial increase in the scope of overall activity, it has become necessary to re-examine functions and responsibilities and make certain modifications in the light of pressing realities.

At the outset, and during the initial years when the scope of Foundation activity was limited, the Board was required by the National Science Foundation Act in its original form to review and approve every grant or contract made by the Foundation. As the volume of funding available for support increased, however, the workload involved in this process placed an unduly heavy demand on the time and attention of the Board, and it became obvious that a change in the procedure was indicated.

Public Law 86–232 of September 8, 1959, as a consequence, provided for delegation of powers and duties from the Board to the Director, including the delegation of authority to authorize funding of projects. The intent of this was to relieve the Board of some of the burden of review and approval of smaller (but numerous) grants. An arrangement devised by the Director and the Board provided for a financial ceiling beneath which the Director was authorized to approve grants independently. The act of 1959 additionally modified the wording of portions of the original legislation to expand the scope of authority for the Foundation.

Further clarification of the relationship between the Director and the National Science Board was delineated in Reorganization Plan No. 2 of 1962. Whereas previously the Director had been an ex officio nonvoting member of the Board, he was then designated, ex officio, a voting member on a basis coordinate with that of other members. In addition to this and other provisions aimed at improving administrative effectiveness, the Reorganization Plan stipulated that the Director was to be chairman (and a voting member) of the five-member Executive Committee of the National Science Board.

Assignment of additional authority to the Executive Committee (by Reorganization Plan No. 2) had the effect of streamlining the Board's exercise of responsibility. The Board was authorized to assign to the Executive Committee such of its powers and duties as were deemed appropriate, except for the function of establishing policy.

More recently additional structural changes within the Board have been made desirable by the rapid evolution of Foundation operations. In earlier years, the Board organized itself into working committees paralleling the various scientific disciplines supported by the Foundation, as well as committees covering such operational areas as scientific personnel and education and institutional programs.

As the need for a broader viewpoint in coordinating and integrating the various programs of the Foundation became manifest, in 1965—at the suggestion of the Director—the Board reorganized itself into three major committees, replacing the former numerous and more restricted working groups. Rather than attempting to name these, they were simply designated Committees I, II, and III.

The purpose of Committee I is defined as examination of matters of broad scientific significance as related to current Foundation programs. This function includes continuing scrutiny of the distribution of Foundation efforts among the various scientific disciplines which may legally be supported, and among the various kinds of activities the Foundation supports, such as research, education, and science information. An important aspect of this continuing operational analysis is examination of Foundation support for the new and expanding sciences and the degree of support these areas are receiving from other Government agencies or from industry. In general, this committee deals with substantive scientific matters of concern to the Foundation and, as a result, of consequence to national policy.

Committee II concerns itself with the operational and administrative aspects of the Foundation, and how these affect and are affected by Foundation relationships with other organizations. Major areas of interest to this committee cover the internal organization of the Foundation, the administrative procedures involved in judging the merit of research proposals, the perennial problem of "overhead" allowances, the policy to be adopted relative to "cost sharing," the percentage of faculty salaries covered by Foundation support, and the effect of Foundation and other Federal programs on the universities' ability to meet the expenses normally associated with grants.

Committee III devotes its attention to long-range planning, and is charged with looking to the estimated level of support for science five or ten years in the future, and deliberation on possible future programs which may involve the Foundation and other Federal agencies with respect to national purposes.

This arrangement has a number of advantages over the earlier pattern. The Board, in only intermittent contact with Foundation operations in any circumstances, is relieved of much attention to detail. Fewer meetings of the full Board are now required, and the Executive Committee can be called into session quickly if rapid action should become necessary.

As the Board has moved toward greater relative emphasis on broad and long-range policy as compared to the details of routine operation, its usefulness to the scientific community and its value as a component of the Foundation have increased. The tendency toward less involvement in operational decisions results in more critical analytical scrutiny of Foundation policy and the policies of Government for science as a whole.

An additional and important system of continuing communication with the scientific and academic communities is maintained through Divisional Committees* composed of educators and scientists appointed to advise the Director on overall program activities. The judgment of these committees has proven to be of immeasurable value in determining both broad and specific approaches to providing support for basic research and science education.

Further informative services are available to the Foundation staff through Advisory Panels comprised of individuals representing specific scientific disciplines. Members of these panels are university faculty and industrial research personnel, and in some cases representatives of agencies of the Federal Government. Several hundred persons, each an authority in his field, serve on these panels.

Foundation Responsibility for National Science Policy

With respect to its responsibility "to develop and encourage the pursuit of a national policy for the promotion of basic research and education in the sciences," the Foundation first approached this task with deliberation. "National science policy" is a term that is difficult to define save in the broadest generalities. It is rather a constellation of interrelated policies. These may be grouped together as "national science policy" because they

*Subsequent to the period covered by this report these committees have been reconstituted and consolidated to form "Advisory Committees" with somewhat broader responsibilities.

affect, directly or indirectly, the level, substance, and conduct of scientific activities in the United States, the opportunities for and content of education in the sciences, and the utilization and development of the Nation's resources for science.

Science policies are shaped by State and local governments, by nongovernmental institutions, enterprises, and organizations as well as by the Federal Government. It is appropriate therefore to think of the national policy for science as a composite of both public and private science policies.

But if there is to be any coherence in such a set of science policies, it is essential that there be a body of reliable information on the status of scientific manpower, facilities, and funds, including data on their distribution by performer groups, by geography, by level of competence, and by field of science.

It was to this need in the realm of policy that the Foundation addressed its initial efforts by instituting a continuing series of studies, data acquisition, and analyses of government and nongovernment activities in an effort to compile a unified picture of the whole. Activities in this connection have become fairly substantial, although commanding only modest funding, and Foundation publications have become the standard source of information on the Nation's supply of scientific and engineering manpower and statistical data on the total national effort in scientific research and development as a whole.

Some of the substantive activities in support of science policy formulation are *Federal Funds for Research, Development, and Other Scientific Activities*, an annual statistical analysis; the National Register of Scientific and Technical Personnel; and the Science Information Exchange maintained by the Smithsonian Institution with the support of the Foundation.

The role of the Foundation with respect to policy-making for basic research and science education was modified to a degree by Reorganization Plan No. 2 of 1962 which also created the Office of Science and Technology in the Executive Office of the President. This plan provided for transfer from the Foundation to the Director of the Office of Science and Technology so much of the function "to develop and encourage the pursuit of a national policy" as will enable the Director of the Office of Science and Technology "to advise and assist the President in achieving coordinated Federal policies for the promotion of basic research and education in the sciences."

Statutory responsibility of the Foundation in the broader context beyond the perimeters of the Federal complex remained unchanged, and the Foundation retains full intellectual responsibility to examine current policy, to make recommendations, and to take action with regard to strengthening the various fields of science. At the same time, the Foundation supports the Office of Science and Technology through continuing studies which assess research opportunities in the sciences, and through recommendations for consideration by the Office of Science and Technology in the planning of overall Federal scientific activity.

In parallel fashion, the Foundation also supports the Federal Council for Science and Technology, which is composed of representatives of the Federal agencies having a substantive interest in science and technology. While the Federal Council serves as a coordinating body, and is concerned with both formulation and suggestion of policy, the Foundation has a statutory responsibility over and above the other agencies to assemble information and present recommendations upon which sound Federal policies for science can be based.

Foundation Support of Basic Research

Although establishment of the National Science Foundation in 1950 constituted Federal recognition of the need to support basic research in the sciences, initial funding provided for the Foundation by Congress was modest. Six years had passed between publication of the report *Science, the Endless Frontier* and the Foundation's first year of activity, bringing with them a change in circumstances that could not have been foreseen by Bush and his associates. Partly because of the exigencies of the quickening Cold War and the conflict in Korea, a number of Federal agencies were already engaged during the early 1950's in substantial programs of support for scientific research, including basic research, and for improvement of science resources.

Even the agencies with rather specific technological objectives rightly justified their support of basic research in recognition of the general need to replenish the reservoir of unexploited basic knowledge. Thus, while the Government was proceeding in the direction of goals envisioned by Bush and Conant, such agencies as the Department of Defense and the Atomic Energy Commission were important vehicles through which Federal funds found their way to science. It was during this period too that the National Institutes of Health began to assume prominence as a source of support outside its own research institutes.

This pattern of pluralistic support for basic research has endured, and has been found to contain a number of advantages. It is favored by the colleges and universities. It has always been endorsed and fostered by the Foundation as sound and appropriate.

The Foundation placed emphasis from the beginning on support for the highest quality of basic research. In fiscal year 1952, the first year in which funds for the purpose were available, the Foundation awarded 96 grants for project research at 59 institutions located in 33 States, the District of Columbia, and Hawaii. The direct grant was chosen from the outset as the most appropriate type of instrument for supporting basic research on the basis that it would provide maximum latitude and academic freedom to qualified investigators, while entailing a minimum of administrative involvement for the institution.

A significant advance in support of research took place in 1956 when the Foundation for the first time provided major assistance for procurement of science facilities, with one grant awarded for construction of a nuclear reactor, and the first five grants in a series providing support for computers at universities.

The year 1956 also saw the preliminary steps which led to establishment of the National Radio Astronomy Observatory at Green Bank, W. Va., and the Kitt Peak National Observatory in Arizona, both now operated for the Foundation by consortia of universities. A study initiated in the same year by the National Academy of Sciences on the gap between performance and potential in the atmospheric sciences led to establishment in 1960 of a third national research center: the National Center for Atmospheric Research at Boulder, Colorado—also operated by an association of universities. These national centers now provide modern facilities for use by significant numbers of visiting university scientists and graduate students, and thus constitute effective extensions of university research activities.

Support for the scientific aspects of *Vanguard,* America's first artificial satellite, and participation by the United States in the International Geophysical Year (IGY) made 1957 a year of notable expansion for the Foundation. The IGY, a comprehensive worldwide scientific undertaking, was the first "national" research program in which the Foundation shared, and was the precursor of a number of others. As the Federal agency uniquely concerned with basic research, the Foundation has come to be regarded as the most appropriate executive agent for coordination and, in some cases, financial management of broad scientific programs in which a number of departments and agencies of the Federal Government participate, along with nongovernmental entities, and often in cooperation with other nations on an international basis.

National research programs are usually undertaken at the initiative of the scientific community, which may request support from the Federal Government after the desirability of U.S. participation has been established. The National Academy of Sciences has been an important intermediary between the scientific community and the Federal Government in such matters, and usually provides continuing advisory services to the Foundation after a national research program has been initiated. Authority to participate in national research programs may arise from the Foundation's organic legislation, by specific legislative acts covering a particular program, or by executive order (which is usually the case with reference to international programs).

Foundation responsibility for national research programs covers two general categories:

1. Programs in which the United States participates as a component of an international group under the auspices of intergovernmental or multinational science organizations. Examples of these are the Antarctic Research Program and the United States-Japan Cooperative Science Program,

for both of which the Foundation bears complete United States responsibility including funding;* and the International Indian Ocean Expedition and the International Years of the Quiet Sun, for which the Foundation is the coordinating agency.

2. Programs which are entirely domestic and which involve basic research, such as Project Mohole, ocean sediment coring, and weather modification.

Foundation responsibility for weather modification is defined in Public Law 85–510 of 1958 which amended the original National Science Foundation Act to add: "to initiate and support a program of study, research, and evaluation in the field of weather modification, giving particular attention to areas that have experienced floods, drought, hail, lightning, fog, tornadoes, hurricanes, or other weather phenomena, and to report annually to the President and the Congress thereon."

There is a third category of national research programs that should be mentioned. These are designated by the Federal Council for Science and Technology and embrace scientific fields that depend substantially on Federal support but in which the responsibility is not so sharply focused in any one agency. Among this category are included the atmospheric sciences, materials research, oceanography, and water resources research. The Foundation participates in all these programs, but only as one of several agencies having an interest in the various fields.

Other programs of support for research added gradually by the Foundation over the years were devised to provide support for major items of equipment such as nuclear accelerators, and specialized facilities such as oceanographic research vessels and environmental laboratories for biological research. Funds have also been provided on a matching basis for construction or renovation of graduate laboratories in a large number of academic institutions.

Support of Science Education

Like the support provided for basic research, Foundation activity in the field of science education dates back to the first full year of operation. Statutory authority for the Foundation to support science education arose from the need to develop an adequate national supply of scientific and technical manpower rather than support for education per se. Foundation policy, however—as in the case of research—placed emphasis from the outset on quality rather than quantity, and support of graduate education became a first priority concern.

The initial program of graduate fellowships for the academic year 1952–53 provided awards at both the predoctoral and postdoctoral levels to 624 candidates selected on the basis of national competition. This emphasis

*The Department of Defense has responsibility for logistic support of the scientific programs in the Antarctic with the U.S. Navy designated as executive agent.

on academic excellence endures as a cornerstone of Foundation policy, and the graduate fellowship program is regarded as one of the Foundation's most effective mechanisms in support of science education. In addition to quantitative expansion of the traditional fellowship program, the Foundation has added specialized variations, notably two postdoctoral programs which provide advanced training for exceptionally able individuals who wish to become even more effective in their fields, and science faculty fellowships for college and university science teachers with the primary aim of enhancing their capability as teachers of undergraduate students.

The Foundation early recognized that the acute shortage of scientific and technical manpower in the early 1950's had deep roots in the educational, social, and economic structure of the Nation, and that correction would require long-range efforts aimed at the basic problem areas. Thus Foundation interest in science education was expanded as rapidly as possible to touch on every level of the education process from primary school to the highest level of postdoctoral study.

New programs have been developed by the Foundation over the years in a continuing effort to discharge its responsibility for science education more fully. Generally speaking, the programs in support of science education have three broad objectives: (a) to assist qualified individuals in obtaining additional advanced training, (b) to improve the quality of curricular material and the methods used in science teaching, (c) to improve the level of knowledge and other qualifications of science teachers.

In fiscal year 1953, the Foundation sponsored its first summer institutes to assist college science teachers in coming up to date with the latest developments in their specialties, with 250 teachers from small colleges participating. In the following summer the institutes program was expanded to secondary school teachers. At the present time, the Foundation institutes programs reach teachers of science, mathematics and engineering from the elementary to the undergraduate level, and are organized and conducted by several hundred colleges and universities. The summer group-training sessions are further augmented by inservice training of teachers at evening classes and a smaller number of academic-year institutes given to teachers who have taken a leave of absence for the purpose of pursuing additional training. Altogether Foundation support for teacher training of this type has provided some 300,000 training opportunities.

A related activity in support of science education is the Foundation effort to provide colleges and universities with undergraduate instructional equipment. On a cost-sharing basis the Foundation provides assistance in procurement of laboratory equipment for undergraduate science programs, and this type of assistance has proven particularly beneficial to large numbers of smaller colleges. The present level of this type of support for science education is about 950 grants annually to more than 500 institutions.

For a number of years the Foundation has provided support for efforts directed to improving the curricula of science courses at both the precollege

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and undergraduate levels. Grants have been made to support outstanding scientists and teachers of science who, working in partnership, have incorporated the most up to date scientific knowledge into textbooks and other instructional media and the results produced by these partnerships have won widespread endorsement throughout the educational community.

Science Information Service

Acceleration in all avenues of scientific activity in the latter years of the 1950's brought with it new recognition of the need for better coordination in the dissemination of science information. While the Foundation from its inception expressed interest in this general problem area by supporting a number of science information activities, this participation by the Foundation was voluntary and permissive under the broad mandate of the original authorizing legislation rather than as the discharge of a specific statutory responsibility.

The Congress in 1958 moved to strengthen and expand the Foundation's information function by incorporating into the National Defense Education Act a provision for establishment of an Office of Science Information Service within the Foundation (Title IX, NDEA). The act also called for establishment of a Science Information Council to be appointed from nongovernmental authorities in such fields as librarianship, scientific documentation, and communications, and having as its purpose to serve in an advisory capacity to the Office of Science Information Service.

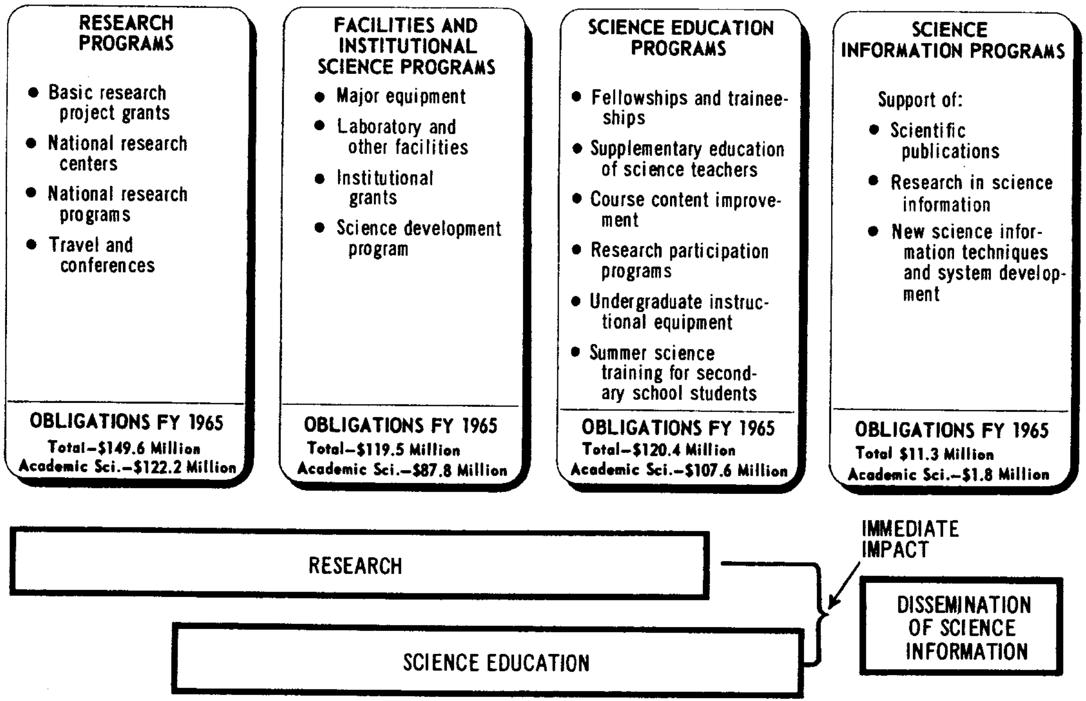
As it is now constituted, the Office of Science Information Service is responsible for providing leadership among non-Federal science information services, and in developing appropriate relationships between Federal and non-Federal activities. The function of coordinating scientific and technical information services within and among the Federal agencies rests with the Office of Science and Technology and a committee of the Federal Council for Science and Technology. Thus the objective of the Foundation's Office of Science Information Service is to supplement internal Federal information activities, and insure that scientists and other users have ready availability to the world's current and past output of significant scientific and technical literature.

Categories of Support

The complex of support mechanisms now employed by the Foundation at the conclusion of 15 years of evolution is illustrated by chart 1. For administrative convenience, the various activities are here arranged in four main categories, but this of course is an oversimplification in terms of the purpose and impact of the various programs. Many programs, notably those listed as Facilities and Institutional Science Programs, have a duality of purpose because of the interlocking nature of research and education, especially at the graduate level where the two are virtually indistinguishable. Even the

MECHANISMS OF SUPPORT

NATIONAL SCIENCE FOUNDATION



SOURCE: National Science Foundation

Chart 1

dissemination of science information is a form of support for research on the one hand, while it unquestionably has a usefulness in promoting advanced education on the other. And just as the various activities generally have an impact on both research and education, so the allotment of funding among the four categories is somewhat arbitrary, assignments being made in terms of the primary purpose of the program although it may very well have multiple effects.

The national research centers provide a good example of this duality of purpose, in that about 60 percent of the research done at the two astronomical observatories is conducted by university scientists and graduate students. Similarly, a substantial portion of research carried out in the Antarctic is performed by university scientists from many parts of the United States.

Of approximately $400 million obligated outside the Foundation in fiscal year 1965, almost three-fourths was committed directly to the country's academic institutions (see chart 2). Another 6 percent went to individuals in the form of fellowships which enabled them to pursue graduate study at these institutions.* Furthermore, a substantial fraction of the funds obligated to "other nonprofit organizations" supports the basic research in which academic scientists participate at the national research centers, as mentioned above, as well as curriculum development and other science education activities which benefit the colleges and universities or other parts of the national educational structure. In addition, nearly all the funds allocated to industry are for the purpose of providing facilities that will be used for research closely associated with scientists in colleges and universities. Thus it may reasonably be said that well in excess of 90 percent of the Foundation's total program is directly or indirectly in support of academic research or science education.

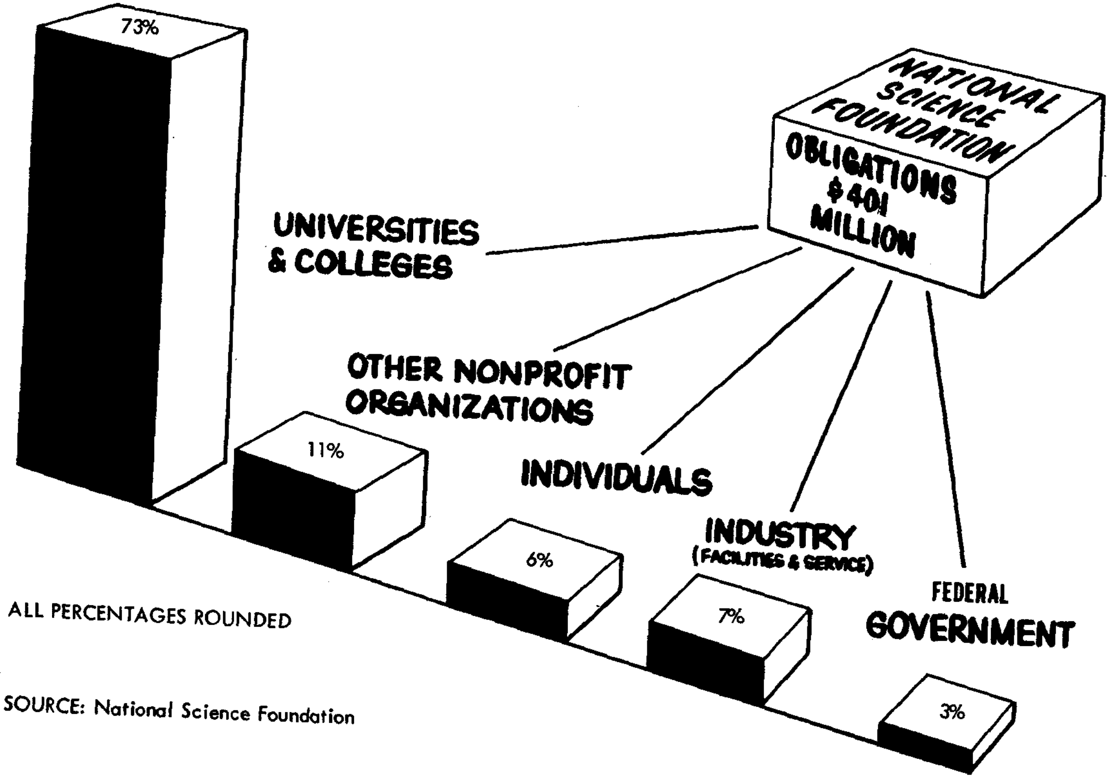
About 1,100 academic institutions in the United States offer programs leading at least to a bachelor's degree in the sciences or engineering. Approximately 1,000 more, including 650 junior colleges, provide more limited amounts of undergraduate training in science. Some 176 universities in the Nation provide training to the Ph. D. level in one or more fields of science.

Altogether, 834 colleges and universities were direct recipients of Foundation funds for academic science during the fiscal year covered by this report. Academic science, used in this context, refers to all types of support having a significant and direct impact on the colleges and universities. In its research support program, the Foundation provided funds to about 300 institutions. Half of these received $70,000 or more during the fiscal year, and each of the top 100 institutions received $200,000 or more.

*This refers only to the costs of fellowships awarded directly to individuals. Funds for "traineeships" awarded by the universities are included in the category "universities and colleges."

DISTRIBUTION OF FUNDS FOR DIRECT SUPPORT OF SCIENCE FY 1965

NATIONAL SCIENCE FOUNDATION



ALL PERCENTAGES ROUNDED

SOURCE: National Science Foundation

Chart 2

The table below illustrates the relationship between support for academic science by the Foundation and the number of degrees awarded during the previous academic year by the institutions supported. As the figures show, institutions receiving support accounted for 99.8 percent of the doctorates awarded, 99.4 percent of the master's and 89.8 percent of the bachelor's degrees earned in the sciences and engineering.

Highest science or engineering degree awarded 1963–64	Fraction of NSF funds, fiscal year 1965	Fraction of degrees conferred—1963–64 (by institutions awarded NSF funds in fiscal year 1965)		
		Ph. D.	Master	Bachelor
	Percent	*Percent*	*Percent*	*Percent*
Ph. D.	88.8	99.8	86.7	52.7
Master	7.3	....	12.7	21.7
Bachelor	3.7	....	....	15.4
No degree	.2	....	....	....
Total	100.0	99.8	99.4	89.8

Further examination of statistics reveals the characteristic which has been described as "institutional imbalance" in support. As seen in the following table the first 200 institutions received 93.4 percent of support provided (with a corresponding record of 97.9 percent of the doctorates awarded), while 234 of the 834 institutions supported shared among them only 3/10 of one percent of Foundation funds for academic science although they graduated 6.2 percent of the science baccalaureates. In the same context, however, it is notable that of the 176 institutions offering programs leading to the Ph. D. degree, only four did not receive support, and these four together accounted for only 18 of the nearly 9,000 doctorates earned during the year.

It is clear that there is a wide qualitative disparity between the leading institutions of higher education and those at the lower levels. But there is more basis for the belief that Federal funds in general are attracted to outstanding institutions because of their quality than for the contrary view that this high quality is the result of Federal support. In any case, it has become increasingly recognized with the passage of time that the future needs of the Nation demand a larger number of institutions of high caliber, with an increased cadre of well-qualified scientists and science educators, with facilities adequate to the requirements of modern research and educational problems, and with an increasing number of opportunities for advanced research and advanced research training.

The Foundation has several programs directed at supporting the institutions, as distinguished from those supporting specific projects within the institutions. A special form of institutional assistance, in existence since

Institutions in order of NSF support, fiscal year 1965	Fraction of NSF support fiscal year 1965	Fraction of total earned degrees in science and engineering—1963–64, awarded by NSF-supported institutions		
		Ph. D.	Master	Bachelor
	Percent	*Percent*	*Percent*	*Percent*
First 10	24.6	28.4	18.6	7.9
Second 10	16.0	11.3	7.6	3.6
Third 10	11.8	11.8	7.5	4.8
Fourth 10	8.2	11.8	7.9	5.1
Fifth 10	6.1	7.1	7.7	3.9
First 50	66.7	70.4	49.3	25.3
Second 50	16.8	19.6	22.8	15.6
Third 50	6.5	6.4	11.8	10.8
Fourth 50	3.4	1.5	5.8	8.0
First 200	93.4	97.9	89.7	59.7
Second 200	5.0	1.6	7.0	15.2
Third 200	1.3	.3	2.1	8.7
Remainder (234)	.3	....	.6	6.2
Total supported	100.0	99.8	99.4	89.8

1961, is the "Institutional Grant," an annual award of funds based on a formula related to the volume of research support provided to the institution by the Foundation. These funds may be used for any purpose which directly supports academic science.

Among the typical purposes for which such funds may be used are: rental of computer time, acquisition of scientific equipment, outfitting of shops, stocking of libraries, student stipends, or salaries for additional faculty. The flexibility inherent in this type of assistance makes it particularly desirable from the viewpoint of the institution involved. An important aspect of this program is that the formula used to determine the amount of the grant is one which favors the smaller or weaker institutions—or, more precisely, it tends to favor the institutions receiving the smaller amounts of direct research support.

During recent years a number of previously less prominent institutions have attained new stature, and the Foundation has adopted various measures aimed at stimulating and accelerating this trend among what have been called the "rising universities." Among these is a new form of institutional support introduced in fiscal year 1965 aimed at broad and rather rapid development of a limited number of institutions having a demonstrated potential for advancement toward the level of excellence which is now characteristic of our truly outstanding institutions.

This new form of support, called the Science Development Program, is considered to be important and promising, and it contains a broad degree of flexibility which will enable the institution to accelerate progress toward achieving its objectives on the basis of plans carefully worked out by the institution itself. During fiscal year 1965, eight grants of this type were awarded, averaging $3.4 million each, to institutions in various parts of the country.

In announcing the first of these Science Development grants President Johnson said: "These grants are only a beginning . . . . This new program will build the apex on the educational pyramid while our other programs broaden and strengthen the base. These are important steps in maintaining the scientific leadership which this country has achieved."

There is reason, accordingly, to hope that this program can be expanded substantially during each of the next several years. I believe that, by providing a major boost through such Science Development grants, the Foundation can assist in bringing the recipient institutions to a position from which they can continue to develop on their own momentum and with their own resources.

During fiscal year 1965 the Foundation staff has been carefully exploring possible ways of implementing an additional type of institutional support, a program designed to reach those institutions which have not yet reached a position of sufficient general strength to enable them to compete strongly for grants under the Science Development Program. This new program will be directed toward further development of "pockets of strength" in specific scientific disciplines which now exist and can be identified in many institutions across the country. It is felt that even one science department which is substantially above average can be of general as well as specific usefulness to the institution in which it exists. The impact of such a nucleus of quality will have an immediate effect on related departments, and will eventually spread to all scientific disciplines represented on the campus.

Another innovation recently initiated by the Foundation is the Graduate Traineeship Program, which is directed toward fuller utilization of the capacity of a large number of institutions to provide training for graduate students in the sciences and engineering. Recipients of regular Foundation fellowships have always been free, as stipulated by law, to attend the institution of their choice, and there has been a natural tendency for them to concentrate at a relatively small number of leading institutions. In the Graduate Traineeship Program, initiated in fiscal year 1964, the institution applies for the number of traineeships it believes it needs in the various eligible fields of science. Grants are awarded on the basis of departmental strength and capacity for expanding the graduate student enrollment. Ultimate selection of the individual recipients is made by the institution from among its own graduate students or undergraduates entering upon graduate training. During its first year the Traineeship Program was limited to the engineering fields. In fiscal year 1965 it was expanded to include mathematics and the physical sciences, with grants being given to almost all universities granting doctorate degrees in the fields eligible. It will be still further broadened in fiscal year 1966 to include the biological and social sciences. In addition to assigning specific numbers of traineeships for particular disciplines, the Foundation additionally allots a number of unrestricted or "floating" traineeships which may be utilized by the institution at its own discretion.

One important aspect of the Traineeship Program is its developmental effect. It gives the institution an opportunity to attract more good graduate students, and this aspect will grow in importance as the program expands. Following the introduction of traineeships, the Foundation is now phasing out its older cooperative fellowship program and diverting the funds used for these to an increase in the number of traineeships and conventional graduate fellowships.

Climate of the mid-1960's

Since the war, science has enjoyed unprecedented and rapidly growing Federal support. Initially this support was primarily directed at immediate exploitation of the practical fruits of science in pursuit of national objectives in such fields as military defense, public health, conservation of natural resources, and industrial development. Federal agencies with responsibilities in these and other technological areas were motivated to support basic research as the source of underlying knowledge necessary for achievement of these goals. Increasingly it has become recognized that continuance and growth of the fruits of science can occur only if the tree that bears them—science itself—is helped to grow and flourish. Federal support for research and development as a whole has approximately doubled since 1960—from $8.1 billion to $16.1 billion—but it is notable that the development share has less than doubled while the support for basic research has more than tripled.

This change in attitude toward the importance of basic research has been accompanied by other changes which have emerged at an accelerating pace, and the concept of Federal support has now been broadened across a wider range of intellectual activity without any diminution in the objectives of science and science education. There is increasing discussion of Federal support for the arts and humanities,* and after long hesitation the concept of Federal support for education in general is now wholly accepted.

The most dramatic and progressive of these changes in the national attitude is, of course, Federal support for education at all levels. Appropriations for the Office of Education have increased about sevenfold in the years from 1960 to the present, and legislation pending at the end of fiscal

*The act establishing a National Foundation for the Arts and Humanities was signed by the President on Sept. 29, 1965, after the period covered by this report.

year 1965 can be expected to bring even further increases. Two impelling motives are at the base of these changes. The first results from recognition that a highly educated people makes the Nation strong in a composite sense; that for our national well-being we must develop the highest competence in all fields of human endeavor; and that to achieve this we must have high quality education at every level.

Secondly, and importantly, Federal policy has evolved in the direction of stronger emphasis on the democratic principle that every citizen is entitled to an opportunity for the best education he has the capacity to absorb effectively, and in the field he finds best suited to his talents.

There is nothing new in principle in these developments, so far as national philosophy is concerned. Public support of education for both of these motives goes back to colonial times. What is new is that in the structure of modern society the Federal Government must share responsibility for attainment of the goals.

This trend is accompanied, though as yet in less full and evident fashion, by an increasing acceptance of the value of scholarship and intellectual activity, not only for potential material rewards, but for its role in fulfillment of the human personality and development of human intellect for their own sake.

Clearly there is a pervasive mood in all parts of the country to improve education at every level, and the general interest extends higher up the educational ladder than ever before. It is my view that there is no reason to believe that science will suffer by sharing the spotlight of Federal support with other branches of scholarship. Rather science can be expected to prosper all the more as a climate more favorable to scholarship in general is developed. Government is committed to the continued support of academic science, and while there may be shifts of emphasis or modifications in levels of support of this type, I see no reason to anticipate any change in basic policy. Support of science for its own sake will, I believe, increase—in absolute amount at least, and probably also as a fraction of the Nation's total investment in science and technology.

The scientific community has played an important role in bringing about the growing interest in all areas of cultural activity and the current intensive popular interest in improving education. The attainments of science, visible for all to see, have demonstrated the public and individual benefits deriving from intellectual accomplishment and higher education. The example set by Federal support for education in the name of science has been a great source of public enlightenment and has opened the way for understanding of the positive and important contributions Federal support can make to education in general without impairing any of the cherished traditional prerogatives. Our reward will be a better intellectual and scholarly climate in the country as a whole, a climate in which science itself can flourish even more.

Challenges for the Future

In examining some of the important developments in the lifetime of the Foundation to date, it becomes clear that significant changes in circumstances have taken place to which current and future activities must be responsive. New problems have appeared with the passage of time, and I would like to touch on a few of the matters which seem to me to be deserving of special consideration in the immediate future.

No drastic adjustment is necessary for the Foundation to fit itself comfortably into the altered climate and probable changes in the pattern and direction of support of science and science education. Because of the breadth and flexibility of its legislative mandate, the Foundation is equipped, within limits, to lend its support to research and education for the dual purpose of promoting scientific productivity and providing an opportunity for increased cultural and intellectual development for larger numbers of people. At the same time Foundation activities can both foster and shelter the image of science as a field of intellectual activity that is worthwhile for its own sake.

For this reason, I believe that the Foundation should be regarded, and should think of itself, as the repository of Federal recognition of science as a national resource—a continuously renewable resource that is vital to the national interest. In addition, the Foundation should be the champion and the protector of basic research—the fountainhead of new ideas and the area most likely to suffer in a period of economic retooling of support.

This is not intended to mean that the Foundation can, or should, assume the function of compensating for every change in the pace of support provided by other Federal agencies, nor should it assume the responsibility for doing all the things that others are disinclined to do. On the contrary, with the assistance of the scientific community, the Foundation should assess the total needs, and take advantage of support provided by all other Federal agencies by building upon it when appropriate, and to the extent of available capacity, in order to fulfill total needs as completely as possible. In the exercise of such leadership and in providing a voice for science within the Federal Government the Foundation can make a most significant contribution to the health of basic research as a component of total national strength.

Need for Increased Support of Research

Recent statistics compiled by the National Science Foundation point to a leveling-off of support for basic research by several of the major Federal agencies. Appearance of this trend raises a question as to the future role of the Foundation in the presence of the widespread belief that Federal support for basic research in our colleges and universities must be progressively increased in the years immediately ahead merely to maintain our present relative position in science while sustaining the pace of technological development.

The need for increased Federal support for basic research can be associated with three causes. First, many first-rate scientists do not now receive a degree of support sufficient to enable them to develop fullest effectiveness, to the detriment of the national scientific capacity. Second, support must be provided for increasing numbers of faculty members and graduate students engaged in research as academic institutions expand their enrollments to meet the needs of the growing college-age population. It is estimated that this increase will be in the order of about ten percent annually for many years to come.

Finally, the inescapable fact must be faced that the cost of research continues to rise. Research becomes more complicated, calling for more sophisticated equipment, and the estimated increased cost per investigator has been placed at about 5 to 7 percent annually. These two estimates combined produce the apparent need for an annual increase of 15 percent or more in support for basic research at academic institutions. Obviously the figure of 15 percent is imprecise, but the problem of determining the appropriate level of basic research support, particularly in the universities, is a matter which is being given serious study by the Foundation and other groups—notably a special panel of the President's Science Advisory Committee.

Regardless of changing requirements, I believe that the pattern of Federal support should endeavor to sustain the high quality of research activity now identified with outstanding individuals and institutions and contribute to its enhancement where possible. Quality has no ceiling, and its existence invites challenge and competition, as well as emulation. Such institutions are important national assets, because they are the leading sources of scientific progress, and because their graduates constitute the vital force which energizes the entire national scientific structure.

At the same time I believe the national interests can be served and the base of overall scientific capability broadened by providing assistance to graduate institutions now possessing acknowledged competence in research and education along with a demonstrable potential for effecting significant qualitative improvement. Special efforts are required if these promising institutions are to make an optimum contribution to the total national capability for science and technology.

In addition to continued support for research for recognized scientists, it is my view that research funds should be made available to promising younger members of science and engineering faculties who have not yet achieved reputations, and whose chances of attracting Federal research support under the criteria applying to established senior scientists are understandably small. This group constitutes a research potential worthy of cultivation and encouragement, and which indeed the country can ill afford to ignore. Moreover, the roles of research and education are so interrelated that modest investments of research funds in such men would, at the same time, yield returns in terms of better educational opportunities for the student bodies at the institutions where these younger scientists are located. This is an area that is under continuing study by the staff of the Foundation.

Problems of Undergraduate Science Education

The National Science Foundation has long been active in undergraduate and especially pre-college education in the sciences. The trends of the times call for more intensive and extensive Federal support in these areas—bearing in mind the need for greater equality of opportunity for the individual students.

There is much that needs to be done to improve undergraduate science teaching. However, I hold little or no brief for the allegation that Federal support of research, although enhancing graduate education, has detracted seriously from undergraduate teaching. There have been expressions of concern in recent months that some of our major universities have become giant research factories concentrating on Federally-sponsored projects to the detriment of their educational function. In my view, this is a seriously exaggerated assessment of the situation.

The good teacher must be a scholar, and research is an important form of scholarship—though by no means the only one. The good teacher must be alive to his field; he must keep up with its contemporary advances, and no better mechanism for this exists than to be actively contributing to advances. The time spent on research and on graduate and other advanced students may not permit every faculty member to devote a substantial amount of attention to students in introductory courses. But this is not a new phenomenon. Some time ago a young chemistry student remarked: "You cannot imagine what a crowd of people come to these lectures. The room is immense, and always quite full. We have to be there half an hour before the time to get a good place, as you would in a theater; there is also a great deal of applause; there are always six or seven hundred people." The quotation is taken from a letter written by Louis Pasteur about a hundred and twenty-five years ago in which he describes the chemistry lectures he attended at the Sorbonne. Large lecture courses are of course traditional in many European universities, but they are by no means a recent development in higher education in this country.

The simple fact is that we have many more outstanding scientists and engineers in our colleges and universities today than we did a generation or two ago. Today's freshman student at a major university may find it harder than it was in his father's student days to meet and talk with the "most outstanding chemist" on the campus—but today, instead of a single chemist overshadowing all others, there are likely to be half a dozen of outstanding competence. Student bodies, on the other hand, have also multiplied, making personal, individual communication difficult.

Serious study of this situation by a number of institutions has been going on as a result of some of the recent expressions of concern—and such self-examination may lead to the discovery of better ways of assuring appropriate lines of communication between undergraduates and professors. But the President of one of our major institutions, in assessing the findings of a study on this problem that he has recently completed, stresses that (in this as in many other nostalgic views of the past) those who are criticizing the present situation are sometimes prone to remember only the best of the past. His conclusion is that the level of undergraduate instruction on his campus has improved rather than deteriorated as a result of the burgeoning research program at that institution in the past few decades.

However, I do not feel that the increasingly severe criticism of the impact of research on teaching can be completely shrugged off. Nor do I feel any sense of complacency about the status of undergraduate science education in our academic institutions as a whole.

Many people feel that, especially in some of the larger institutions, introductory science courses are viewed as elimination contests, a method for "separating the men from the boys" before the former get on with the serious business of pursuing careers in science. Perhaps more thought given to presentation of subject matter in such a way as to inspire interest and to give the student a better opportunity to appreciate its deeper meanings would improve the progress of those equipped and motivated to persevere in science and would also prove useful in the more general sense to those who cannot or do not wish to pursue careers in science.

In any case there is much room for improvement in undergraduate science curricula in most of our institutions. Especially in the 4-year colleges there is a serious problem of recruiting and retaining science faculty members of real competence and enabling them to keep pace with the progress of science.

The Foundation has several modest programs to assist in improving undergraduate education. Among these are curriculum improvement projects, science faculty fellowships, undergraduate research participation programs, summer institutes for college teachers, faculty exchange relationships, and others. But these programs are all modest in size, and can provide only correspondingly modest amounts of help in dealing with a problem which is of nationwide and massive scale. The Foundation has the legislative authority to deal more fully with some of these problems, and it is my intention to push forward in the development of ideas and mechanisms which will be recognized as appropriate for implementation by the Foundation. In doing so, we shall work closely with the Office of Education, to make sure that our efforts and theirs are complementary rather than competitive, mutually reinforcing rather than duplicating. The continuing close relationships between these two agencies give me reason to believe that we will have no difficulty in finding areas of operation where the specialized experience and competence of the National Science Foundation can be used to augment with good effect the broader, "education-wide" activities of the Office of Education.

Interdisciplinary Approach to National Problems

A continuing issue—one that can only be attacked and never disposed of—is that of using the methods and findings of the pure and applied sciences to help deal with pressing social problems of an increasingly complex society. In general, the major problems which loom large before the Nation are almost all related in one way or another to science and technology. But there is rarely a social problem which is the exclusive concern of a single scientific discipline, in the traditional sense of the term. Many problems can be dealt with in part by chemistry, or in part by other fields within the physical sciences; some problems clearly require the attention of engineers and social scientists; still others cannot be solved without the aid of life scientists and physical scientists.

Whether one thinks of the need for improved systems of transportation, better conditions of urban life, cleaner (which is to say less polluted) waterways, or lower rates of juvenile delinquency, science and technology must be thought of as constituting one of the major resources available to those who must cope with these problems. "Science and technology" in this case means broad, multidisciplinary ranges of expertise rather than the narrower concept of specialization which has so long characterized our image of the constituent entities of the scientific enterprise.

This trend toward broad treatment of *scientific* problems has been with us for some time. Mathematicians and physicists have teamed up repeatedly to probe into questions having a mutuality of interest. In many advanced areas today the distinction between chemistry and biology has almost disappeared, and the interdisciplinary approach is now commonplace in a large number of other areas. Thus bridges have been built between distinctive disciplines of the physical sciences, and between the physical and life sciences. There are still far too few such bridges connecting the natural sciences, engineering and the social sciences, although links between these broad domains are becoming somewhat less rare.

The National Science Foundation, along with all Federal agencies concerned with scientific and technical matters, must try to devise more effective ways of facilitating and encouraging partnerships of effort between engineers, natural scientists, and social scientists—partnerships which will increasingly be required if we are to find, without undue delay, adequate solutions to our urgent social problems. I realize that the difficulties inherent in this task are great, and obviously the Foundation cannot hope to accomplish more than a fraction of what needs to be done. But it is my conviction that the

Foundation has a role to play in this area, and we will be examining continuously the ways in which Foundation activities in support of research, science education, and resource studies can be more helpful in this regard. New approaches to the fulfillment or our responsibilities along these lines may require an examination of the current organizational structure of the Foundation, and if such an examination reveals the need to create new "system-oriented" units, we stand ready to bring such units into being as promptly as possible.

A major factor relating to this interdisciplinary approach to substantive areas of national concern revolves on the problem of disseminating scientific information as promptly and widely as possible. Much has been done to improve the various mechanisms that have been devised for this purpose, and the Foundation has played a growing role in this regard through its Office of Science Information Service. However, we feel that our responsibility in this field is a broader one, and it is our intent to seek out additional ways by which the Foundation can help to improve the dialog between those engaged in uncovering scientific knowledge and those in industry, government, and elsewhere who have need of such knowledge in solving practical problems.

Whether this will take the form of special conferences, working groups drawn from each of the relevant sectors, or special studies undertaken by staff or consultants—or still other possible approaches—I cannot say at this time. We are hopeful that through such mechanisms we will be able to carry out our responsibilities in this area more fully.

In reviewing the work of the Foundation over its lifetime of 15 years it is clear that much of what has been accomplished can be attributed in large measure to the harmonious relationship developed between the Foundation and the scientific community. One of the factors contributing to this is the position of the Foundation that the scientists of the nation are best equipped to determine what is in the best interests of science. Over the years there has grown up an interdependence between the Government and our colleges and universities, an interdependence which thrives best when the requests Government makes of educational institutions are consistent with the institution's inherent goals.

Whether Government support is proffered in support of research or science education, it is the conviction of the Foundation that such support should be as direct as possible, and encumbered only with the minimum of administrative restriction necessary to satisfy the normal requirements of sound fiscal management. Good intentions can too readily be frustrated and rapport undermined by excessive emphasis on restrictions and restraints which may tend to inhibit the intellectual flexibility of academic institutions.

The Nation clearly benefits as a result of Government support which strengthens our colleges and universities, but the benefits can be adulterated if excessive time and energy must be diverted into avenues not closely and directly related to the development of scientific or educational potential. This concern weighs heavily in Foundation planning, and policy favors the less constraining techniques of support in so far as possible.

As we look to the years ahead, the Foundation recognizes additional areas of opportunity which now invite exploration. While the picture of the past is satisfying, the years ahead will be years of increasing fulfillment. We must foster and encourage the evolutionary process by which the Foundation has grown, for science is indeed an endless frontier, and we must adapt ourselves to its ever-changing pattern in meeting the continuing challenge.

LELAND J. HAWORTH

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PROGRAM ACTIVITIES
of the
NATIONAL SCIENCE FOUNDATION

INTRODUCTION

The function of an Annual Report is, of course, to give an account of the events, the decisions, the progress and the setbacks, of the year under review. This the National Science Foundation Annual Report attempts to do with some degree of completeness each year. To be fully informative, the report also discusses some of the events that may have preceded or followed the year being reported, where these events shed light upon or are particularly relevant to the activities of the year.

In addition, during certain years when it appears particularly appropriate, a more extended essay-report is given on a subject of especial concern to NSF. Last year, for example, the report laid particular stress upon the Foundation's Institutional Programs, for the fiscal year it covered saw the fruition of a then-new program—Science Development—of great importance, and the continuation of other programs that have had appreciable impact on the Nation's institutions of higher learning.

This year it has seemed particularly appropriate to discuss in detail the Foundation's programs in Science Education. Fiscal year 1965, and the first part of fiscal year 1966, have been very important ones for American education. The Elementary and Secondary Education Act of 1965, and the Higher Education Act of 1965—following 7 years after the National Defense Education Act of 1958—are designed to upgrade the quality of U.S. schools at every academic level. For the past decade and more, leading up to these acts, there has been a great ferment of discussion, self-criticism, and experimentation in the American educational community. Science education activities have been an integral part of this ferment, and the Foundation's vital role in this area was recognized very early. NSF has attempted to construct programs and policies to make maximum contributions to the quality of science education at every academic level, and to help significantly in the widespread expansion of the intellectual and scientific content of science courses.

Some of the innovations encouraged by NSF have set precedents useful to educators in fields other than science. Some NSF science education programs have been adapted for other types of education. Some, having served a useful purpose as stimulus or experiment, have become outmoded and have been dropped. Others have appeared to meet continuing needs, and have been continued and expanded. As new problems in science education have been successively identified, new programs have been devised to meet them.

So the process of experiment—carefully defined and controlled, but hopefully creative and of lasting benefit to the Nation's schools—continues. This year is a logical year for a full report, in a historical and social context, on the Foundation's programs in science education, on their impact upon our schools, and on some of their implications for the future.

The remainder of the Annual Report discusses, in the fashion generally followed in previous years, the significant activities that have taken place in other areas of National Science Foundation concern. The division of the discussion corresponds roughly, but not exactly, to the administrative organization of NSF. The report on the National Research Centers has for the first time been separated and considerably expanded, to give additional recognition to the important work they are doing in the furtherance of U.S. scientific leadership.

As was the case last year, the list of grants, contracts, and fellowship and traineeship awards is published in a separate volume, entitled *National Science Foundation Grants and Awards, Fiscal Year 1965* (NSF 66–2).

PROGRESS IN SCIENCE EDUCATION

Progress in science and technology depends heavily upon the quality of science education provided by the Nation's schools, colleges, and universities. Fully recognizing this fact, the Congress of the United States included, as a major part of the National Science Foundation's mission, strengthening education in the sciences. The only Federal agency specifically charged with this responsibility, NSF has sought to meet the most critical needs for improvement at all educational levels. Rapid changes in science, expanding enrollments in colleges and universities, and the growing need for the products of scientific research and development add to the complexity of the overall problem.

During its 15 years of existence, the Foundation has helped bring about many favorable changes in science education. Through its grants and fellowship awards, the strength of the Nation in science education has been markedly increased. This goal could have been achieved only through the generous assistance and cooperation of the scientific and educational community. The task is by no means completed, but what has been accomplished is encouraging.

In charting its early course for improving science education on a national scale, NSF sought the advice and counsel of scientists from universities, colleges, and research establishments. Proposed activities had to take into account the overall objective of NSF-supported educational activities—that is, to ensure that the Nation produces adequate numbers of well-trained scientists and engineers to do the things our national goals require. Problem areas requiring immediate attention had to be identified and appropriate solutions determined.

Because the training of young scientists was of paramount importance, fellowship programs were the first to be supported. Begun in 1952, the early fellowship programs provided assistance to those promising young men and women who had completed their college education but required postgraduate training in order to become leaders in science and engineering. As other needs were identified, new programs were added, so that today the Foundation supports a wide variety of activities to help undergraduates, graduate students, and mature scientists. To these individuals the Foundation has a major responsibility, for they represent the source of scientific potential and achievement. At the graduate level, NSF educational programs have a direct and essential impact on the growth of science.

Other educational activities have direct benefit to both scientific research and education. A program begun in 1959 provides stimulating research experience for college teachers, as it enhances their teaching capability. Another program supports the purchase of much-needed equipment to provide adequate laboratory training for undergraduate students. Such support has had a widespread influence throughout the Nation and has helped many small colleges, as well as the large universities that train most undergraduate science majors.

In addition to programs administered specifically as educational activities, research projects supported by the Foundation provide a great deal of science education as a byproduct. Each year a substantial number of research assistants and other graduate students receive skilled guidance and training from the senior scientists who direct the research.

Early in the Foundation's history the supplementary training needs of science teachers became apparent. Teacher education of the past several decades commonly emphasized instructional techniques and methodology rather than subject matter. Consequently, teachers did not learn enough science. The increasing pace of scientific discovery compounded the problem, particularly for secondary school teachers.

Well aware of the critical situation, the Congress strongly favored using Federal funds to provide necessary training for the Nation's teachers. Beginning in 1953 with two small experimental projects, the Foundation over the years has supported a substantial number of "institutes" where teachers are taught contemporary science, mathematics, or engineering. Emphasis thus far has been placed on meeting the needs of secondary school teachers, although there are also institutes for elementary schools and college teachers.

Institutes have proved to be exceptionally effective means for educating science teachers. These group-training activities, organized and conducted by universities and colleges, are offered in the summer and during the school year. A small number of "academic year" institutes provide training for teachers who take leave of absence to study on a full-time basis. Since these training activities were initiated, about 300,000 teacher-training opportunities have been provided through Foundation support. The number of individual teachers who have received training is, of course, considerably smaller because many teachers have attended more than one institute.

Improvement of science curricula and of materials used in science instruction represented another challenge to the Foundation. Problems in this area were obvious—solutions were not. The Foundation's approach was to arrange for outstanding scientists and teachers to work together on the updating and improvement of science course content. Large-scale projects concerned with physics, mathematics, chemistry, and biology courses for secondary school students were the first to receive support. More recently, elementary schools and undergraduate courses have received attention.

Substantial progress has thus been made in modernizing science education for the youth of the Nation. These groups of scientists and edu-

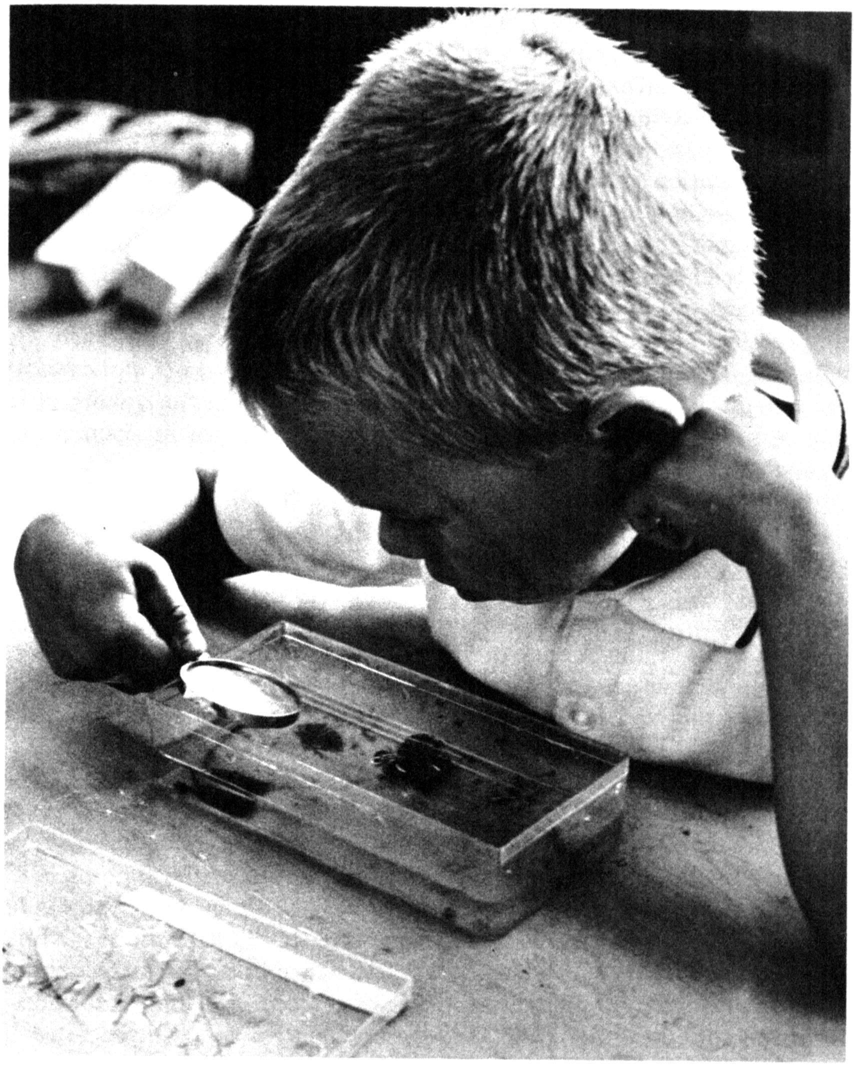

Figure 1.—*Examining, wondering, analyzing, and eventually understanding . . . A child uses materials of the Elementary Science Study, an NSF-supported project to improve science course content.*

cators have incorporated the latest scientific ideas into textbooks used in classrooms and in laboratory experiments as well as in equipment used to demonstrate the principles of science. Presently the Foundation is involved in attempts to understand and improve the learning process itself.

At the pre-college level, the Foundation's role in educational activities is primarily that of an innovator. Its programs and projects are concerned with identifying new needs of teachers, students, and school systems, and experimenting with various approaches to meeting those needs. Teacher-training institutes and course content improvement projects are typical examples of such efforts.

In administering its science education programs, NSF has always followed certain basic principles. It in no way interferes with local control of education. Nor does it consider that NSF-supported programs represent a single solution to the problem at hand. The advice of the scientific and educational community regarding the priority needs and nature of science instruction is of prime importance to NSF.

In recent years the question of wide geographical distribution of support has been emphasized. The Foundation agrees that such distribution is indeed desirable, feeling also that this should not come before the pursuit of excellence in science education. Upon the quality of its scientists and engineers hinges the Nation's leadership in science and technology.

GRADUATE EDUCATION IN SCIENCE

Directed toward ensuring an adequate supply of competent engineers and scientists, NSF fellowship support began early and has continued successfully over the years. Fellowships for high-ability individuals at the graduate and advanced levels of study have augmented the scientific strength of the Nation. In the past 2 years, this effort has been further extended by the establishment of graduate traineeships, to which able students are appointed locally by U.S. universities.

Rapid growth in scientific knowledge, together with sharp increases in the numbers of those seeking advanced degrees, has created new problems for graduate institutions—particularly at the departmental level. Through Graduate Education Development Projects, the Foundation offers modest support, chiefly on a one-time basis, to assist the efforts of an institution to attain or maintain excellence in its graduate training programs in science. At the frontiers of science, the Foundation continues to support Advanced Science Seminars—a program initiated in fiscal year 1959. These seminars provide, on a regional or national basis, advanced and often unique educational opportunities as a supplement to those offered by individual graduate schools.

Fellowships and Traineeships

The predoctoral and postdoctoral fellowship programs are based on the well-founded premise that students at this educational level know quite accurately what careers they wish to undertake. The programs permit the student to pursue the field of science that interests him most. These fellowships are awarded—in national competition—on the basis of merit and ability without assignment of quotas by field or discipline. Only in cases of substantially equal merit do considerations such as discipline or geography enter the picture.

Additional fellowship programs have been added periodically to meet new needs. In 1956, the Foundation established the Senior Postdoctoral Program; in 1957, the Science Faculty; in 1959, the Cooperative Graduate, Graduate Teaching Assistants, and Secondary School Teachers Programs; and in 1963, a program for Senior Foreign Scientists. In the face of expanding graduate enrollments, the Graduate Traineeship Program was introduced in fiscal year 1964 to provide greatly increased support for graduate students. It involves a minimum of administrative effort from both the Foundation and the participating institutions.

The Foundation has also been prompt to modify or terminate fellowship programs when their objectives were being met effectively by other means. It became quite apparent by fiscal year 1966 that the Cooperative Graduate and Graduate Traineeship Programs were providing the same desirable degree of geographic distribution of educational benefits and funds and were covering the same fields. As a consequence, the Cooperative Graduate Fellowship Program will be terminated in 1966 when present fellows complete their tenures. The Foundation is also in the process of closing out its program of Summer Fellowships for Secondary School Teachers. The educational needs for which that program was established are now being met through sequential summer institutes which enable secondary-school teacher participants to attain advanced degrees in most of the scientific disciplines.

From 1952 to the end of fiscal year 1965, nearly $166 million will have been used for the support of graduate students and advanced scholars through the Foundation's fellowship and traineeship programs. This represents a total of 38,463 fellowship awards offered to the most able individuals identified from among 136,173 applicants, and 4,004 traineeships for awards by 163 institutions receiving grants. The high standards of selection in the national competitions for Foundation fellowships are a measure of scholarly excellence recognized throughout the scientific community.

The Foundation's support for graduate students has steadily increased, reaching an all-time high this year. Its fiscal year 1965 program offered 1,934 Graduate Fellowships; 1,224 Cooperative Graduate Fellowships; and 2,784 Graduate Traineeships. The total, 5,942, represents about 3.5 percent of all graduate students enrolled in fields supported under the Foundation's authority. Through grants for basic research in the universities, the Foundation supports additional thousands of graduate students in research on scientific investigations and projects. These awards and assistantships affect not only individuals but institutions as well. Where Foundation-supported graduate students attend school, how many attend any particular school, and what their training consists of at these schools are vitally important in shaping future developments in science education in our Nation.

The number of U.S. science students applying for the Foundation's fellowships (including summer awards) increased by nearly 1,450 in fiscal year 1965, to a total of 16,643. An 18 percent gain in the Graduate Program accounted for most of the increase in student applications. In both the Graduate and Cooperative Graduate Fellowship Programs, it was possible to award fellowships to only 1 out of every 10 new applicants. As a consequence, the Foundation publicized among universities seeking to attract capable graduate students to their campuses the names of those applicants who were considered qualified for NSF Graduate Fellowships but for whom the Foundation did not have sufficient funds to offer awards. This group consisted of 1,941 high-ability students, most of whom were college seniors.

After the Graduate Fellowship Program had been in operation for several years, the Foundation noted that its fellows, being free to choose the fellowship institution they wished to attend, tended to gravitate toward the large, better-known universities. Many excellent graduate schools with a shorter history had few, if any, Foundation fellows in attendance.

The Cooperative Graduate Fellowship Program, initiated in 1959, alleviated this situation by providing for a broader distribution of its fellows among U.S. graduate schools. In this program the graduate student applies directly to the institution of his choice and is initially evaluated and recommended to the Foundation by that institution. The candidate's qualifications are further evaluated by a national panel of scientists. Their recommendations are then considered by the Foundation in selecting the awardees. As a result of this program, the Foundation succeeded in including in its fellowship efforts a group of students and a number of educational institutions which had not previously participated.

In 1964 the mounting need to expand graduate education in engineering, mathematics, and the physical sciences led to the introduction of the Graduate Traineeship Program. The principal objective of this program is to bring about an increase in the number of qualified individuals who undertake and complete advanced study leading to master's and doctoral degrees in the fields covered. Emphasis is placed on making grants to institutions whose existing facilities and staff can accommodate additional first-year graduate students in programs of high quality, or whose students can, through traineeships, make faster progress toward the Ph. D. degree. A rather large number of institutions participate in this program. For example, in fiscal year 1965, 162 schools received 1,859 new traineeships, while the Cooperative Graduate Program reached only 123 schools.

In its first year the Graduate Traineeship Program provided support only to graduate students in engineering. In the past year, field coverage was extended to the physical sciences and mathematics. The 1,859 new traineeships awarded this year represent 3.3 percent of the total full-time enrollment (fall 1964) in the units submitting proposals. All 50 States and the District of Columbia were represented in both applicant and grantee populations.

Thus, through the Graduate Traineeship Program the Foundation has been able to broaden its geographical distribution of funds and to help more institutions develop their graduate education. This program also enables NSF to respond to immediate and short-run demands for additional trained manpower in particular scientific fields.

Teaching experience as a part of graduate training has also been a matter of concern to the Foundation, particularly because studies show that a high proportion of fellows accept academic positions upon completing their degree work. Beginning as early as 1955 NSF instituted progressive policies in its predoctoral programs to encourage a limited amount of teaching by fellows. Terminal survey forms submitted by Graduate fellows clearly indicate these measures have met with success. Only about 13 to 16 percent of the fellows had teaching experience in the years from 1956 to 1960; permission for fellows to accept some remuneration from the institution for teaching after 1960 brought substantial increases in this proportion in the next few years. In academic year 1962–63, 33.2 percent of the 1,473 fellows submitting reports had taught during tenure. Survey forms from Cooperative Graduate fellows in the first 4 years of that program, in which acceptance of some remuneration was always permissible, also showed that about 36 percent engaged in some teaching during tenure. Another survey of teaching experience, addressed to the fellows and trainees, is planned for the 1965–66 academic year. It is expected that the number of those engaged in some teaching will have increased again, as a consequence of further encouragement by the Foundation.

Since fiscal year 1959 the Foundation has helped graduate teaching assistants in science, mathematics, or engineering to concentrate on research work in a full-time basis during the summer. As well as enabling teaching assistants to accelerate their progress toward the advanced degree, such opportunities very likely help improve the attractiveness of teaching assistantships. In fiscal year 1965 the Foundation offered 896 awards in this program.

Other fiscal year 1965 fellowship awards for advanced level study were: 325 Science Faculty Fellowships, 98 Senior Postdoctoral Fellowships, 49 Senior Foreign Scientists Fellowships, 229 Postdoctoral Fellowships, and, in the last year of the program, 287 Summer Fellowships for Secondary School Teachers.

Of particular significance is the program of Science Faculty Fellowships, which enables undergraduate teachers at smaller universities and colleges to make progress toward their own advanced study or to obtain much-needed intellectual refreshment and updating on scientific subject matter from time to time. These fellowships make it possible for more mature scholars to intermingle study with teaching and research, and they assist materially to improve the quality of science teaching at smaller institutions, especially those less heavily involved in research. Both the number of applications received and the number of awards offered in this program have held relatively steady in the past few years.

Senior Postdoctoral Fellowships are awarded to scientists of demonstrated ability and special aptitude for productive research in the sciences. These highly prized awards are for study and research in depth, and the program has flexible features which permit a measure of adjustment to the individual needs of the fellow. In recent years the number of such awards has remained nearly constant.

Postdoctoral Fellowships give young U.S. scientists who have recently received a doctoral degree additional advanced training preparatory to undertaking specialized scientific work. In fiscal year 1965, for budgetary reasons, fewer fellowships were offered than in the previous year. However, additional awards were offered in the program of NATO Postdoctoral Fellowships in Science, which the Foundation administers for U.S. citizens at the request of the U.S. Department of State. Therefore, the total fellowship support available for U.S. citizens who have recently received doctoral degrees remained relatively constant.

Senior Foreign Scientists Fellowships are offered to distinguished scientists from other countries. These fellows are nominated for the award by U.S. host universities. During their residence in this country, they conduct seminars, participate in on-going research, lecture, and in other appropriate ways share their specialized knowledge with faculty members and students.

The Foundation has always considered it to be of utmost importance to coordinate its fellowship and traineeship activities with those of other Federal agencies. When NSF inaugurated its first fellowship program in 1952, it convened an informal meeting with other Federal fellowship administrators to discuss provisions of the various fellowships then in existence. Additional meetings, usually chaired by the head of the Foundation's Fellowships Section, have been held, at first once a year but more recently twice a year. By means of these conferences, a high degree of uniformity has been achieved in such areas as predoctoral stipends and cost-of-education allowances in scientific fellowships supported by the Government.

The importance of having close, cooperative relations with the graduate schools in the Nation is obvious. In recent years the Foundation has held several regional meetings with representatives from the universities granting doctoral degrees in the science fields supported in the fellowship programs. The discussions at these meetings enable the Foundation to keep abreast of, and be responsive to, new needs that develop in graduate education in science.

Advanced Science Education

Enrollments in graduate schools have been increasing at an annual rate of 10 percent in recent years. Not only do facilities need to be expanded and modernized, but training programs also. Many institutions are establishing new doctoral programs; others are expanding current offerings. The pressures on graduate schools have created new and varied problems whose solutions require outside assistance. Through Graduate Education Development Projects the Foundation is assisting in the solution of such problems.

NSF's approach to this need has been *experimental*. It intends to continue to support a variety of forward-looking plans designed to improve advanced science education. However, the educational community increasingly requests immediate *developmental* support (especially for the general upgrading of departments, and the Foundation will seek to satisfy this demand within the limits of its financial resources.

Graduate Education Development Projects, a forerunner of the Foundation's Science Development Program (see page 132), were begun in 1962. The Science Development Program is broader in nature in that the emphasis is on upgrading the overall quality of the institution's science activities rather than being limited to the educational aspects. About 40 of the Graduate Education Development Projects have provided support for new ventures in science education. The following brief description of some of these projects illustrates the variety of activities being supported.

A grant was made to the University of Arizona for the development of a newly established department designed to provide comprehensive training in the emergent science of hydrology. Graduate training is featured and is supervised by an interdisciplinary committee of representatives from geology, appropriate fields of agriculture, civil engineering, and atmospheric physics.

The Georgia Institute of Technology has received support for the development of graduate degree programs in information science. The objective of these programs is to produce two categories of specialists greatly needed to cope with the widely publicized scientific information explosion. The first kind will serve in libraries, industrial and research laboratories, and information centers as specialists in science information and literature analysts; the second will be concerned with the theory and problems of the major aspects of the storage, processing, and use of information.

A plan for the improvement of research and teaching in geology is being supported at Northwestern University. The strength of this department has resided in the quantitative aspects of geology. The grant will enable the department to broaden this interest in the development and application of statistical procedures, particularly in geochemistry and geophysics.

A grant to Duke University provides for a development program in its college of engineering. The broad objective of this project is to improve education in all phases of engineering at the institution. This involves reorganization of the curriculum with the eventual dissolution of traditional departmentation, the upgrading of faculty, reduction of teaching loads of key members of the staff, and the creation of a more stimulating intellectual atmosphere.

The University of Rochester has received a grant for the establishment of a faculty curriculum-study seminar in its department of anthropology. Support is given for comprehensive, intensive curriculum study and planning in social anthropology. The materials developed under this project and the conclusions reached are to be disseminated through professional journals.

A grant to the University of California at Davis provides for a laboratory in advanced biocomputing programming techniques for second-year graduate students majoring in zoology, physiology, genetics, and biometry. The emphasis is on the creative use of the computer as a research tool in advanced biology.

Programed training in social research for graduate students is provided through a grant to Johns Hopkins University. The plan is for the staff to invent examples of appropriate social research, have the relevant data programed, prepare an accompanying syllabus, and then test and refine the examples by using them with students. The end result will be a set of materials providing a means for the student to simulate actual research undertakings but with structured examples which have unambiguous outcomes, which are capable of completion within specified time periods and yet have the dynamic and challenging properties of actual research.

The kind of support provided in Graduate Education Development Projects varies and depends on the nature of the activities supported. It includes primarily faculty salaries, graduate student stipends, library materials, minor pieces of equipment, computer and ship time, travel, and the expenses of disseminating the results.

Through Advanced Science Seminars, held mostly in the summer, the Foundation offers to qualified participants special educational opportunities of a type normally unavailable to students and faculty in university graduate schools. Full coverage of all disciplines is provided through the Seminars which deal with substantive science. For example, at Bowdoin College some 40 graduate students and 12 postdoctoral students were given an opportunity to attend an 8-week special course in advanced homological algebra with a distinguished algebraist as the principal lecturer and a number of established mathematicians in this field as assistants. In addition to the daily lectures, a wide variety of workshops, discussion sessions, colloquia, and seminars was regularly scheduled so that each participant, regardless of his level of preparation, could find a group of peers.

Exemplifying Federal agency cooperation was a special session at North Carolina State University on the actions of toxicants on plant and animal metabolism, jointly supported by the U.S. Public Health Service and the Foundation. In this case, university graduate faculty took part in a program presenting international authorities concerned with metabolic effects of pesticides, fungicides, and growth-regulating chemicals. When participants at various professional levels are included in a single seminar—as illustrated at the University of Denver where graduate faculty, postdoctoral and graduate students, and industrial scientists met together for an 8-week course dealing with metallurgical phenomena—many benefits accrue. All participants in this seminar were able to gain from the lectures of senior scientists from the academic and industrial communities, and the younger men were benefited by discussions with the more experienced faculty members participating. Using a similar format, but a quite different orientation, was a summer-long program at Woods Hole Oceanographic Institution. It dealt with geophysical dynamics, in which interdisciplinary instruction and research training in physics, chemistry, geology, and astronomy were provided to a group of eight graduate and postdoctoral students. Each participant worked directly under the leadership of a research scientist.

There has been a steady increase in the support of field training seminars, mainly because universities have been unable to provide in-the-field training for students in educational areas which require such activity. For example, three universities (Stanford, Pittsburgh, and Nevada) cooperated in setting up projects which enabled 36 graduate students in anthropology, selected from the Nation as a whole, to take part in field training programs of 10 weeks' duration. Two projects were centered in rural Mexico, the third in the Great Basin Region of the United States. In each of these the student anthropologists lived in native villages while learning the skills and procedures involved in anthropological field work. A training program in glaciology of the Juneau Icefield in Alaska has been supported for several years under a grant to Michigan State University. This program provides essential instruction in field techniques to graduate students who expect to undertake thesis research in the near future. In addition to training in research techniques in glaciology, participants gain valuable experience in living and working under difficult and isolated icefield conditions.

Over the years there has been a steady increase in the number of requests for support of Advanced Science Seminars, which were initiated in 1959, but the number of grants awarded has not changed substantially in the past 4 years. In fiscal year 1965 the Foundation supported 37 of the 67 requests for support.

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The programs discussed under Graduate Education in Science are considered to be closely related to the Foundation's responsibility for promoting basic research. They represent support for the Nation's main source of scientific strength—the highly able graduate students and mature scientists. Continued and increased attention must be given to the training needs of such individuals.

SCIENCE EDUCATION FOR TEACHERS

Good instruction depends to a large extent on well trained teachers. Early in the Foundation's history it became quite clear that many science teachers were in need of additional science training. A significant number of them, whose training dated from another era and emphasized technique rather than subject matter, were not teaching contemporary science. To provide the supplementary training that they needed so badly the Foundation began its summer institutes in 1953. Since then the scope of the early NSF science education programs has been broadened to include both full-time and part-time study during the summer and/or the academic year.

Teacher-training institutes are one of the Foundation's most notable innovations. They are group training activities in science, mathematics, or engineering specially designed for the needs of groups of teachers with similar backgrounds. Organized and conducted by universities and colleges, institutes are very effective in updating and upgrading the subject-matter knowledge of teachers. Instruction is provided to teachers ranging from the elementary school level to the undergraduate level, with emphasis so far on secondary school teachers.

The colleges and universities that conduct institutes and other teacher-training activities assume full responsibility for the planning and administration of such programs. Proposals for institutes are submitted to the National Science Foundation by institutions and are evaluated by panels of nongovernmental consultants—scientists and educators—who advise the Foundation. The plans judged to be most meritorious and most likely to offer the greatest educational benefits to the teacher-participants receive financial support—allowances for the participating teachers and operational costs for the colleges and universities that conduct the training.

The concept of specially designed training programs for teachers, although initiated in the sciences, has been adapted for other disciplines. The Office of Education, for example, supports the retraining of teachers of foreign languages and English and of vocational guidance counselors.

Elementary and Secondary School Teachers

Over the years the Foundation has deliberately concentrated on the training of high school teachers. It is in the high school that science first appears in the form of specific courses taught by specialized teachers.

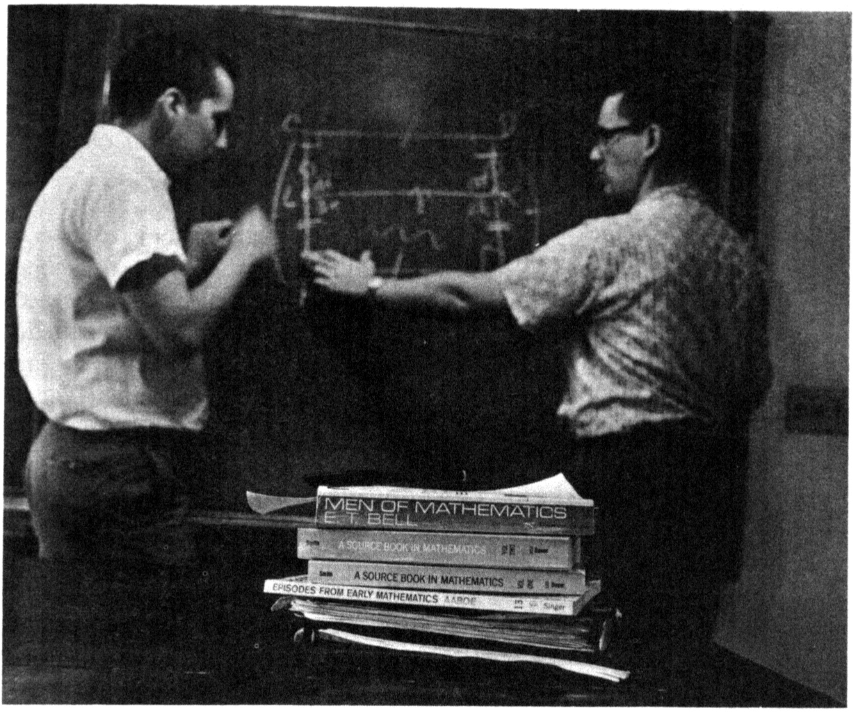

Figure 2.—*Homework assignments done, high school mathematics teachers ponder blackboard problem at summer institute held at Adelphi College.*

Hence, not only is the high school a crucial point in science education, but it is also the stage of the educational process in which the greatest and most effective impact can be achieved rapidly by teacher improvement.

Summer institutes are usually conducted for a 6- to 8-week period during the summer. (This schedule gives most teachers time for a brief vacation before returning to their teaching duties in the autumn.) These institutes provide teachers the opportunity to review basic subject matter and to become better acquainted with recent discoveries in the subjects they teach.

The first summer institute specifically designed for secondary school teachers was conducted in 1954. Since then more than 2,500 summer institutes have been supported. Approximately 146,000 training opportunities for secondary-school teachers have been provided through these institutes, during the period 1954 through 1965.

Academic Year Institutes and In-Service Institutes, similar in purpose to Summer Institutes, have also proved valuable. These were initiated in fiscal year 1956. In the Academic Year Institutes, secondary school teachers can study intensively an appropriate sequence of courses in the subject matter of their disciplines on a full-time basis for 9 to 12 months.

The In-Service Institutes, in contrast, offer part-time instruction in science and mathematics so that teachers may attend while still teaching full time in their schools. Classes are held on Saturdays or during after-school hours.

In addition to the teacher institutes the Foundation has encouraged college and university scientists to involve secondary school teachers in their research programs with a view toward making them better teachers. In some instances the especially qualified teacher may take a research project back to his high school and work on it there during the academic year, seeking advice and guidance from his research mentor from time to time. The program of Research Participation for High School Teachers was first supported in 1959. Conferences for Secondary School Teachers, initiated in 1964, are group activities of short duration held during the summer or during other vacation periods. These activities are more limited and specialized in scope than institutes.

Local project directors choose the participants in Institutes and Research Participation Programs in competition with individuals from the entire Nation. These activities are directed toward the education of the individual teacher, without specific attention to the institutional impact of such efforts. As experience with teachers and school systems has accrued, the need for a concerted effect on local school systems became evident. In response to this need the Foundation, since 1961, has attempted to assist individual school systems with substantial revisions in their overall instruction programs in the sciences through its Cooperative College-School Science Program. In these projects the local college or university works with the school teachers, and in some cases their students, to prepare them to incorporate a new curriculum or to effect their own local reform. Many are highly experimental and all are quite individualized.

In recent years some institutes, primarily in-service institutes, have been designed to help local school systems improve the teachers' knowledge of science. Some programs are aimed at helping teachers to adopt new curricular materials and others at general upgrading of science instruction. Increasingly, very well-prepared secondary school teachers are serving as instructors in in-service institutes for elementary school teachers.

To date only summer institutes and in-service institutes are available to elementary school teachers. Teacher training at this level presents some special problems. In fact, it is difficult to determine appropriate activities for strengthening science and mathematics in the elementary schools. A major consideration is the fact that very few of the approximately 1,100,000 elementary school teachers in the United States (kindergarten through grade 6) are trained in science and qualified to teach it.

A second consideration is the lack of clarity about just what in science and mathematics can and should be taught at this level.

The situation with regard to the curriculum in mathematics, science, and social sciences is now very different from what it was 20, or 10, or even 5 years ago. While it is true that some schools and teachers have always experimented with new content and methods, there has rarely been the present kind of ferment about the material or the curriculum. NSF has supported some 30 projects concerned with the development of new instructional materials for the elementary grades, as well as a number of projects designed to improve subject-matter backgrounds of elementary school supervisors and leading teachers, to devise better courses for prospective teachers, and to prepare materials for in-service programs conducted by school systems. Many other projects are being funded by the U.S. Office of Education, private foundations, and State and local governments.

Until a few years ago, except for a relatively small number of experimentally minded schools, most elementary schools followed similar programs in mathematics, science, and the social sciences. Mathematics was mainly arithmetic with heavy emphasis on drill and homely applications, and occasional slight excursions into geometry and algebra. A relatively small amount of attention was given to science, and this usually through reading and recitation. The social studies program purported to include topics from the social sciences, but history was the subject most taught.

Now that thoroughly competent scholars have become engaged in the difficult and vital task of defining significant content for school curricula, the situation is changing drastically. For one thing, all significant curriculum projects find that the learning capabilities of children have been grossly underestimated. What the limits of learning capacity may be are simply not known. Various projects find, for example, that it is quite possible to lead second-graders to some intuitive notions on the relativistic aspects of motion; to encourage pupils in all grades to try to discover the rules involved in mathematical operations for themselves; to get pupils to understand the fundamentals of logic as early as the fifth and sixth grades. Of course a sixth-grader might be able to do even more if he had, from kindergarten on up, a carefully developed sequence in mathematics and the sciences.

As the report of the Cambridge Conference on School Mathematics, *Goals for School Mathematics,* (Houghton Mifflin Co., 1963, p. 26) puts it: ". . . the experience of a few bold experimenters amply proves that the present apparent limits on the insight and creativity of children are being set by the materials provided to them, and not by the native talent of the children."

Another common thread running through the major curriculum improvement projects is heavy reliance on a Socratic approach in mathematics and, in science, emphasis on observation and experimentation with actual phenomena as the only valid starting point. The pupil must really see how things may work, rather than merely accept an explanation given by a teacher or a book. Thus, a course in physical science that could be used in the seventh or eighth grade carefully avoids words like "ion," "electron," and "proton" because the physical experiments which are the heart of the course provide no basis for the understanding of such concepts.

This sort of experimentation also reveals that individual differences in rate of learning and total capability may become very much more evident. A Stanford University project, for instance, finds it very difficult for a whole team of people to develop enough interesting problems in arithmetic for very bright first graders involved in an experiment in computer-assisted instruction. Simply because a topic *can* be taught, at least under some circumstances, does not necessarily mean that it *should* be given a place at a given level.

Finally, the experimental studies in school curricula are producing a wealth of materials. It is hoped that commercial producers of educational materials will be able to draw extensively on these resources in developing their own products. However, a given school faces the problem of "mixing and matching" the output of various projects in order to make a logical, coherent curriculum. While some projects themselves are developing sequential materials, others are deliberately designing units that lend themselves to utilization in a great variety of ways. Furthermore, there is uniform agreement among scholars, educational institutions, and supporting agencies that there must be a number of efforts to devise different approaches and materials for any subject at any level. A vigorous pluralism is one of the hallmarks of American education.

These various factors create difficult problems with respect to the education of teachers. It is unlikely that the curriculum for elementary schools will ever settle down to a final form. In order to utilize new and changing materials, teachers will require a significantly deeper general education that encompasses the breadth of human knowledge but still can be obtained within 4 or 5 years of college. Most importantly, such education must lay the groundwork for the teachers' learning more and being pleased, not embarrassed, by the questions eager students may be able to ask. Moreover, both college experience and subsequent continuing education of teachers must show mathematics and science as the pursuit of truth through processes of inquiry, not as embalmed "bodies of knowledge." Devising and conducting such courses in colleges are as much of a major challenge to imaginative scholars as creating materials for children in the elementary schools. Further, these courses are likely to contravene some of the traditional practices of many college teachers and to require of them a greater sophistication of knowledge and a greater devotion to the inquiry approach.

In summary, discovering what kinds of curricula and conditions of learning will best serve our children is an exceedingly difficult task. It requires bold experimentation led by some of the best minds of the Nation. Meanwhile, successful implementation of the new programs in actual classrooms requires a competence in the education of prospective teachers, as well as of those now teaching, which has not yet been attained. This, in turn, requires attention to the education of teachers of teachers.

By concentrating on support for supplementary training for secondary school teachers and major course-content improvement efforts in the high schools, the scientific community and the Foundation have gained valuable experience for grappling with the problems at the elementary school level. Indeed, the secondary school efforts have had a considerable impact on both the elementary and college levels. Although support for activities which benefit the lower grades is much smaller than the amounts received by other levels, it has been increasing each year and the results are encouraging. The Foundation's responsibility in this area must be reassessed, especially in the light of the U.S. Office of Education's expanded role.

College Teachers

Institutes and conferences for college teachers are designed to offer supplementary training that is not regularly available in graduate schools. Most have been conducted at an advanced level, but a shift is now under way toward greater emphasis on instruction in basic subject matter. This is in response to serious and growing imbalances in the supply of adequately prepared science teachers needed to staff faculties of all types of institutions concerned with undergraduate work in science. The unprecedented increase in college enrollments is an obvious factor influencing the situation.

The Foundation has increasingly tried to help larger institutions recruit able teaching assistants and to help small colleges retain their better instructors by enabling them to carry on research at their home campuses. Further training needs are reflected in the fact that community and junior colleges are drawing staff from secondary schools. For example, a report of the Research Division of the National Education Association shows that of all new junior college teachers in 1963–64 and 1964–65, more than 30 percent were high school teachers one year earlier. The fact is that increasingly there is need for periodic retraining for college teachers.

The Foundation's concern for the training of college faculty began early. In 1953 2 summer institutes with 42 NSF-supported college teachers marked the beginning of NSF educational activities for these teachers. The success of this pioneer program sparked the whole "institutes" concept, which grew steadily in succeeding years. In 1958

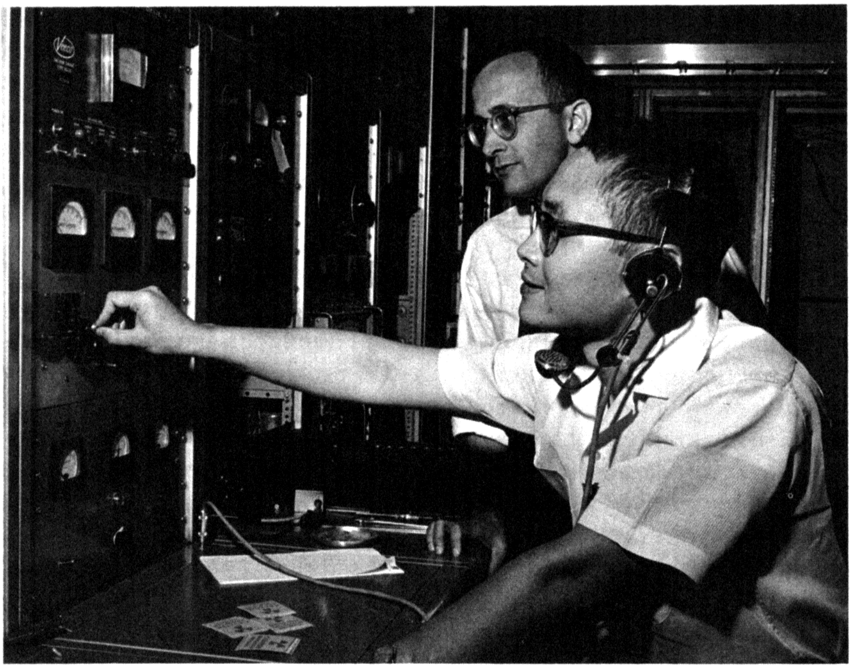

Figure 3.—*Institute for college teachers . . . Shown here with his advisor, a faculty member of Augustana College participating in an NSF-sponsored summer institute for physics teachers at Ohio State University.*

there were 300 college teachers enrolled in eight institutes. The year 1959 saw a marked increase, with 1,865 college teachers enrolled in 51 institutes. In that year also, new programs were initiated or old ones so extended as to include college teachers for the first time in activities previously operated only for the benefit of secondary school teachers. A total of 111 projects in 5 different programs provided participation for 3,300 teaching scientists in 1959; the proportion of college science faculty members served by these programs increased from 0.3 percent to 3.4 percent. Growth since 1959 has been gradual, with 3.9 percent of the Nation's college science teachers offered retraining opportunities in NSF-supported activities in 1965.

Almost all NSF-supported educational activities for college teachers are aimed at increasing their command of subject-matter. The need in this area, a problem even in early post-World War II years, has become increasingly serious. There are a number of reasons why college teachers must give more attention to keeping up on scientific subject matter:

(a) The constant increase in new scientific knowledge progressively decreases the adequacy of a teacher's original academic preparation.

(b) Improvements in high school curricular and teaching standards in science compel colleges to upgrade their programs at all levels.

(c) Unprecedented increases in college enrollments force many colleges to employ teachers with minimal graduate training. This situation grows more acute each year.

(d) The rapid growth in numbers of community and junior colleges forces them to recruit instructors from the ranks of high school teachers who lack experience in teaching the level of subject matter required in their new positions. The NEA study cited above reveals that 13.4 percent of the new college teachers appointed in 1964–65 came directly from high school assignments. This source provided 21.8 percent of those employed by small nonpublic colleges and 21.3 percent of those employed by State colleges. These are the teachers that most urgently require additional training in basic subject matter, if they are to function effectively in their new posts.

(e) The transformation of junior colleges and of numerous teachers' colleges into 4-year multipurpose institutions has also contributed to the recruitment of teachers whose backgrounds are inadequate for their new college teaching assignments.

To meet remedial and refresher training needs of science college teachers, the Foundation has experimented with a variety of programs. The institute-type programs described earlier are available to teachers at this level. Summer institutes again have assisted more teachers than any other individual program; 15,838 training opportunities have been provided to college teachers during the program's 13-year existence. In its 7 years of operation the Academic Year Institutes Program has provided training for 781 college teachers. In-service institutes have provided training opportunities to 266 college science teachers during its 3-year existence.

Conference programs were first supported in 1959. These are short-term training programs of 1 to 4 weeks' duration and are focused on specialized topics. Most of them follow traditional disciplinary lines in mathematics, physical science, biology, social science, or engineering. Some, however, are multidisciplinary, involving several of the established disciplines, or interdisciplinary dealing with subject matter that transcends the usual academic departmental boundaries. Many conferences deal with recent advances in a particular scientific area. Typical examples: a 6½-day meeting dealing with comparative endocrinology held at the University of Washington; a 16-day session on colloid, surface, and macromolecular chemistry conducted at Lehigh University; a 20-day conference on electronic instrumentation at Princeton University; a 12-day seminar on the undergraduate teaching of heat, mass, and momentum transfer at the Massachusetts Institute of Technology. Among the longer conferences supported recently were a 26-day colloquium on optimization theory conducted at Stanford University for teachers of chemical engineering and a 25-day conference on the applications of linear algebra at the University of California at Santa Barbara.

The Supplementary Training for College Teachers Program also initiated in fiscal year 1959, serves as a mechanism for handling proposals that involve experimental projects or that do not come within the scope of established educational programs. From this experimental area have risen several ideas that have been developed into established teacher improvement programs; others were discontinued after 1 to 3 years of trial. Some 4,100 college teachers have participated in various experimental projects since the beginning of this program.

Because research is a potent and stimulating teacher, the Foundation tries to provide college teachers with research opportunities. It is an exhilarating and instructive experience to be able to pose a significant and unanswered question and through research to seek an answer to that question. This is the rationale for the Foundation's Research Participation Program for college teachers.

This program affords college teachers the opportunity to become full-time research associates of experienced investigators at institutions that conduct major research programs during summer periods. Participants include science teachers from 4-year and junior colleges, and from developing universities. For some, this 8- to 12-weeks' training is a first experience in research, for others it is a return to research after their interest in it has long been inhibited by the pressures of heavy teaching schedules. Given this research opportunity, many teachers demonstrate considerable promise and develop a continuing interest in research.

On occasion as many as half the summer research participants are granted "Academic Year Extensions" which permit them to carry on research at their home institutions during the following 2 academic years under continued guidance from the research supervisor of the original grantee institution. Experience with the first 2 years of such extensions of support has demonstrated that some of these teachers show sufficient promise in research to justify a second extention, to bring them to a level at which they may compete with established investigators for regular research grants. Plans for a second Academic Year Extension have been approved for initiation in fiscal year 1966. During its 7 years of operation, this program has afforded research participation opportunities to 2,387 college science teachers. This kind of activity has proved especially helpful to faculty development in the smaller colleges.

The Visiting Scientists (College) Program began in 1954 out of concern for the need to upgrade instruction in science and mathematics in college departments, particularly in those which offered courses in scientific fields not regularly covered in NSF-supported summer conferences or institutes. Very few institutes have been conducted in, for example, anthropology, economics, oceanography, psychology, applied mathematics, or the newer specialties within the basic sciences. Furthermore, the Foundation recognized that a solitary college teacher-participant returning to a department after attending an institute or conference could, at best, have only a slight impact on instructional improvement. It was difficult for him to communicate what he had learned to his colleagues and to translate his training into action. A visiting scientist, on the other hand, in the course of a 2- or 3-day visit could bring an awareness of significant new developments to an entire department simultaneously.

Wide acceptance of the initial program of visiting mathematicians led to its renewal and gradual expansion into the total of 19 fields of science currently supported. Under this program national professional societies arrange visits of outstanding American scientists to liberal arts colleges, small or developing universities, teacher training institutions, and junior colleges. Visiting scientists help college science faculty members who are not in the forefront of science to keep abreast of developments in their respective fields of science, to obtain the perspective needed for the solution of their research and teaching problems, to spark desirable changes in curricula and laboratory arrangements, and to stimulate interest in scientific fields among undergraduates.

The Science Faculty Fellowship Program, designed to provide intellectual refreshment and updating for those who have been immersed in teaching, usually at small institutions, is particularly important for faculty of colleges and universities that do not produce large numbers of science doctorates but which turn out a significant number of undergraduate students who continue on to graduate school. Such institutions are a very important source of future scientists, often identifying and orienting potential Ph. D. candidates in science. Opportunities for advanced training of college faculty indeed help to strengthen the quality of science instruction provided by these institutions.

COURSE CONTENT AND MATERIALS

Today's science cannot be taught with yesterday's concepts and instructional materials. Consequently, the National Science Foundation has taken a leading role in bringing about science curriculum reform across the Nation. Its efforts began in 1954; to date the Foundation has granted support totaling $68.6 million for 362 different course improvement projects, which have varied greatly in scope and cost; some have involved two to a dozen grants over periods of 2 to 10 years. Such projects have dealt with all fields of mathematics, science, and engineering, and all educational levels. Initial emphasis was on improvement of courses for secondary schools, but substantial and increasing attention is being given to elementary and to collegiate instruction.

Course content improvement projects represent the combined efforts of many of the Nation's outstanding scientists and teachers in constructing courses that emphasize up-to-date subject matter presented with appropriate rigor and using improved teaching aids. Considerable progress has been made in physics, mathematics, chemistry, and biology; a significant number of secondary schools are now using course materials developed by the various NSF-supported study groups.

The many requests for support for course-content improvement projects—submitted by various colleges, universities, and professional societies in the United States—have led the Foundation to develop a set of guiding principles that applies to the support of such projects. The National Science Foundation seeks to support research and development

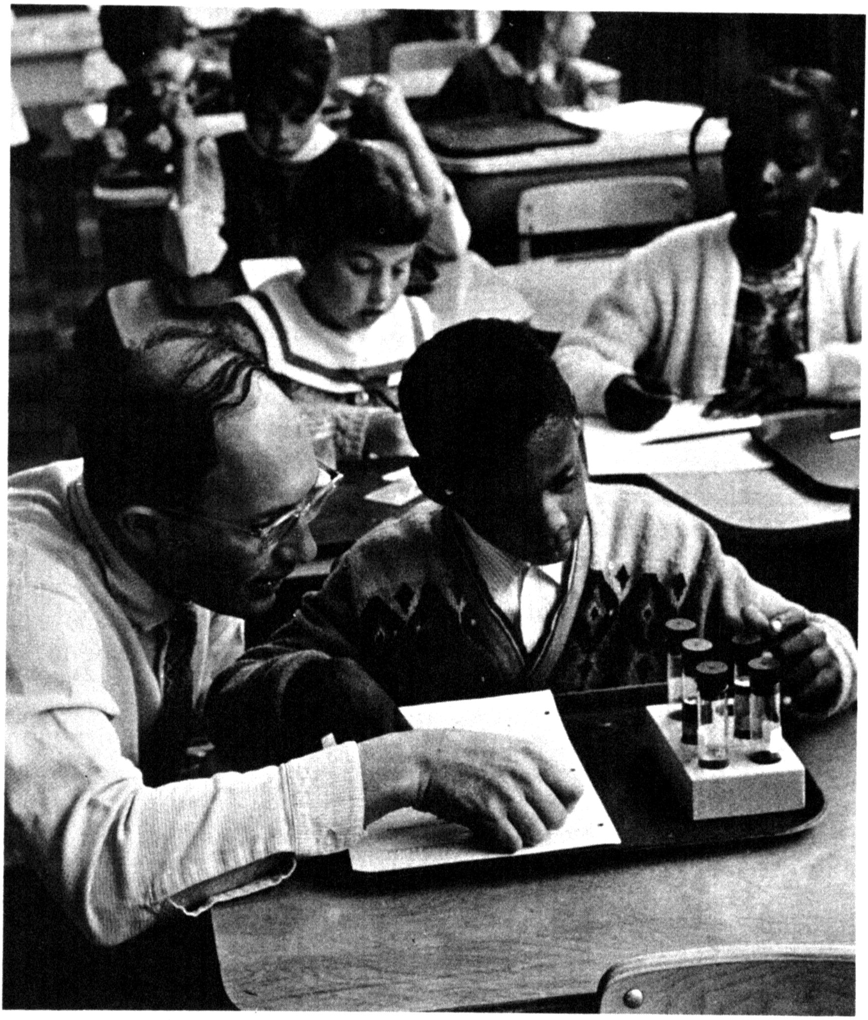

Figure 4.—***Renowned University of California physicist works directly with young children, in his NSF-supported project to devise improved science curricula for elementary schools.***

work on the substance of courses and tools of instruction. Foundation funds may not be used to promote the adoption of any specific curriculum, course, or other instructional material. Courses, textbooks, films, and the like are expected to make their way on their own merits. As appropriate the teacher, school, or school system must be left completely free to decide whether and how to use them. To help teachers and schools develop a basis for making a decision, however, efforts are made by the Foundation and its grantees to distribute information about the projects as widely as possible.

The Foundation's early investigation of the status of science instructional material revealed a serious gap between the content of textbooks in use and current scientific knowledge. This situation can be ascribed, in part, to a long-standing lack of interest in the preparation of textbooks, especially for precollege students, by scholars in the various fields. The inadequacies were made increasingly apparent by the explosive growth of knowledge and scientific development after World War II. In an effort to bridge the gap the Foundation decided to encourage the reappraisal of instructional materials by leading scientists and to enlist their active participation in the development of improved materials.

One type of project for course content improvement involves a commission of leaders in a particular field, who undertake a continuing analysis of what kinds of curricula best meet contemporary needs and what steps are required to bring such curricula into being. These commissions seek to stimulate scientists to create models of the desired materials.

Other projects develop new textbooks, laboratory programs, materials for preservice and inservice education of teachers, film and television presentations, and other aids to learning.

Curriculum improvement projects supported by the Foundation are organized and led by first-rate scientists, with the close cooperation of excellent teachers experienced in the appropriate academic levels. Also assisting are experts in film making and equipment designing. Materials are thoroughly tested in varied classroom situations and repeatedly revised before they are made generally available. Since it is fully recognized that there is no one best way to test any subject at a given level, support is normally given to several promising approaches to a specific subject or level. Course materials developed under NSF support usually are made available to the schools through commercial publishers.

In supporting new materials development the Foundation intends that they may serve as sources upon which individual scholars, teachers, and commercial producers of educational materials may draw in developing their own versions of new textbooks, films, and other materials. Further, through its projects the Foundation seeks to set new standards of quality and effectiveness in science curricula.

To date, grantees for course content improvement projects (which include colleges, universities, nonprofit research institutions, and professional and educational societies) represent a wide geographical distribution. They, or their headquarters, have been located in 39 States and the District of Columbia. Experimental versions of new materials for mathematics and science for elementary and secondary schools have been tested in all 50 States, the District of Columbia, and Puerto Rico. Schools in all States are using new courses for which materials are available in definitive form, and scientists and teachers from all parts of the United States have been involved in the projects.

A brief discussion of certain projects will serve to illustrate the kinds of NSF-supported efforts for improvement at the various educational levels.

Projects for Elementary and Secondary Schools

Mathematics and science in elementary and junior high schools are of special concern because they lay the foundations of interest and capability for all later study. The bolder and more innovative projects concerned with mathematics and science for elementary and junior high schools are necessarily highly experimental, long-time endeavors. Scientists must think through their subjects to extract a core of far-reaching ideas to which pupils can be led through appropriate laboratory and field work. This often requires a penetrating examination of the conceptual structure of a field. Furthermore, scientists must be personally involved in testing approaches in classrooms at various levels to find how well a particular presentation works and where it fits in the intellectual development of children whose backgrounds of experience and interest vary over an extremely wide range. In at least some projects, experimentation must proceed up through the grades, step by step; such projects may therefore have to continue for 10 or more years.

The School Mathematics Study Group (SMSG) is making the largest concerted effort ever undertaken anywhere in any subject to prepare improved model materials for school curricula. Since it was organized in 1958, SMSG has produced more than 125 books and pamphlets (many went through experimental editions before appearing in generally available form), as well as a course on film for elementary teachers, newsletters, and other materials. Among SMSG activities in progress a notable item is a long-range study of mathematical abilities, which will follow the progress of students taking conventional and newer types of mathematics curricula over 5-year periods (in some cases 8 years), with beginning points in the 4th, 7th, and 10th grades. SMSG is also experimenting with courses in mathematics linked with topics in the biological sciences, calculus, modifications of courses to meet the special needs of culturally deprived children, further translations into

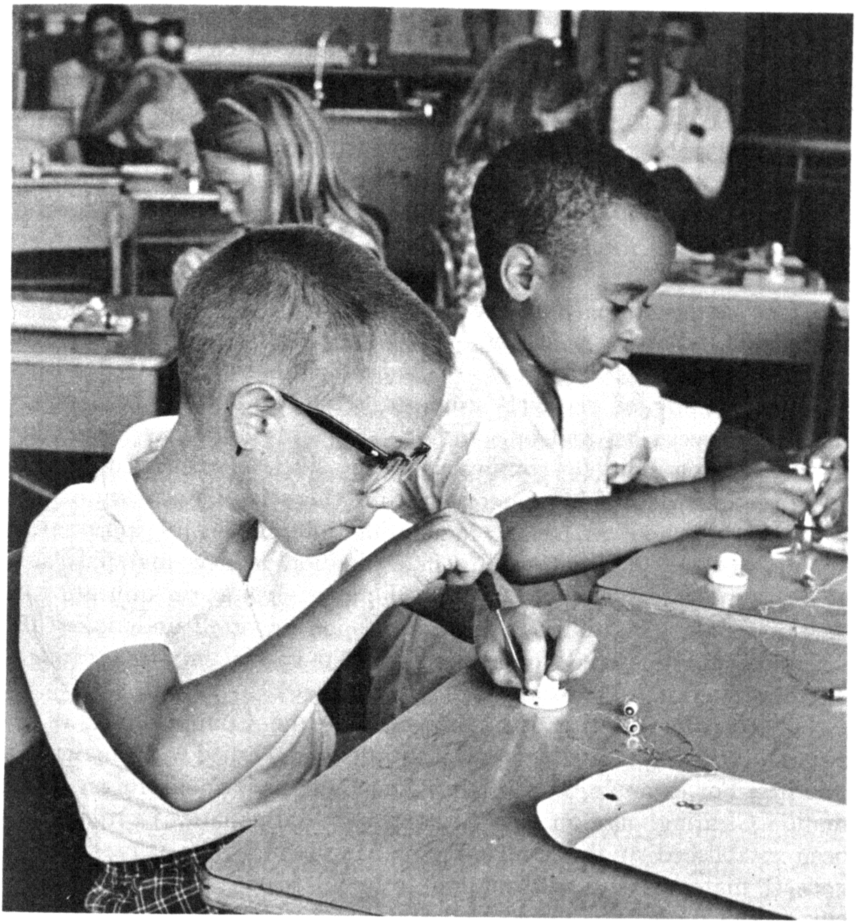

Figure 5.—*Working individually on similar projects . . . small children learning about science at an elementary level, while serving to test a new unit of the Elementary Science Study.*

Spanish, and fundamental experimentation on the teaching of mathematics in schools.

Over the past 10 years an extensive body of thought and experience on what can be done in school mathematics has been accumulated through a variety of experimental projects and the hard thinking of scores of the Nation's leading mathematicians. In 1963, a group called the Cambridge Conference on School Mathematics devoted a summer month to a forecast of what might be a feasible and desirable mathematics curriculum for a decade or two hence. In essence, the report predicts that eventually it will be possible to have a curriculum in elementary and secondary schools that incorporates the equivalent of 3 years of mathematics now provided by good liberal arts colleges (2 years of calculus and a semester each of linear algebra and probability beyond what high schools now do).

Other mathematics projects include a group at Stanford University developing hardware and programs for a study of computer-based instruction in mathematics in the elementary grades and the Syracuse University-Webster College Madison Mathematics Project, which is exploring a variety of presentations of arithmetic, axiomatic algebra, coordinate geometry, rudimentary study of functions, logic, limits, and certain portions of physics for grades 1–9, and new approaches to teacher education. The Minnesota Mathematics and Science Teaching Project (MINNEMAST) seeks to create an integrated mathematics and science program for the grades from kindergarten through 9.

In 1962, following a feasibility study, the American Association for the Advancement of Science established a Commission on Science Education consisting of research scientists, school administrators, science education specialists, and outstanding teachers. The Commission has assumed responsibility for continuous review of school science curriculum improvement, developing interest within the scientific community in working on school materials, facilitating interchange of information among working groups, assisting in evaluation of new materials, and advising schools and curriculum development groups on utilization of new materials. In addition, the Commission has itself undertaken the development of materials for grades K–6, with special emphasis throughout the sequence on the processes of scientific work.

The coordinating function performed by the Commission is of inestimable value to individuals and institutions concerned with curriculum reform. For example, as a result of the Commission's efforts an Information Clearinghouse on New Science and Mathematics Curricula has been established at the University of Maryland. The Clearinghouse collects materials and information from all science and mathematics curriculum projects in the United States and publishes periodic reports summarizing the year's developments. This report is made available, upon request, to all interested individuals, groups, and schools.

The greatest effort ever made to devise new and better materials for high school biology has been that of the Biological Sciences Curriculum Study (BSCS), administered first by the American Institute of Biological Sciences and later by the University of Colorado. Since 1958, more than 2,000 biologists, scientists in other disciplines, educators, and teachers have helped to develop an extensive battery of materials. BSCS has produced three complete 10th-grade courses, each with textbook, laboratory guide and teacher's guide as well as a teacher's handbook of background information, extended laboratory studies in depth, collections of research problems for bright students, pamphlets for supplementary reading, a book on equipment and techniques for the teaching laboratory, films, a course for advanced students, special materials for less able students, special studies on high school biology and teacher education, and examinations. During 1964–65 approximately 580,000 students, or 20 percent of all taking high school biology, used one of the texts.

The world-famous Virus Laboratory at the University of California has prepared another aid, a series of eight motion pictures on the nature of viruses and implications of virus studies for fundamental biological problems. The series has been shown repeatedly on all educational television stations, and used extensively in both high schools and colleges.

Two major projects, both involving chemists and teachers from across the country, have prepared new high school courses in chemistry. Both emphasize an experimental, laboratory-oriented approach, the interplay between experiments and imaginative ideas used to interpret data, and contemporary theory. The Chemical Education Material Study, sponsored by the University of California at Berkeley, has produced a textbook, laboratory guide, teacher's guide, achievement examinations, programed pamphlets, wall charts, and some 30 films. More than 350,000 students in the United States and some nine other countries used these courses during 1964–65.

The pioneering major curriculum project led by distinguished scientists was the Physical Science Study Committee, which produced a textbook, a laboratory guide, new and low-cost apparatus in kit form, 54 films which set the tone and standards for the course, achievement tests, a laboratory of 43 paperbound books on topics of science, and extensive teacher's guides. During 1964–65 approximately 50 percent of students taking high school physics were using the PSSC course. Many others at least did some of the experiments or saw some of the films. Over the past 7 years, more than 635,000 U.S. students have used the course, as have thousands of teachers and students in Central and South America, Canada, Japan, Israel, Norway, Denmark, Finland, Spain, Italy, India, New Zealand, and elsewhere. Similar widespread interest has been shown for materials in other fields.

During the past 3 or 4 years, scholars in the social sciences have also come to recognize that they too share responsibility for creating, in their disciplines, superior model materials for elementary and secondary schools. The most ambitious effort to date has been undertaken by a nationwide team of scholars whose purpose is to develop materials to effect a marked improvement in the quality of social science instruction from grades 1 through 12. The materials will consist of a series of related units and sequences that can be used both within the framework of existing curricula and as part of new curricula that school systems may develop. The materials will provide opportunities for students to relate basic concepts from the social sciences to conditions in the 20th century, and will draw upon such disciplines as anthropology, psychology, economics, sociology, geography, linguistics, archaeology, political science, and the history and philosophy of science for their content.

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A record phenomenon in high school science has been the introduction of an earth science course in many schools, typically in the ninth grade. To meet school requests for excellent materials in this subject, the American Geological Institute has organized a major earth science curriculum project. A textbook, laboratory guide, teacher's guide, new apparatus, and a variety of reference and supplementary materials are now in their first trial year. Definitive versions should become available by 1967.

For atmospheric science instruction in secondary schools and also for use in college programs, the American Meteorological Society is sponsoring two projects. One is the production of about 20 monographs concerned with physical processes and principles in the atmosphere; the other is a series of approximately 20 motion pictures, 20–30 minutes in length, and a number of short film-loops. Filmed presentations are particularly appropriate for meteorology because phenomena are often of very small scale (e.g., formation of raindrops) or very large scale (e.g., global patterns of atmospheric circulation); further, time-lapse and high-speed photography make visible sequences of events with very long or very short time spans.

Projects for Colleges and Universities

More projects, but usually of smaller scale, are supported at the college and university level than at the precollege level. This is due to the fact that college curricula include a far greater diversity of courses than do school programs.

One promising approach to collegiate problems has been the emergence of commissions of outstanding scholars which can provide continuing leadership to the scientific professions in reforming college programs. Specific course development projects are often stimulated by such groups.

Thus, since 1960 the Commission on the Undergraduate Program in Mathematics has conducted a searching examination of college curricula in mathematics for students who plan to: go on to graduate study in mathematics; enter the physical sciences or engineering; major in the biological, social, or management sciences; become teachers in elementary or secondary schools; or prepare for careers in computer science. Recognizing that many smaller institutions cannot offer more than one curriculum, the Commission is also publishing specifications for a general college program in mathematics.

Attention is being given to problems of preparing teachers to handle new mathematics programs. For elementary teachers, courses have been developed by the State College of Iowa and the National Council of Teachers of Mathematics. Educational Services Incorporated is preparing a four-course sequence on mathematics and teaching techniques for prospective elementary school personnel. Cornell University is completing a course in algebra and the University of Minnesota a course in geometry for future high school teachers.

A number of mathematicians are cooperating with the Committee on Education Media of the Mathematical Association of America on the production, use, and evaluation of new media—films, television, programed learning, etc.—in mathematics instruction. A series of 25 filmed lectures by distinguished lecturers is in production, along with a new course for prospective elementary school teachers which will make extensive use of film and programed presentations. For courses on calculus the Committee will prepare a number of films and short programed units on suitable topics.

In 1959–60 some 60 leading physicists participated in a series of three conferences designed to explore ways to improve college physics teaching. Recognizing the need for a continuing body to stimulate and guide curriculum development, to collect and disseminate information on experiments in improving physics teaching, to encourage new developments in course content, laboratory practice, laboratory apparatus, teaching aids, and to help institutions organize programs for improving the capabilities of faculties, the conferences urged the formation of a Commission on College Physics, which subsequently has helped to focus some of the talent and energy of several hundred physicists on undergraduate education.

Detailed curriculum recommendations have emeregd from conferences involving physics teachers from smaller colleges, a conference of physicists from universities with doctoral programs, and a joint conference involving the two groups. This study particularly recommended the development of a curriculum for the many students who are not likely to become research physicists—a curriculum emphasizing the synthesis of physical ideas from a somewhat less analytical and mathematical point of view than is the case in curricula for prospective research workers. Subsequent working groups established the feasibility of preparing suitable materials, and a major writing effort began at the University of Washington in 1965.

In the last few years several groups have given special attention to basic college physics courses, especially those for physical science and engineering students. A most notable team, drawn from the University of California and Cornell and Harvard Universities, is preparing a course based on the assumption that the students will have had high school physics of PSSC quality. It is intended to present physics in the way it is used by physicists working in the forefront of the field. The first of five volumes of text and the first two of three laboratory guides have recently been published; others will appear within the next year or so.

The Science Teaching Center at the Massachusetts Institute of Technology is also developing a physics course with text, new laboratory apparatus, and films. Washington University at St. Louis has prepared a course designed for all science-oriented students, with special attention to demonstration and laboratory apparatus. Further aid in improving lecture demonstrations will be supplied by a two-volume sourcebook, sponsored by the American Association of Physics Teachers, which will bring together detailed descriptions of the demonstrations now available in America and Europe. Other projects concerned with experiments and apparatus are under way at the University of Washington and Rensselaer Polytechnic Institute.

Organized in 1963, the Commission on Undergraduate Education in the Biological Sciences, under grants to Washington University and George Washington University, is providing guidance, stimulation, and coordination for efforts to improve college instruction in the life sciences. Two conferences have been held to review the experience of 15 institutions which have recently made major changes in their biology curricula. Through regional conferences the results of this review were made available to some 800 other institutions. Panels are examining such problems as biology for nonmajors, curricula for students intending to follow careers in biology, preparation of prospective teachers, interrelationships with cognate disciplines, need for new instructional materials, means for improving the competence of college teachers, and other problems.

Improvement in laboratory instruction is a crucial problem in biology. Assistance has been provided for the development of experiments in elementary human physiology and general physiology (American Physiological Society), a laboratory course in instrumentation (Massachusetts Institute of Technology), a sourcebook of laboratory studies in plant pathology (American Pathological Society), and a sourcebook for mycology (American Mycological Society).

Films are of special value in the teaching of biology, both to bring eminent scientists before many more students than they can reach directly, and particularly to show students events, processes, organisms, and habitats that they would otherwise never encounter. Illustrative of the first category is a series of five films on "The Promise of Life Sciences," in which leading investigators tell about the advancing frontier in their special fields. The second is exemplified by a series of 18 short films on microbiology intended primarily for advanced undergraduate classes and medical schools, produced by the University of California.

The "commission" organization in chemistry is the American Council on College Chemistry, supported by grants to the University of Pennsylvania. The Council is giving attention to general chemistry courses, curricula for majors in the field, teaching aids, programs for prospective teachers, and chemistry for nonmajors. The group is cooperating with its counterparts in other disciplines on a number of mutual problems.

Among new chemistry courses, Johns Hopkins University has devised a first course based essentially on elementary thermodynamics and a simple quantum mechanical picture of the structure of atoms. NSF support aided the development of the laboratory, which emphasizes a physical chemistry approach, together with films showing moving models of atomic and molecular structure and chemical reactions. The course has been adopted in some form by more than 100 institutions. More recently a modern course in organic chemistry has been developed at Johns Hopkins, and a problem-oriented laboratory organic course was devised at Ohio State University.

Support has been provided for a relatively large number of varied projects in the rapidly changing field of engineering. There have been influential conferences and reports on desirable directions for curriculum development in such areas as technical institutes, chemical engineering, ceramic engineering, civil engineering, sanitary engineering, and theoretical and applied mechanics, with reports making the thinking of leading departments in these fields available to all engineering schools. A major reexamination of the "Goals of Engineering Education" at all levels is being sponsored by the American Society for Engineering Education.

The Commission on Engineering Education has made a thorough study of potentialities of the case method in teaching design. As a result, case writing projects are now under way at Stanford and Cornell Universities. The Commission, urging that more engineering educators find ways to bring realistic experience with design into their own classroom, organized summer 1965 workshops on engineering design at six leading institutions.

Leadership for engineering films has been provided by the National Committee on Films in Fluid Mechanics. By 1968 the Committee plans to release 25 long films and 160 film-loops showing the behavior of fluid systems; 6 films and about 20 loops are now available. A comparable project is being undertaken by the National Committee for Electrical Engineering Films.

Illustrative of course development projects is the work of the Semiconductor Electronics Education Committee. Representatives of a score of universities and a number of industrial organizations are cooperating in the development of a teaching program which demonstrates introductory semiconductor physics, principles of semiconductor devices, and important features of circuit design employing semiconductors. A series of seven textbooks went through two trial editions; final editions are being published this year, together with four films. Other projects include the development of a new approach to the science of materials at Iowa State University, and new approaches to systems engineering at the Polytechnic Institute of Brooklyn, Georgia Institute of Technology, Michigan State University, and Purdue University.

During the period 1959–62, under grants to the University of California, a number of anthropologists cooperated in an intensive examination of college teaching in this field and of resources available for the purpose. The resulting two-volume report, along with the many conferences and discussions that went into its preparation, stimulated most colleges and universities to reexamine their programs.

Through films, students of anthropology can be given access to actual data in a way not otherwise possible except through very expensive field study and wide access to museum collections. Projects have been sponsored by the University of California at Berkeley, the University of California at Los Angeles, San Fernando Valley State College, and Harvard University.

A summer study sponsored by the University of Michigan in 1960 reviewed the undergraduate curriculum in psychology and developed guidelines for the future. This report has already had significant influence upon a considerable number of institutions. More specific course improvement materials include a series of 10 films, produced under grants to the American Psychological Association, in which leading investigators in experimental psychology present up-to-date research in important areas. Another is an experiment at Dartmouth College on ways to provide meaningful laboratory experience to undergraduate students in courses in sociology.

In summary, the Foundation views curriculum improvement as a continuing and increasingly important area of national concern. It must be a continuing effort because new developments at a given level are necessarily required to build on improvements made as a result of earlier efforts. Further, the full impact of curriculum improvement cannot be accurately assessed in quantitative terms at this time. There is considerable evidence that the projects supported by the Foundation are providing a pattern that is having a significant effect in the improvement of teaching materials both within and beyond the scientific disciplines, and that the materials produced are serving as models and sources for scholars who wish to develop their own versions along similar lines. It is conceivable that the impact of NSF-supported projects on curriculum improvement in all scholarly disciplines may be even greater than the impact of the specific course materials themselves.

OTHER SCIENCE EDUCATION ACTIVITIES

The growing need for scientists has made it increasingly important that students who have the interest and intellectual potential to become scientists be identified and offered specialized instruction while they are still in high school. College students who show high ability in science often need independent and self-directed study to encourage and develop their interest in scientific careers. To assist such students the Foundation has supported several programs of specialized training in recent years.

Activities for High-Ability Secondary School Students

A significant number of secondary school students—although a relatively small proportion of their total number—have the ability and special aptitude to become the scientists and engineers of their generation. To reinforce their early interest and their motivation to study science, the Foundation provides support that makes possible contact between the most capable students and mature scientists, and thus broadens their

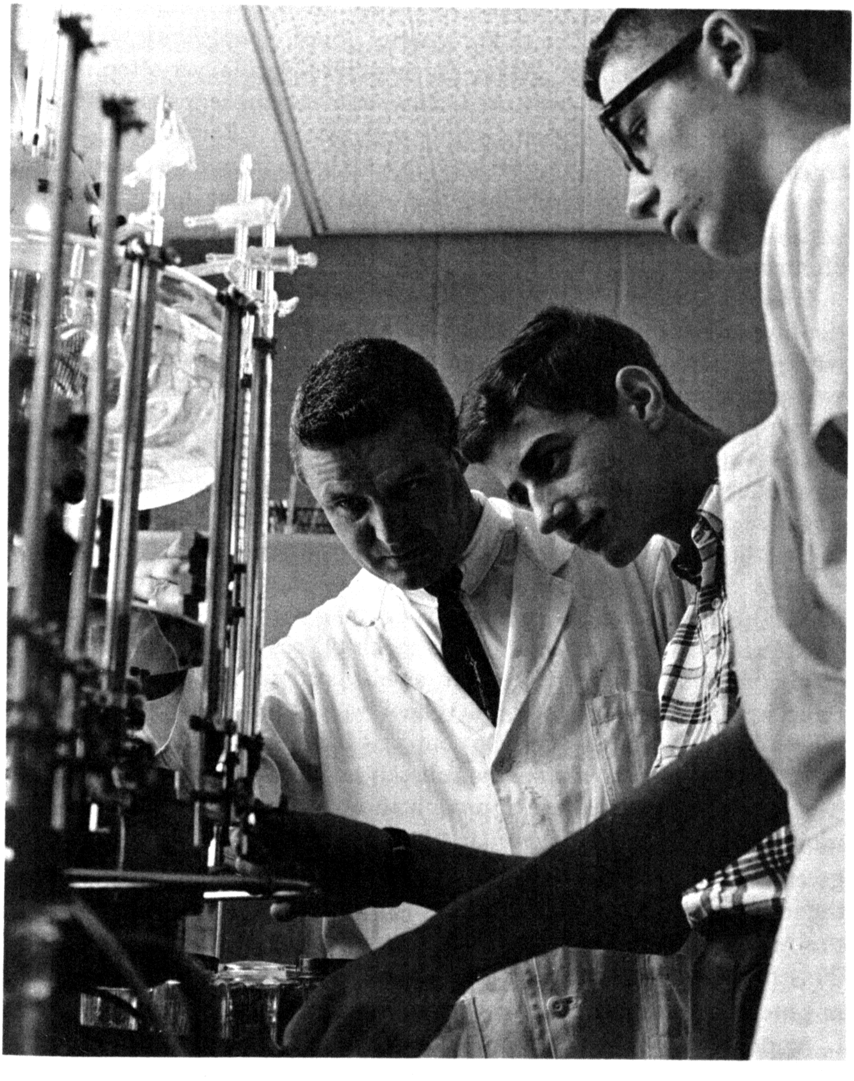

Figure 6.—*Biology teacher at LaSalle College works with advanced secondary school students in program supported by the National Science Foundation.*

views of the scientific enterprise. Such experience also serves to dissuade from science those who do not really belong there.

Developmental studies of adolescents have shown that the interest of students in science peaks during the junior high school years. They are curious about the physical world and easily aroused by interesting phenomena and exciting people. In their senior high school years they become increasingly exposed to crosscurrents of other ideas, including many influences leading away from academic achievement. They are most impressionable at these ages and constantly test themselves in relation to new ideas. Young people are especially influenced by adults whom they can admire, people who have already accomplished things which students would like to know more about, people with whom they can identify themselves. Many teachers fill this role, yet often, it is the occasional visitor in a dramatic setting who can make a sharper impact than the familiar person who is always available. For this reason good teachers spice their own presentations with visits from experts, and these are particularly successful when the experts are able to communicate with the student audience and when the subjects that they present are of intrinsic interest to the group.

It is this phenomenon of identification with adults that forms part of the rationale behind NSF's programs for motivating potential scientists while still in high school. The other element is the intrinsic challenge of well-presented subject matter. The athlete and the entertainer are glamorous figures to almost all adolescents, but the prestigious scientist has a glamor of his own for academically able students. The closer their own interests and ambitions are to the accomplishments of the scientist the more susceptible these students are to his influence.

For the fortunate student who is able to attend one of the summer projects supported under the Secondary Science Training Program (SSTP), these contacts are multiplied many times. In a course-centered project one or more scientists teach classes in small groups under ideal conditions. The subject matter has been carefully selected so that there is no duplication of high school work or of that which will be taught in early college. On the contrary, it covers topics in depth in the field that the student himself has chosen as most fascinating to him and it is taught by the nearest approach to an expert that he will find for some time to come. There are few educational experiences with a greater thrill for potential mathematicians, for instance, than to sit at the feet of a renowned mathematician and find that they, too, can master the reasoning processes that lead to advanced mathematical concepts. This tutorial arrangement is duplicated in the natural sciences and is an integral feature of the Secondary Science Training Program.

Students placed in research laboratories in SSTP as junior members of research teams have ample time to interact with and learn from the senior scientists and the other team members. What the student learns about the specific research project, its goals and associated techniques, is of course very useful, but what he learns about the attitudes of a scientist and the atmosphere of a research laboratory is even more important. He must go through the tedium of data gathering, the excitement of analysis to determine whether hypotheses have been proved, and the disappointment of temporary failure. This forms the test for him as to whether he is suited to a scientific life. Most participants report that this is a critical point at which they decide to dedicate themselves to science, while a few decide that it does not hold the appeal that they had thought.

In summary, the talented, science-oriented student is as susceptible as any other adolescent to hero worship. His heroes must be appealing in terms of the interests and expectations of such a student and his standards are very high. The mature scientist who is willing to contribute time and knowledge to this student is in a key position to influence the career planning of the youngster. The important elements of the relationship are the ability and willingness of the scientist to deal with the student at the student's level and the opportunity to discuss matters in depth to the satisfaction of the student.

The appearance of the Foundation's summer programs, which provide challenging classroom and laboratory training or full-time research participation in a scientific laboratory for the high-ability student, has added a new dimension to the educational scene. Whereas summer programs of similar character existed in only a few isolated instances before the Foundation's entry in 1959, today an increasing number of school systems are operating summer sessions—in all academic subjects—for superior students. The Foundation's program, working through colleges and research laboratories, helps to set a high standard for these activities. A recent trend is the adaptation of these programs to academic year activities, usually conducted on Saturdays, and such programs are increasing in number. About 47,660 students have participated in this NSF-supported training since it was initiated in 1959.

In addition, the Foundation now supports a few experimental projects aimed directly at the able secondary school students in culturally and educationally disadvantaged areas. For these students, projects designed to provide challenging scientific subject matter in stimulating environments are offered for humanitarian reasons as well as to encourage bright students to choose a career in science and to help prepare them for the next steps in that direction. All such activities are conducted by scientists from colleges and universities, and the facilities of the university are made available to the students.

Supplementary projects for the benefit of secondary school students include NSF-supported visits of scientists to high schools for the purpose of talking with the students, helping them with their science projects, and consulting with the science teachers. Also, a special series of lectures

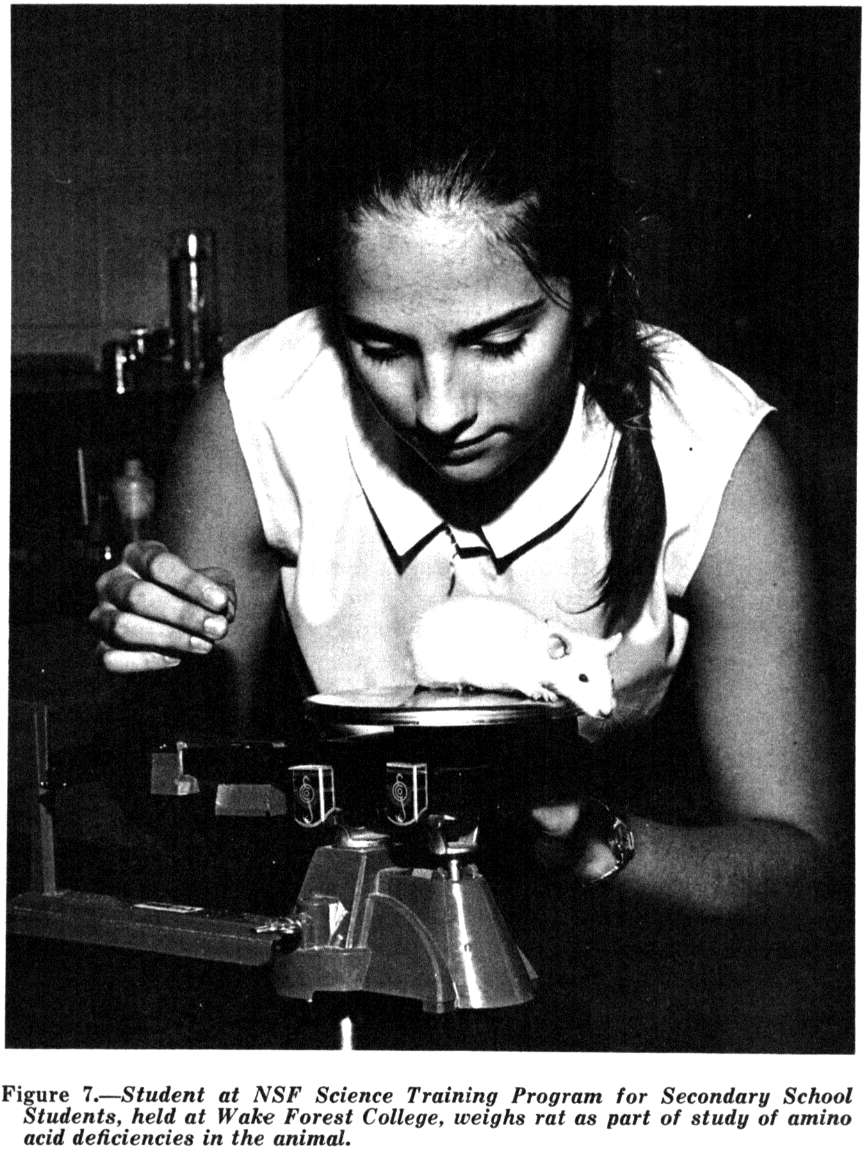

Figure 7.—***Student at NSF Science Training Program for Secondary School Students, held at Wake Forest College, weighs rat as part of study of amino acid deficiencies in the animal.***

is given during school holiday periods in major cities through Foundation support. Extra-curricular activities for superior students, which include special Saturday classes for groups like the Junior Academy of Science, encourage students to engage in independent research and to read scientific materials. Previously the Foundation supported the Traveling Science Library and the Traveling Science Demonstration-Lecture projects. These projects made available at the local level stimulating scientific literature, scientific demonstrations, and lectures in areas where such activities were not normally accessible. Having served their purpose in encouraging local interest and sponsorship of similar efforts, these two projects were terminated in 1963. Other projects include, for example, support to professional societies for the preparation of special materials on a given discipline, educational science activities at museums and planetaria, and assistance to national scientific journals for the publication of research papers prepared by secondary school students.

The results of the various activities at this level are noteworthy. In addition to having a stimulating effect on the students themselves, they have had an equally beneficial effect on the faculty.

This experience has played its part in increasing the enthusiasm of scientists for working with problems at the secondary and elementary school levels and improving the quality of the instructional materials offered.

Activities for Able Undergraduate Students

Participation in research at the undergraduate level often serves as a testing ground that helps students decide whether or not they should go on to study beyond the baccalaureate in science. It also adds significantly to the college student's understanding of the scientific process.

In 1958 the Foundation established the Undergraduate Research Participation Program to encourage the development of able undergraduates into competent and independent scientific investigators. However, the history of research participation as a mechanism for educating and training fledgling scholars begins well before 1958.

The background of the master-apprentice system for training undergraduates is worthy of note. Some of the intellectual ancestors of American higher education—in particular, faculty of Oxford and Cambridge—stressed for generations the importance of learning rather than teaching. They reasoned that the student, given access to working scholars and to the recorded knowledge of past and present civilizations, should be able to develop his own pattern of learning and his own particular competence. In this sort of master-apprentice system, research and learning become allies, not antagonists. Student participation in faculty research is thus a powerful means of developing independence and intellectual standards in the novice.

In the United States the experimental small colleges must be given major credit for adapting research participation and independent study to the American scene. For example, since its founding in 1908, Reed College in Oregon has insisted that each candidate for the baccalaureate present a piece of scholarly work as evidence of his emergence from the dependent role of student into the status of independent scholar. In the 1920's Swarthmore College in Pennsylvania developed a pattern which extends a great deal of freedom for individualized intellectual effort—usually including research participation—to about 40 percent of the student body while offering more formal instruction to the remainder. This practice is still in effect at the college.

Over the last 10 years, many universities have developed Honors Programs which offer to perhaps 5 to 15 percent of the undergraduate body great freedom to engage in independent scholarly pursuits limited only by the capacity, energy, and level of maturity of the individual. For the advanced undergraduate student, research participation and independent study are important elements of such activity.

Beyond the more visible institutional approaches are found styles of education and training that seem to be characteristic of particular disciplines. For example, undergraduate research participation and independent study in biology and chemistry were well established before 1940, but, in the engineering schools, it is quite limited and, where present, is usually of fairly recent origin.

The Foundation's awareness of the value of research participation began quite early. In the mid-1950's the Foundation, through its research units, supported a series of conferences on the nature of undergraduate research participation in various disciplines. The record of grants for education in science prior to the initiation of a specific program shows favorable responses to requests for support of undergraduate research participation in such fields as marine biology and mathematics. From 1951 to the present, basic research proposals in selected cases have included provision for use of undergraduate as well as graduate research assistants.

Currently NSF-supported Undergraduate Research Participation projects are carried out on a full-time basis for periods of not less than 8 weeks or on a part-time basis during the academic year. Most commonly the same student works on the same problem for one summer and one academic year, so the total of opportunities provided (indicated below by period of operation) is nearly twice the total number of students who receive this training.

Number of Opportunities for Participation in Each Period of Operation

Summer

1959	*1960*	*1961*	*1962*	*1963*	*1964*	*1965*	*Total*
1,276	1,777	2,433	3,343	3,462	3,953	3,532	19,776

Academic year

1959–60	*1960–61*	*1961–62*	*1962–63*	*1963–64*	*1964–65*	*Total*
1,355	1,602	2,090	3,740	3,169	3,165	15,121

The relevant student population is predominately junior and senior science majors, although many freshmen and sophomores have participated.

Response of the academic community to the Undergraduate Research Participation Program has been enthusiastic and sustained. The experience of the past 7 years demonstrates that able students who engage in essentially independent scientific research as junior colleagues of experienced scientists will develop rapidly in scientific maturity and scholarly competence. Further, these students will be better equipped for graduate study than their peers and more likely to undertake such study. The Foundation thus views undergraduate research participation as an effective means of increasing both the Nation's scientific capability and its strength in science education.

Closely related to the effectiveness of undergraduate research participation is, of course, the quality of instructional equipment being used at colleges and universities. Good research requires modern laboratory equipment and materials; these too receive Foundation support.

Instructional Scientific Equipment Program

In the Foundation's study of undergraduate science education, it was apparent early that modern instructional scientific equipment was generally lacking. In many instances the implementation of plans for new and improved instructional programs was hampered by lack of suitable equipment. Demands upon the financial resources of the undergraduate colleges rose to the point where the purchase of equipment was precluded or deferred until some indefinite future time.

Colleges and universities always have faced the necessity for updating their instructional programs. In recent years this need has been urgent because of the remarkable growth of scientific knowledge, revolutionary developments in instrumentation, and advancing technology in communication. It has now become clear that students are more capable of understanding scientific ideas and processes earlier than had been assumed. Development of new and improved curricular materials for both the high school and college levels through efforts by national groups and the heightened standards of achievement demanded by graduate and professional schools have generated heavy pressures for increased excellence in undergraduate instruction.

Convinced of a pressing institutional need for up-to-date equipment, the Foundation introduced the Instructional Scientific Equipment Program in fiscal year 1962. It provides matching grants for the equipment required to implement a broad range of local improvements in undergraduate science education. In the competition for such equipment grants, priority has always been given to academic units that present evidence of sound self-examination by a competent staff and realistic planning for developing an improved curriculum. Therefore, the objective of the program has, since its inception, been to stimulate the greatest possible relative improvement in science education on local campuses by providing the latest types of instructional equipment. Although

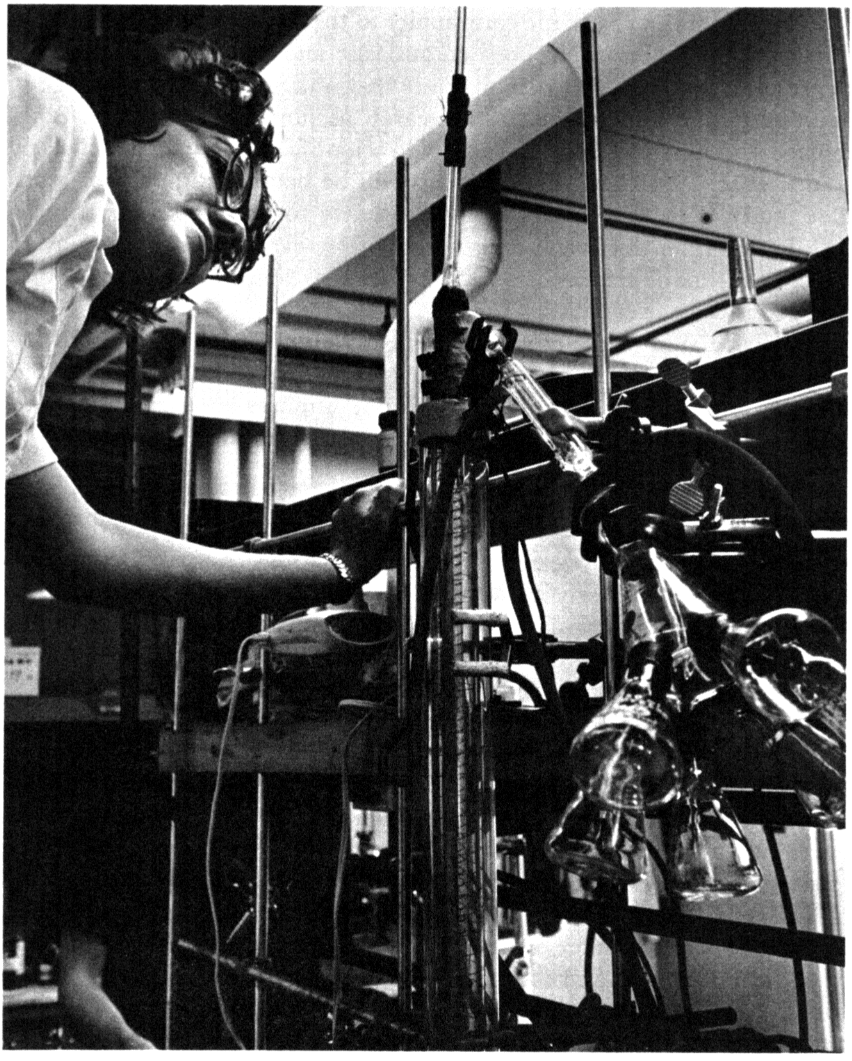

Figure 8.—*University of Oregon student uses equipment furnished in her qualitative organic chemistry laboratory by NSF's Instructional Scientific Equipment Program.*

a significant number of institutions have been assisted by this program, the need remains critical. In fact, recent surveys of the national need for additional scientific equipment indicate that undergraduate institutions should spend more than $1 billion for such equipment by the end of 1970.

Since 1962, grants have been awarded annually in all 50 states (with the exception of Alaska in 1963) and the District of Columbia. Grants also have been made in Guam, Puerto Rico, and the Virgin Islands.

During the 4-year existence of this program, 5,488 proposals from 1,119 institutions requesting a total of $70,467,660 have been received, and as many as 3,082 grants totaling $29,976,522 have been awarded to a total of 890 institutions. The widespread institutional and disciplinary distribution of grants is evidence that the program has a broad impact nationally.

COMPLEMENTARY FUNCTIONS OF THE U.S. OFFICE OF EDUCATION

Two agencies of the Federal Government are most centrally and directly involved in the support of educational activities in the United States. The National Science Foundation's responsibilities in education are limited to science education, but the U.S. Office of Education under the Department of Health, Education, and Welfare, has broad responsibilities for education in general. Relationships between these agencies vary all the way from those which are statutory, through *ad hoc* committees, to close, informal contacts between officials responsible for administering separate programs in areas of joint responsibility. Over the years a spirit of understanding and cooperation has developed between the agencies, resulting in mutual helpfulness in carrying out their separate tasks.

One of the major areas of shared responsibility between the National Science Foundation and the Office of Education is support for the construction of graduate facilities at institutions of higher education. Under the Higher Education Facilities Act of 1963 the Office of Education provides grants and loans for both graduate and undergraduate facilities in colleges and universities. Grants to 4-year undergraduate institutions are limited to the support of facilities devoted to science mathematics, modern foreign languages, engineering, and libraries. Graduate facilities, however, may be supported in all fields except the medical sciences, theology, and divinity.

The objective of the graduate grants program is to develop new centers of excellence in graduate studies to increase the number of highly qualified people who can fill the needs of the community in industry, government, teaching, and research.

The facilities program administered by the Office of Education complements the program of the National Science Foundation. The Foundation's program is primarily concerned with research facilities, while the Office of Education's program includes the support of facilities for teaching as well. A proposal in the sciences not deemed appropriate for a grant from the National Science Foundation because of limited research space projected might well be appropriate for a grant under the Higher Education Facilities Act. Coordination between the National Science Foundation and the Office of Education programs is effected by statutory NSF membership on the Committee which advises the Office of Education on graduate facility grants. With respect to undergraduate facilities, the Foundation does not, in general, make grants for such facilities as are supported by the Office of Education under the Facilities Act.

Another area of shared responsibility between the two agencies is the improvement of the qualifications of elementary and secondary school teachers. The Office of Education's institute programs are for teachers of modern foreign languages, English history, geography, reading, as well as for those who teach disadvantaged youth, for school library personnel, and for educational media specialists. While deepening and broadening of the teacher's subject-matter competence is an aim, these institutes emphasize pedagogy. Stress is laid upon improvement of the teaching skills. NSF-supported institutes at this educational level are limited to teachers of the sciences and mathematics. NSF institutes, of course, are specifically designed for updating and ungrading the teachers' knowledge of subject matter.

Thus the teacher-training activities of each agency involve different disciplines and are designed to achieve different objectives.

Graduate fellowship programs also represent an area of mutual responsibility. The National Defense Education Act fellowships administered by the Office of Education are intended to increase significantly the number of graduate students entering college teaching. National Science Foundation fellowships provide support to graduate students, college teachers, and advanced scholars for study or work in science, mathematics, or engineering. The Foundation's aim is to increase the Nation's scientific potential.

Efforts to improve education through curriculum improvement projects under the OE Cooperative Research Program and through NSF-supported course content improvement projects represent still another major area of mutual responsibility. The Office of Education's Curriculum Improvement Program includes projects dealing with a curriculum, a course, a subject, or any aspect of these. Any subject field at one or more grades or levels of education from preschool through higher and adult education may be covered. This program represents an attempt to approach curriculum improvement as an integrated whole. The Office of Education attempts to identify and then to stimulate projects to fill gaps that may be created by the development of specialized courses or curricula or to provide alternatives to already existing curriculum improvement efforts.

NSF-supported course content improvement efforts cover all educational levels but are, of course, restricted to the fields of science, mathematics, and engineering. At the elementary level the Foundation encourages a broad-discipline approach since science is interwoven into a unified course of study in the elementary grades. But at progressively higher levels the Foundation supports projects dealing with material of a more specialized or delimited nature and almost entirely concerned with the substance of science. Most projects are intended to produce instructional materials of various kinds, including textbooks for student use, supplemental written materials for student use (booklets on special topics, etc.), films, laboratory syllabi, laboratory equipment, or teachers' manuals. Some individual projects produce all of these; others, only one or more.

To ensure that the efforts of the Office of Education and the National Science Foundation in the curriculum area complement each other, close coordination is maintained. An NSF staff member serves on the OE curriculum improvement review panel. NSF and OE staff members sometimes conduct joint site visits to investigate the research potential of proposed project locations. The Office of Education and the Foundation jointly review and fund proposals which relate to both agencies.

Both the U.S. Office of Education and the National Science Foundation will continue to administer their activities in such a way as to avoid duplication and conflict. On the basis of past experience, the Foundation foresees no problems of coordination and only a total gain for the Nation from the expansion of the responsibilities of the Office of Education and the enlargement of Federal resources for assistance to education.

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SUPPORT OF SCIENTIFIC RESEARCH

Support of basic scientific research provided by the National Science Foundation has been largely concentrated in academic institutions and in closely allied nonprofit institutions. This concentration has been by deliberate choice in order that Foundation research funds might most effectively contribute to the training of scientists and engineers, particularly at the graduate level. Although this policy has resulted in little support being provided for research in industry and commercial laboratories, the Foundation recognizes the importance of keeping these laboratories strong and is constantly reviewing its policies in the light of its basic mission to make the United States as strong as possible in science and engineering.

The principal mechanism for direct support of basic science is the well-known program of project research grants which are awarded to institutions for the work of individual scientists or small groups of scientists working together. However, it is important to remember that this is by no means the only mechanism used. For example, a program of grants for specialized research facilities and equipment has been developed to provide for needs which cannot be met through individual research grants. Again, where the Foundation has been assigned partial or total responsibility for U.S. participation in a major national program, support is provided from funds specially appropriated for the purpose. Typical of such "national research programs" are the recently concluded International Indian Ocean Expedition and the currently active International Years of the Quiet Sun. A fourth mechanism is through the national research centers, such as the Kitt Peak National Observatory, which provide special facilities and research opportunities that cannot be undertaken by a single college or university. These four mechanisms of research support by the Foundation are reviewed in some detail in the following pages.

It should be added, however, that still other programs contribute importantly to the conduct of basic research. Programs for fellowships and traineeships, undergraduate research participation, graduate science facilities, science information services, institutional grants for science, and the new science development program all sustain our scientific research endeavors.

Direct support of basic research accounted for about 36 percent of the $416 million obligated by the Foundation in fiscal year 1965, including funds for basic research project grants, for the national programs, and for research at the national centers. An additional 40 percent can be considered as contributing indirectly to the conduct of basic research through fellowship awards, facility grants, and the other programs noted above.

BASIC RESEARCH PROJECTS

Of the funds awarded for direct support of basic research, about 80 percent was made available through a competitive program of project grants, most of which are awarded for the work of individual investigators. The remaining 20 percent was allocated under specific programs for which funds were specially earmarked in the budget. In this general project grant competition, the Foundation took final action on 6,047 basic research proposals requesting $505 million in fiscal year 1965, and made 3,228 grants in the amount of $122 million in response to these proposals. Thus, some support was available for about 54 percent of the proposals acted upon, but only 24 percent of the total funds requested could be granted. In the 3,228 grants made, the $122 million provided was $165 million less than the amount requested. This means that the average successful proposal was reduced by 57 percent from the requested figure. Some of this decrease resulted from a reduction in the allowed duration, typically from 3 to 2 years; the rest from a reduction in the scope of the programs supported.

About 95 percent of the funds for basic research project grants went to 288 colleges and universities. Table 1 shows the distribution of these funds by State, and the total number of institutions and the number of academic institutions supported in each State. Proposals were received from 313 institutions, so that over 90 percent of the institutions submitting proposals received one or more grants. Half of the institutions awarded basic research grants received less than $70,000 each. Slightly more than one-third received $200,000 or more in grants. In this latter hundred or so institutions is concentrated much of our capability for maintaining U.S. leadership in science. From this group must come the additional front rank institutions which must be added to the 20 or 30 institutions which have already achieved worldwide recognition as outstanding centers in scientific research. It is to the emerging institutions in this group that the Foundation's Science Development Program is primarily directed.

Table 1.—*NSF Grants for Research Project Support, Amount, Number of Institutions, by State, Fiscal Year 1965**

State	Amount		Institutions supported	
	Total	College and university	Total	College and university
Alabama	$171, 200	$164, 200	3	2
Alaska	552, 600	552, 600	1	1
Arizona	1, 363, 400	1, 363, 400	3	3
Arkansas	175, 700	175, 700	2	2
California	17, 889, 962	17, 603, 462	37	29
Colorado	1, 414, 900	1, 414, 900	7	7
Connecticut	3, 432, 250	3, 353, 750	10	6
Delaware	191, 000	191, 000	1	1
District of Columbia	1, 534, 612	602, 100	14	5
Florida	2, 512, 800	2, 426, 700	10	6
Georgia	883, 625	883, 625	3	3
Hawaii	1, 368, 900	1, 219, 200	2	1
Idaho	90, 600	86, 600	4	3
Illinois	7, 078, 800	6, 714, 950	18	12
Indiana	4, 485, 550	4, 485, 500	7	7
Iowa	677, 700	677, 700	5	5
Kansas	1, 305, 500	1, 305, 500	6	6
Kentucky	737, 500	737, 500	3	3
Louisiana	563, 825	563, 825	4	4
Maine	84, 200	28, 800	3	1
Maryland	2, 269, 900	2, 038, 300	4	3
Massachusetts	11, 496, 150	10, 598, 650	27	19
Michigan	4, 952, 370	4, 913, 970	8	6
Minnesota	1, 684, 450	1, 684, 450	3	3
Mississippi	100, 600	76, 100	3	2
Missouri	1, 703, 450	1, 701, 550	4	3
Montana	286, 900	286, 900	2	2
Nebraska	282, 150	282, 150	2	2
Nevada	212, 200	212, 200	1	1
New Hampshire	433, 450	433, 450	2	2
New Jersey	4, 794, 350	4, 386, 550	5	4
New Mexico	726, 550	726, 550	6	6
New York	15, 790, 300	14, 353, 196	53	29
North Carolina	1, 715, 670	1, 715, 670	6	6
North Dakota	34, 000	34, 000	1	1
Ohio	3, 078, 100	3, 058, 000	18	16
Oklahoma	701, 150	701, 150	3	3
Oregon	2, 151, 450	2, 145, 450	7	6
Pennsylvania	7, 773, 990	6, 679, 890	30	19
Rhode Island	1, 677, 400	1, 585, 700	5	2
South Carolina	228, 900	199, 400	3	2
South Dakota	62, 500	62, 500	4	4
Tennessee	609, 300	587, 300	5	4

See footnote at end of table.

Table 1.—*NSF Grants for Research Project Support, Amount, Number of Institutions, by State, Fiscal Year 1965*—Continued*

State	Amount		Institutions supported	
	Total	College and university	Total	College and university
Texas	2, 706, 289	2, 387, 789	13	11
Utah	1, 139, 700	1, 139, 700	3	3
Vermont	43, 700	43, 700	2	2
Virginia	948, 850	897, 650	8	7
Washington	2, 188, 638	2, 188, 638	6	6
West Virginia	284, 500	284, 500	1	1
Wisconsin	3, 753, 800	3, 698, 300	8	5
Wyoming	149, 900	149, 900	1	1
Grand total	$120, 495, 281	$114, 004, 315	387	288

*Includes only grants awarded in general competition. Not included are research grants awarded for national programs, national centers, etc.

Fortunately, these hundred institutions are well distributed throughout the length and breadth of our land. This fact is clearly demonstrated in the following tabluation which shows how these universities are distributed among the various regions of the country:

Table 2.—*Distribution of Institutions Receiving NSF Research Grants*

Region	100 institutions	Twenty receiving most NSF Research Grant Funds
New England	12	3
Middle Atlantic	20	4
East North Central	14	5
West North Central	9	1
South Atlantic	12	2
East South Central	4	0
West South Central	7	0
Mountain	7	0
Pacific	13	5
Other (Alaska and Hawaii)	2	0
	100	20

The geographic distribution of these hundred institutions is much broader than it is for the "top twenty," defined here as the 20 institutions receiving most research grant funds from the Foundation in fiscal years 1964 and 1965. This analysis clearly demonstrates that there are universities in every region of the country which can be built to positions of outstanding strength in science.

The nearly 300 colleges and universities which receive research project support from the Foundation include substantially all those which are now capable of making significant contributions to the advancement of science and engineering through research. Furthermore, available funds are insufficient fully to develop and exploit the capabilities for doing creative research inherent even in this limited group. An important problem facing us today is that there are more than a thousand institutions of higher education which award baccalaureate degrees in one or more fields of science, and more than 2,000 institutions where science is taught at a level beyond the secondary-school curriculum. Many believe that undergraduate students should be taught by scholars who are themselves actively engaged in significant research, and that the best students should be given an opportunity to participate in research. Obviously, this is now possible in only a small fraction of our institutions. Such a goal may, in fact, be unrealistic, even for the long term.

Effective research requires some concentration of activity. It is well recognized that there is a "critical level" for a research program, below which inefficiency and discouragement are likely to set in. For the short term, we may have no choice, then, but to find ways of providing adequate undergraduate education in science without the immediate presence of significant research. One thing can be done at once: high priority must be given to programs aimed at a better geographic distribution of strong centers of research and graduate education. Such centers can in turn interact constructively with institutions providing undergraduate education in the sciences, but not themselves able to sustain active research programs.

Table 2 shows that NSF grants to colleges awarding undergraduate degrees only have increased substantially in the past 10 years, but that only a small fraction of such schools can compete successfully for research project funds. The average amount received by each such institution in fiscal year 1965 was only $30,000.

It is evident that the broad problem of strengthening science in 4-year colleges cannot be solved merely by increasing the funds available for support of basic research on a quality competitive basis. A comprehensive program tailored to the special needs of these institutions is the only practicable solution.

Support of basic research abroad in fiscal year 1965 continued under severe limitations, but showed a slight increase in dollars obligated. A research project at a foreign institution is supported only if it can be

Table 3.—*NSF Research Grants to Foreign Institutions*

Country	Fiscal year 1964		Fiscal year 1965	
	Number	Amount	Number	Amount
Argentina	....	....	1	$14,900
Australia	3	$179,700	2	111,300
Bermuda	2	47,900	3	172,700
Canada	6	30,500	9	194,700
Ethiopia	1	11,200	....	....
France	1	78,800	....	....
Iceland	....	....	1	32,900
Israel	1	25,000	1	40,000
Italy	....	....	2	70,000
Japan	....	....	1	2,000
Lebanon	1	24,600	....	....
Mexico	....	....	1	31,500
Nigeria	2	21,250	1	27,600
Philippines	1	55,200	....	....
Rhodesia	1	41,120	....	....
Switzerland	1	7,000	....	....
United Kingdom	1	9,500	1	25,000
	21	531,770	23	722,600

clearly demonstrated that such support is necessary for the progress of science in the United States. Table 3 compares grants made in fiscal years 1964 and 1965.

Table 4 summarizes the research grants program by subject categories based on the Foundation's organizational structure. A detailed listing by State, institution, principal investigator(s), title of project, duration, and amount can be found in the publication, *National Science Foundation, Grants and Awards, Fiscal Year 1965,* NSF 66–2.

Mathematical and Physical Sciences

The scope and number of projects being supported in the mathematical and physical sciences are very large, so that the achievements of NSF grantees can only be hinted at by citing a few instances which have occurred recently and which may be of interest to the lay reader.

The characteristics of the research in the individual mathematical and physical disciplines vary considerably from one another: Astronomy—of little direct practical use, it concentrates on the extremes in nature (which are therefore extremely interesting) such as great size, mass, time, and energy. Atmospheric Sciences—of overwhelming practical importance, the complex swirling medium which is our present day atmosphere seems to have little to offer in the way of an historical record or an elegant

Table 4.—*National Science Foundation Research Project Awards, by Field of Science, Fiscal Year 1965*

	Number of awards	Total amount
Biological and medical sciences:		
Developmental biology	120	$4, 389, 232
Environmental biology	153	4, 612, 500
Genetic biology	101	4, 340, 450
Metabolic biology	118	3, 815, 100
Molecular biology	200	9, 564, 076
Psychobiology	121	4, 126, 296
Regulatory biology	155	5, 001, 260
Systematic biology	233	4, 811, 275
General biology	26	2, 630, 150
Subtotal	1, 227	43, 290, 339
Mathematical and physical sciences:		
Astronomy	74	4, 519, 600
Atmospheric sciences	49	4, 309, 091
Chemistry	306	10, 541, 100
Earth sciences	246	10, 753, 696
Mathematical sciences	361	10, 982, 400
Physics	220	13, 581, 870
General mathematical and physical sciences	1	23, 600
Subtotal	1, 257	54, 711, 357
Engineering sciences:		
Engineering chemistry	82	2, 638, 900
Engineering energetics	61	2, 616, 100
Engineering mechanics	126	3, 884, 350
Engineering materials	64	2, 430, 650
Engineering systems	58	2, 175, 600
Special engineering projects	19	211, 199
Subtotal	410	13, 956, 799
Social sciences:		
Anthropological sciences	125	2, 896, 300
Economic sciences	67	2, 454, 950
Sociological sciences	98	3, 474, 400
History and philosophy of science	38	891, 296
Special projects and resources	6	562, 700
Subtotal	334	10, 279, 646
Total	3, 228	122, 238, 141

understanding of fundamental physical systems. Solid Earth Sciences and Oceanography—of great industrial and military importance, yet full of the romance of exploring the present-day world and of deciphering the solidified records of the ancient past. Physics—highly useful, yet its basic research practitioners are really most interested in discovering and understanding the most primitive physical systems, however microscopic and remote from everyday life they may be. Chemistry—tremendously useful, enormously complex and esoteric. And finally, Mathematics—of great practical importance, even while many of its purest and most distinguished scholars vigorously assert that the best mathematics research should never be judged by the criterion of its applicability.

Yet despite these differences in point of view, a glance through the following accounts makes it clear that there is an important and probably growing interdependence among the disciplines and the industrial and social enterprises to which they can make a useful contribution. In the first one, for example, it may be noted that although the work is largely astronomical in nature, the investigator (Bigg) initially became interested in Jupiter because he hoped that in studying its eruptions he would learn something about the genesis of major storms in the earth's atmosphere.

The Effect of The Motions of Jupiter's Innermost Satellite on Its Emission of Long Wavelength Radio Energy—For about 10 years it has been known that the planet Jupiter emits sporatic bursts of radio waves. This radiation is in the region of the radio spectrum at wavelengths near 15 meters (about 50 feet) and is usually called decametric, to distinguish it from the fainter but steady radiation which the planet emits at short wavelengths. The sporadic decametric radiation has been under observation, with NSF support, for a number of years by James W. Warwick at the University of Colorado. From the wealth of data obtained in this investigation a significant discovery was made this year by E. K. Bigg, a staff associate of Warwick. He noted a strong correlation between the sporadic radio bursts and the position of Io, the closest to Jupiter of the four bright satellites. The decametric radiation appears to be emitted primarily by an active region which is located within a fairly narrow area of Jupiter's surface. Conditions seem to be most favorable for the bursts to occur when this area faces the Earth, at the same time that a line joining Jupiter to Io is approximately perpendicular to the Jupiter-Earth direction.

The origin of the decametric radiation is not yet clear, but the close correlation with the position of Io seems to indicate that the satellite, moving through the magnetic field around Jupiter, disturbs the charged particles trapped there and causes them to precipitate into the ionosphere, producing the radio emissions. Thus, planetary radio astronomy is proving to be a new tool for investigating the physical conditions around planets, opening up a new method for studying planetary atmospheres.

The investigation described in the next item has been supported as research both in atmospheric scienes and in astronomy and illustrates the versatility of sophisticated new instrumentation. The principal investigator, incidentally, is a member of the physics department of the University.

Observations of Elements of Low Abundance in the Atmospheres of Planets and in Interstellar Space—When light passes through gas clouds containing the elements sodium and lithium, certain very distinct colors of light are absorbed by the gas and subsequently reemitted by it in other directions. This effect can be used as a means of detecting the presence of these elements, particularly when the clouds are in inaccessibly remote places such as the atmospheres of other planets or interstellar space.

When the total abundance of the gas to be observed by this method is very small, the amount of the light which it absorbs or scatters, even at the characteristic colors (spectral lines) which it specifically resonates to, is very small. In order to measure it, it is necessary to build oberving equipment which has the highest possible sensitivity to light of the characteristic colors and has the ability to distiguish such light from light of other colors which are nearly the same but which are not those in which one is interested. The instrument which has been most commonly used for this purpose is the so-called slit spectrograph, in which the light which is to be analyzed is passed through a narrow slit, and then dispersed into its component colors by means of a grating or prism. The light on leaving the dispersing element passes into a camera which takes a picture of the slit. Because of the dispersion, however, many pictures of the slit are obtained side by side, each one in a different color. If one wishes to compare the intensities of two different colors (wavelengths) of light in the incoming illumination, one need only compare the brightnesses of the corresponding images of the slit as seen by the spectrograph camera.

A basic difficulty with this type of instrument has been that if the colors to be compared are very similar (have nearly equal wavelength), the corresponding slit images are close to one another and tend to overlap. To avoid this effect it is possible to make the slit narrower, thus giving sharper images and reducing the overlap. This, however, is done at the cost of reducing the amount of light which can pass through the slit. If the slit is narrowed too much, it may become impossible to measure the faint images accurately or even to see them at all. The problem becomes even more difficult if one is observing light which is intrinsically faint before it reaches the slit.

In order to develop a spectrograph which can be used to measure light colors in very faint sources, Julian Mack at the University of Wisconsin and his coworkers Fred Roesler, D. P. McNutt, and R. Chabbal have developed a specialized instrument using the principles of a device known as a Fabry-Perot interferometer. In effect it is rather similar in its operation to that of an organ pipe. The organ pipe is operated by generating and feeding into it a whole spectrum of sound pitches (instead of colors as in the case of light), each with its own characteristic wavelength. The pipe, however, has a characteristic length of its own. A sound pitch which has a wavelength which is the same length as that of the pipe can set up vibrations within the pipe which are easily sustained, and a resonant note is emitted from the pipe. In general other sound pitches having different wavelengths, when fed into the pipe, are reflected back out again at the source and resonance does not occur. In the case of the Fabry-Perot interferometer, light colors (wavelengths) from the source to be analyzed are fed into a tube and caused to be reflected back and forth between extremely accurately ground flat glass surfaces. Only those colors of light having wavelengths such that an integral number of them is precisely equal to the length of the tube (or, as it turns out, twice the length of the tube) tend to pass through it and the others are reflected back toward the source.

The instrument developed by Mack and his collaborators employs a number of such optically resonant tubes, and incorporates many improvements to give it the greatest possible stability and refinement. Since it does not use an entrance slit as in the case of a conventional spectograph, it can analyze all the light from a broad source such as a portion of the sky or a cloud of interstellar gas, while at the same time being able to distinguish between the intensities of colors which are extremely close together.

The new instrument has been used to survey the change with time of the distribution of sodium gas high in the earth's atmosphere by observing the amount of its characteristic colors (wavelengths) in the sunlight which it scatters toward the earth. It has also been used to look for the characteristic emissions of lithium gas in the direct light from the sun (the total light available from the sun is very great, but that from the scarce element is extremely faint), and contrary to previous reports it appears that no lithium can be detected. This latter result is of considerable importance since the earlier suspected presence of lithium had implied that the turbulent convection of the gas in the sun between the surface and interior of the sun was necessarily very small, since lithium is destroyed very rapidly by thermonuclear reactions when exposed to the tens of millions of degrees of temperature existing in the solar interior.

In another application radiation from the gas clouds surrounding the star Alpha Cygni were observed at the characteristic wavelengths of gaseous sodium. It was found that small shifts in these wavelengths due to motions of the gas toward or away from the earth could be detected (like the shift in pitch of a sound emitted by a source which is approaching or receding from the observer). It thus appears that a powerful new tool for the study of the interstellar medium may be at hand.

When one attempts to develop theories of the history of the earth during prehistoric times, one can at best only suggest reasonable hypotheses and then test their implications in a painstaking manner against many hundreds of bits of physical evidence found in the structure and composition of sediments and rocks, in fossil remains of ancient life and the like. The following theory has yet to withstand many tests of this type, but it is promising and worthy of note.

Evolution of the Earth's Atmosphere—Lloyd V. Berkner and Lauriston C. Marshall, both of the Graduate Research Center of the Southwest, have been investigating the broad problem of the history of the earth's atmosphere with particular reference to its temperature and chemical composition. This research has a significant bearing on some other important historical problems, including the processes of initiation of life on earth and the steps in biological evolution.

There now appears to be wide agreement based on geologic evidence that the earth originated 4 to 5 billion years ago, at which time it was essentially solid and had no significant atmosphere. Any primeval atmosphere the newly formed earth may have retained was probably dissipated by the gradual escape of the lighter gases such as hydrogen and helium. In contrast, it may be noted that these light elements are relatively more abundant in the atmospheres of the larger planets and the sun, which have a much larger gravitational field than the earth.

One of the most interesting facts about the earth's atmosphere today is the large content of oxygen—about 21 percent, a condition unique among the planets of the solar system. How did this develop? In light of some of the related facts, scholars have not been able to agree on how a stable atmosphere could have come into being containing this amount of oxygen. On the one hand, there is a theory propounded about 150 years ago that has found wide acceptance among scientists; it states essentially that the present geologic balance of oceans, continents, atmosphere, rocks, sediments, and life has been achieved as a gradual process subject to natural conditions which have not changed throughout geologic time extending back through 3 or 4 billion years. On the other hand, however, it is increasingly clear from geologic evidence that highly organized forms of modern life as they exist in the sea and on land have come into being only within the past 600 million years.

Berkner and Marshall's study adopts the basic premise that the earth was without a primordial atmosphere and that its atmosphere developed later as a result of local heating and volcanic action associated with continent building. Since oxygen production cannot be explained in this way, its initial formation is attributed to photochemical dissociation of water vapor. It is now possible to make reasonably good estimates of the rate at which such dissociation can proceed since recent measurements from space vehicles have provided good data on the intensity of solar ultraviolet radiation.

The rise of oxygen content above the initial low level produced by photochemical dissociation of water can only be associated with photosynthetic activity, which in turn depends upon the ecologic conditions prevailing at any period. Throughout the pre-Cambrian period (prior to 600 million years ago), the quantity of lethal solar ultraviolet radiation reaching the surface of the earth must have been sufficient to penetrate through 5 or 10 meters depth in water, and thus limited the origin and early evolution of life to organisms living in small lakes or protected shallow seas where excessive convection did not bring life too close to the surface, and yet where it received attentuated and thus nonlethal sunlight.

When, as a result of this process, enough oxygen had been introduced into the atmosphere to bring its oxygen content up to about one-hundredth of its present level, the ocean surfaces were sufficiently protected by the atmospheric oxygen from the solar ultraviolet radiation to permit widespread extension of life to the entire ocean surface. It is hypothesized that when this occurred, enough oxygen was produced to permit a number of important new biological mechanisms to evolve. The investigators, therefore, call this oxygenic level the "first critical level" and identify the time at which it was attained with the explosive evolutionary advances which took place during the Cambrian period (approximately 600 million years ago). The rate of oxygen production then continued to increase as metabolism in many new forms of life took place.

Eventually the land surfaces were sufficiently shadowed from lethal solar ultraviolet radiation by the atmospheric oxygen to permit the spread of life to dry land. This oxygenic level (1/10 present atmospheric level) is termed the "second critical level" and is identified with the appearance of the organisms found on land at the end of the Silurian epoch (about 420 million years ago). Subsequently, the oxygen content must have increased rapidly up to the time of the Carboniferous period (about 300 million years ago.) Thereafter, the atmospheric oxygen may have fluctuated through later times before arriving at the present quasi-steady level.

The physical and evolutionary evidence concerning the development of the earth appears to support such a model, and thus the theory may have solved the so-called "puzzle" of the Cambrian evolutionary explosion and of certain subsequent radical evolutionary advances.

As a means of providing additional evidence against which theories such as the foregoing one can be checked, the method described below for sampling the sediments on the continental shelf should be particularly useful.

Studies of Ocean Bottom Sediments—Because of the difficulty in obtaining samples of the structure and composition of the crust of the earth lying beneath the oceans, little is actually known about its properties. Yet the importance of such samples of the suboceanic crust to the solution of important scientific problems is quite apparent. These sediments could, among other things, provide knowledge of the age of ocean basins, of the earth's climatic history, and of the origin, history, and structure of the continental shelf (a shallow region of the oceans bordering on land masses). Such investigation of the continental shelf might result in the discovery of new and economically recoverable mineral resources. Studies of samples from the shelf and from the outer edge of the shelf where it slopes into the deep ocean may provide information about past large-scale movements of the oceans as they have invaded and retreated from the continents, and whether such changes are cyclic.

Until 1961 the studies of the oceanic crust were largely limited to the use of indirect methods—seismology (the manner in which sound waves are deflected by the ocean bottom and the underlying layers), gravity (unusually heavy rocks cause local changes in the strength of the earth's gravitational attraction), and magnetism (local masses of magnetic minerals cause local changes in the earth's magnetic field). Some information could also be obtained at that time from the study of the upper 50 to 100 feet of unconsolidated sediments, using bottom samples in the form of cylindrical cores brought up from the bottom with the aid of special coring devices. In the spring of 1961 Phase I of Project Mohole demonstrated the feasibility of using a drilling vessel to obtain much longer and deeper cores of sediments that comprise the upper layers of the oceanic crust. Although this was first accomplished as a part of Project Mohole, it was soon recognized that the way had been opened for a program of deep ocean sediment investigations which do not require the vast engineering development program that was essential to Project Mohole [1] for drilling through the crust into the mantle of the earth, a much deeper penetration.

The current program of sediment coring, which was initiated this past year, has already accomplished one of the most significant recent advances in oceanography. This is the completion of an ocean drilling and coring program on the continental shelf, continental slope, and the Blake Plateau off the eastern coast of Florida. The drilling took place on six sites along a track beginning about 22 miles from Jacksonville in 81 feet of water and extended 250 miles offshore where the ocean depth reaches 3,500 feet. The deepest hole drilled was 1,050 feet below the ocean bottom.

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[1] See page 94.

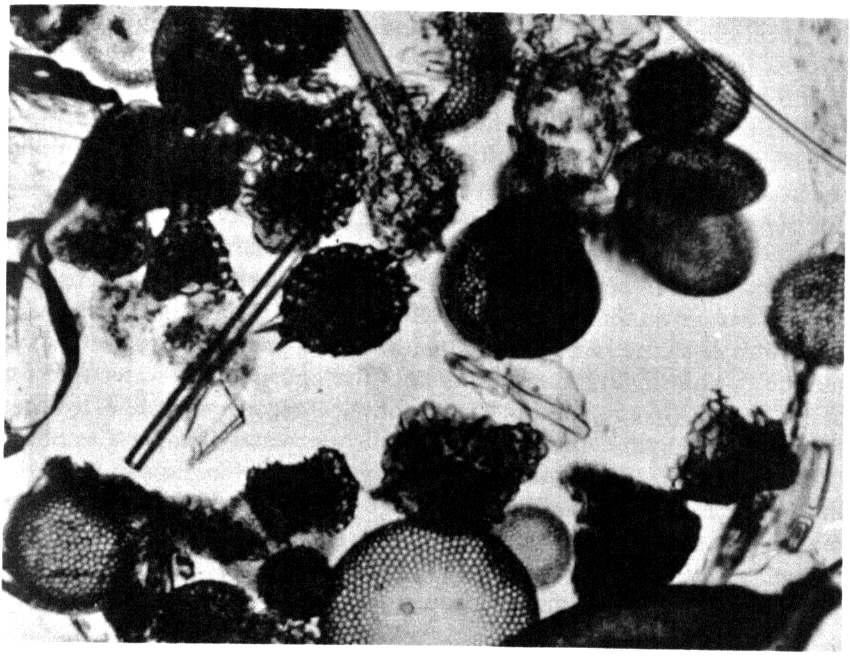

Figure 9.—*Diatoms, sponge spicules, and other forms of tiny marine life, sieved from an ocean sediment sample. These organisms provide many clues to important scientific problems such as age of the ocean basins and climatic history of the earth.*

The drilling program began in April and continued for about 1 month, with Foundation support to the Lamont Geological Observatory. The entire operation was under the supervision of JOIDES (Joint Oceanographic Institutions' Deep Earth Sampling), an organization composed of the University of Miami (Institute of Marine Science), University of California (Scripps Institution of Oceanography), Columbia University (Lamont Geological Observatory), and the Woods Hole Oceanographic Institution. Representatives of the U.S. Geological Survey and other institutions were aboard the drilling vessel *Caldrill*. The Pan American Petroleum Corp., which had the vessel under charter at that time, had agreed that JOIDES could use the vessel for such drilling at no cost for moving the vessel to or from the drill site. The ship was put to its most severe test when drilling at two sites bordering the Gulf Stream. Here currents of more than 3 knots were encountered, but they did not prevent the collection of long cores in this geologically important region.

Because of the short time since the completion of the sampling only preliminary results are available. These results which are described below amply demonstrate the success of the operation.

The core samples and seismological information concerning the region indicate that sedimentation has been a dominant factor in constructing the Shelf, Slope, and the Blake Plateau during the Tertiary Period (from 1 to 75 million years ago). The lower elevation of the Plateau is due in part to a thinner accumulation of sediments during the Tertiary Period rather than to shifting of the layers after formation.

Certain distinct underground layers were found to extend from under the land area to under the continental shelf. Fresh water aquifers (porous sloping underground layers of rock, lying between impermeable layers) were found some 22 miles offshore. Artesian water was encountered at a depth of between about 400 and 1,000 feet. It was under sufficient pressure so that it forced itself out of the drill hole and through the drill hole casing in a stream which rose to some 30 feet above the sea surface. This finding greatly increases the known fresh water reserves in the Florida-Georgia area. The geophysical records also indicated that the known mainland phosphate ore beds also extend under the Shelf.

In most of the holes nearly continuous layers were found from the Paleocene Epoch (60 million years ago) to the present. But on the middle part of the Blake Plateau sediments of the Middle Miocene Epoch (about 11 to 25 million years ago) are missing. Fossil evidence suggests that the layers have dropped downward since sedimentation occurred.

In the deepest portions of the inshore cores, shallow water fossils were found under deep water fossils and may be a valuable key in the interpretation of the history of this continental margin.

Turning from the past history of the earth to more contemporary and disturbing developments, some recent work on the mechanism of earthquakes is described below. This is an effort which may eventually lead to the possibility of predicting the location and time of future destructive disturbances, and as such assumes an importance well beyond the undoubted intellectual interest of the scientific work itself.

The Detection and Prediction of Earthquakes—The possibility of understanding and perhaps of predicting the occurrence of earthquakes is increasingly occupying the attentions of many U.S. scientists. A group of rather sophisticated experiments is presently underway along our most famous fault—the San Andreas in California. A recent study by a group of investigators at the California Institute of Technology has indicated that it is now possible to indicate more accurately than before areas likely to have earthquakes. Using data from over 10,000 earthquakes recorded by the Caltech network of seismological stations in Southern California from 1934 to 1963, maps were developed showing the average effects of earthquakes over the area, the average amount of strain released and the statistical distribution of earthquakes in any one district.

Virtually all of the earthquakes studied occurred in areas of abundant faulting, mainly branching from the great San Andreas Fault which slices 600 miles through California from beyond the Mexican border to the

Mendocino coast. This fault probably originated 50 or 60 million years ago. Surprisingly, it was discovered that the San Andreas itself is presently among the most seismically quiet areas in the region. It was also shown that Southern California has more than 200 locally felt earthquakes each year and can expect a magnitude eight shock (comparable to the San Francisco earthquake of 1906) about twice a century.

Clarence Allen, Charles Richter, and John Nordquist, of the Caltech Seismological Laboratory, and Pierre St. Amand, a geophysicist with the U.S. Navy, found that the areas of low earthquake activity include the Oceanside-San Diego-Tijuana region, the western and easternmost Mojave Desert, and the central San Joaquin Valley. Inasmuch as these areas also lack faults that show movements during the past million years, they probably are truly stable. San Diego, however, has been shaken during the past 10 years more often than other large Southern California cities, but this has been caused by earthquakes centered much farther south in Baja California. The earthquake hazard in any specific locality in California is less dependent upon nearness to a fault than most people suppose because no part of the region is very far from one or another

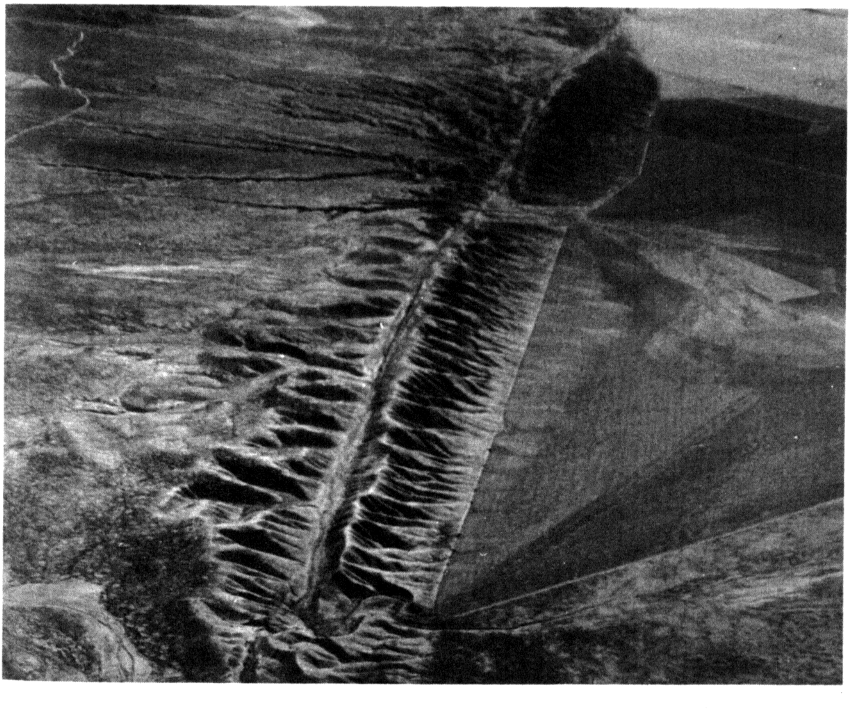

Figure 10.—*Aerial photograph shows clearly the demarcation line of the San Andreas fault, major source of earthquake activity, as it cuts across California. Several sophisticated research projects are under way with NSF support to determine characteristics, movement, and perhaps earthquake predictability based on this fault.*

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potentially active fault and because shaking caused by a large earthquake affects a very wide area.

Active areas, both from the aspects of faulting and earthquakes, include the Salton Sea trough, the Agua Blanca-San Miguel fault region south and east of Ensenada, most of the transverse mountain ranges (the Santa Ynez, Santa Monica, San Gabriel, and San Bernardino mountains), the central Mojave Desert, and most of Owens Valley.

If one were to name areas in Southern California where one would expect large earthquakes to occur in the future, it might be those areas which have considerable geologic evidence of fault activity within the past million years, but which for the past few years have been seismically quiet. The most obvious of these areas is the San Andreas Fault zone for several hundred miles northwest from San Bernardino, which has been suspiciously quiet for the past 30 years. Two other areas are the central Owens Valley and the Banning-Mission Creek fault zone along the east side of the Salton Sea.

An earthquake is believed to be caused by a sudden rupture along a line of weakness (a fault) in rocks where the seismic strain has been built up by the slow movement of the land off to one side of the fault in relation to the area on the other side of it. It is known that land west of the San Andreas Fault is moving northward at the rate of about 2 inches a year in relation to the land east of it. If no slipping occurs for a period of time along sections of this great fault to relieve the accumulating strain, then seismologists are likely to say: "We are due for an earthquake along such-and-such a segment of the fault."

Many seismologists believe that perhaps small, more or less continual slippage, occurs along sections of the San Andreas, thus relieving, at least in part, what is believed to be the accumulation of strain. Don Tocher, of the University of California, Berkeley, has for a number of years been measuring the differential movement of a cracked concrete floor of a winery near Hollister that is built right on the fault. The floor on one side of the crack is creeping some three-quarters of an inch per year in relation to the floor on the other side of it. There are indications of creep along other segments of the big fault—notably between San Luis Obispo and Bakersfield, and in parts of the Imperial Valley. However, the concrete lining of a water tunnel of the Owens Valley aqueduct directly through the fault has not cracked at the fault since it was built in 1913.

In the very active Imperial Valley, it is felt that moderate-sized earthquakes may be occurring often enough to prevent the building up of seismic strain that could trigger a great earthquake.

A related project presently underway at Caltech is designed to bring to bear every possible geophysical tool in an effort to better understand the San Andreas Fault, particularly with regard to problems of strain accumulation and strain release. The initial instrumentation effort is being concentrated in the Lake Hughes area, 40 miles northwest of Pasadena. Here the fault is well-defined and is bounded on both sides by well-exposed crystalline rocks.

Using seven trailer-mounted portable seismometers, earthquakes with magnitudes down to M=O are being systematically recorded, and initial results indicate that a considerable amount of micro-earthquake activity is, indeed, taking place along the fault.

Many seismologists now believe that these micro-earthquakes are related directly to the occurrence of larger quakes, and that rapid surveys of the micro-earthquake activity of a region can enable one to contour seismicity maps that would otherwise take years to prepare.

The Caltech scientists were fortunate enough to have occupied a site just before a larger quake near San Bernardino, and their measurements indicated that the number of micro-earthquakes definitely increased prior to the larger shock. Such a result, if substantiated by future work, is of the greatest interest for possible earthquake prediction.

Another research effort which promises to yield social and economic benefits concerns attempts to find better ways of initiating and controlling the precipitation of moisture from clouds. Unlike the other programs of the Division, the Weather Modification Program was established specifically for the purpose of obtaining knowledge which would have direct application to a national need.

A New Chemical Agent for Producing Artificial Precipitation From Clouds—The chemical urea, which is both plentiful and cheap, was tested as a cloud seeding agent in February 1965 over northern Wisconsin, and proved to be as effective or possibly even more effective than dry ice in triggering the release of snow from relatively thick, heavy layers of supercooled stratus clouds. Urea is particularly effective as a seeding agent because it markedly cools the solution into which it dissolves. Thus, when seeded into a cold cloud, it quickly produces ice crystals from the cloud droplets with which it comes into contact. It also has the advantage that, being a dry powder, it can be dispensed from an aircraft without the perishability problems inherent with dry ice, and without the thermal generators required for dispensing the commonly used seeding agent silver iodide. Its cost is about 5 cents a pound compared to 8 cents a pound for dry ice or $25 a pound for silver iodide. Morever, it can produce crystals in clouds warmer than −6° C., which is the maximum temperature at which ice crystals are formed by silver iodide.

The reason for the success of urea as a seeding agent was discovered by Robert Knollenberg, a graduate student of the University of Wisconsin, who worked on the NSF-supported Project Whitetop of the University of Chicago. Under the direction of Roscoe Braham, Mr. Knollenberg developed a more effective method for detecting freezing nuclei

Figure 11.—***Scientists from the National Center for Atmospheric Research collect aerosol samples in uncontaminated air over the Continental Divide in Colorado, in project to explore the hypothesis that occasional large freezing nuclei counts are associated with the presence of fresh stratospheric air and with certain meteoric showers.***

in a cold chamber, and was able to detect the almost invisible ice nuclei that were formed when finely milled urea powder was sifted into the cold chamber. These ice crystals were so small that they escaped observation by other researchers in the field who had tried and failed to find results when using coarsely ground urea powder. A combination of increased detection sensitivity and milling refinements in reducing urea to micro-sized particles provided the necessary answer. Further tests on urea and other materials which become cooler when dissolved in water are being continued by Mr. Knollenberg at the University of Wisconsin.

Turning to the field of physics, the next account concerns a new instrument which promises to have important applications to other research disciplines and technology. Coincidentally, the laser is a device which involves many of the same principles as those affecting the operation of the interferometer mentioned earlier in connection with the observation of elements of low abundance in atmospheres. In the case of the laser light energy of a very precise color is generated inside the interferometer and then allowed to leave the instrument whence it may be used for whatever purpose it is required.

Production of High-Power, Short-Pulse Duration Light Beams With the Aid of a Laser Containing Lead Vapor—Lasers, devices capable of producing very fine, very high intensity beams of light, have proven of great value for the conduct of basic research into the properties of solids and liquids. Indeed, their unique characteristics are already being exploited in medical and industrial applications—eye surgery, communications, etc. The laser beams are also capable of burning holes through metal objects. Recently an NSF grantee, Grant R. Fowles of the University of Utah managed to construct a laser in which the light beam was produced by a vapor of lead atoms. Previous lasers have used a variety of solids and gases to produce a light beam, but this laser is unique in several ways. In particular, a far greater fraction of the total light produced in the vapor (about 40 percent) can be extracted from this laser than from other lasers. In addition, the light beam is emitted in single short bursts of very high power, and not in a series of ragged bursts as in most other lasers. Since the trapping of light within lasers and the erratic light pulses from them have been problems in making certain laser devices, this new type of laser may well be technologically important.

It appears that a whole new family of important instruments for use in research and industrial applications may be about to emerge as a result of intensive research during the past several decades on the behavior of matter at very low temperatures.

The Design of Ultraprecise Instruments Based on the Results of Fundamental Research on Superconductivity—A great many metals and alloys are known to lose all resistance to the passage of electricity when cooled to very low temperatures. This condition is referred to as superconductivity, and has been one of the most puzzling enigmas of modern solid state physics. The fact that no material has ever been found to exhibit superconductivity at a temperature above −425° F. (35° above absolute zero) clearly shows that superconductivity could not exist in the presence of the strong vibrations of atoms associated with moderate or high temperatures.

This intriguing and peculiar phenomenon has been under intensive study in university, Government, and industrial laboratories with such good results that in the last 4 years an entirely new area of technological development has been created. For example, devices have been developed suitable for electrical switching and memory circuits for electronic computers that operate in less than a billionth of a second. Many of the university scientists whose contributions to fundamental knowledge about superconductivity have made possible this technological progress are grantees of the National Science Foundation.

Following World War II, the refrigeration equipment necessary to produce very low temperatures became commercially available, and scientific interest in low-temperature phenomena began to grow. This was particularly true after Fritz London of Duke University suggested that the electrons in superconductors might be governed by the same physical laws that apply to the motions of the electrons in isolated atoms. Electrons surrounding the nucleus of an atom are known to be in constant motion in well-defined and highly stable orbits. The fact that an electrical current flowing in a superconducting circuit will continue to flow as long as the circuit remains in the superconducting state was the basis for the hypothesis that a superconductor may possess electrical stability similar to that of electrons in atoms. In 1961 the first definitive evidence that this hypothesis is correct was obtained simultaneously by R. Doll and N. Nabauer in Germany and by William Fairbank and Bascomb Deaver of Stanford University working under an NSF grant. Following this, other experiments by NSF grantees William Little and Ronald Parks, also of Stanford University, and by J.E. Mercereau and L. T. Crane of the Ford Motor Co. showed that London's ideas were undoubtedly correct in giving a broad description of the superconducting state.

Almost immediately thereafter, two revolutionary additional ideas were proposed. B. D. Josephson, a graduate student at Cambridge University, predicted that electrons could pass between two separated superconductors without encountering any electrical resistance provided that a certain maximum current was not exceeded and the spacing between superconductors was sufficiently small. On the other hand, A.A. Abrikosov, a Russian theoretician, showed that an earlier theory by two other Russians, V. L. Ginzburg and L. D. Landau, predicted the nature of the effects to be expected when superconductors are placed in a magnetic field. Aspects of these ideas were subsequently confirmed by a great many experimenters, including NSF grantees Bernard Serin (Rutgers University), M. Tinkham (University of California, Berkeley), and R. D. Parks (University of Rochester), as well as investigators in the industrial laboratories at RCA, General Electric, Ford Motor Co., Westinghouse, and IBM, also in universities in England, France, and the Netherlands. Progress was so rapid and so many scientists were involved that NSF and other Federal agencies sponsored two international conferences, one in 1963 and one in 1964, to permit exchange of the latest information. In the space of a mere 2 years the interaction of superconductors with magnetic fields was thoroughly understood.

Meanwhile, J. E. Mercereau at the Ford Motor Co. found a way to use Josephson's idea to open an entirely new area of investigation. Put in its simplest terms, his program was to use superconducting circuits

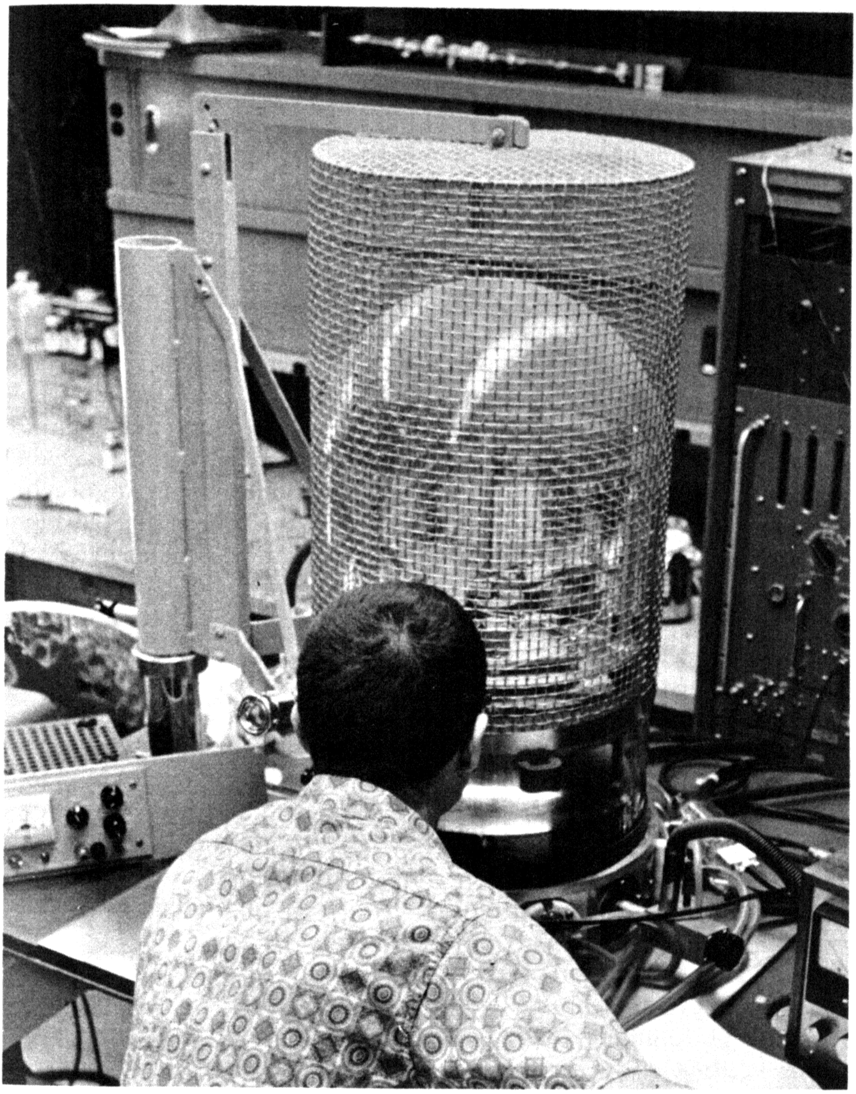


Figure 12.—*Stanford University scientist fabricating Josephson junction for research in superconductivity.*

to construct technological devices incorporating the advantages of stability and sensitivity which they possess. Thus far, these investigations have resulted in the development of instruments capable of measuring magnetic fields as small as one billionth of the earth's magnetic field, and of devices suitable for electrical switching and memory circuits in electronic computers capable of operating in less than a billionth of a second. Many other devices, such as highly stable "clocks" or frequency sources, have also been devised.

Another extraordinary phenomenon which occurs at very low temperatures is the manner in which liquid helium completely loses is viscosity. Since the following account compares this phenomenon to that of superconductivity, the reader may wish to refer to the foregoing paragraphs on that subject.

***Observations of Very Long Lived Vortices in Superfluid Helium*—** As the atoms or molecules of a gas are progressively cooled, the gas first condenses into a liquid and then ultimately freezes into a solid as the temperature goes lower and lower. This is true for every substance except helium gas, which remains a liquid even at absolute zero temperature unless a pressure of several atmospheres is applied to the liquid. As absolute zero is approached, liquid helium suddenly loses its viscosity and can flow unimpeded through even microscopic sized tubes. This phenomenon is called superfluidity, and bears a striking resemblance to superconductivity in that (1) in both phenomena particles are able to move without apparent friction, and (2) both phenomena are peculiar to temperatures in the region of absolute zero. It has been suggested that both obey the comparatively simple physical laws which govern the motions of electrons in atoms, and just as superconducting electrical circuits can support electrical currents for an arbitrarily long time without the presence of an energy source (such as a battery), so a superfluid should be able to support a vortex (i.e., a little eddy in the fluid) for an indefinite period.

An impediment to experimental verification of this idea is that vortices are too small to see, and thus have been extremely hard to detect.

However, after almost 15 years of developing techniques for observing superfluid vortices, two different types of experiments have suddenly proven successful. The first, developed by Fred Reif at the University of California in Berkeley, measures the velocity of electrically charged subatomic particles when accelerated in liquid helium. These particles become attached to certain types of helium vortices, and their electrical charge provides a means of detecting the motions of the vortices in the liquid. These studies have provided a tremendous advance in our understanding of the microscopic motions of a superfluid. A second type of experiment perfected by John D. Reppy at Yale University under NSF support and by W. Zimmermann at the University of Minnesota has led to the detection of other types of vortices by using the fact that they possess many of the physical properties of spinning gyroscopes. These vortices were shown to persist over very long periods of time without loss of energy, and to obey the basic physical principles originally suggested by the theory.

Many modern instruments depend for their operation on the use of parts, such as transistors, which must be made from materials of the greatest attainable purity. For these materials we must turn to the chemists. The following is an account of a promising new method for accomplishing the purification of inorganic compounds.

Producing Highly Purified Metal Compounds With Gas Chromatography—The gas chromatography process has been most useful in isolating highly purified organic compounds from mixtures of compounds. (Organic compounds contain carbon; most compounds found in living matter are of this kind.) Recently a significant breakthrough was made by a Foundation grantee, R. S. Juret of the University of Illinois in adapting this process to the separation of inorganic compounds.

In gas chromatography, the gas mixture to be analyzed is made to move past a stationary liquid or solid. The various components of the mixture deposit themselves at different points in the liquid or solid. The deposits usually differ in color. Because the process requires that the compounds being separated be in gaseous form, it was most successful when used with the more volatile organic compounds.

Dr. Juret in his new technique first combines metals with the element fluorine to form gaseous compounds. The mixture of metal fluoride compounds can then be separated by chromatography. Not only is this method of great general value to the analytical chemist, but it may become most useful in the preparation of high purity inorganic compounds for use as semiconductors.

Another segment of society to which the research activities of chemists are of inestimable value is that of the pharmaceutical and chemical manufacturing industries. The following research may lead to major savings in the design of new manufacturing processes.

Effects of Solvents on Organic Reactions—Most reactions of organic compounds, such as are used in making plastics, drugs, and detergents, are carried out in solution. It has become increasingly obvious in recent years that the solvent plays an active role in determining the course of such reactions. An important approach which has been used in an effort to understand reactions occurring in solution is that of making a systematic study of the manner in which the reactions are affected when changes in the composition of solvent mixtures are made. Energies of activation (the energies which must be supplied during a reaction in order to make it occur) are usually derived in each case and the details of the interaction between the reacting species and the solvent are deduced. Because of the difficulty in making the necessary measurements, however, the calculations have not properly taken into account the energy due to interaction between the reacting compounds and the solvent itself. As a consequence the theory of reactions in solutions has not been uniformly satisfactory.

Using a specially constructed calorimeter, Edward M. Arnett of the University of Pittsburgh has recently measured the temperature changes which occur on dissolving a wide variety of compounds in mixtures of water and alcohol. The results of this Foundation-supported research show that large and unexpected differences exist between the heat of solution of a compound in pure water and its heat of solution in a solvent containing small amounts of alcohol. Significantly, in the cases where direct comparison is possible, these differences exactly correspond to unexplained anomalies in activation energies which have previously been observed. Thus, for the organic chemist, Arnett's work has threefold importance: It provides the basis for understanding some puzzling phenomena; it demonstrates clearly that the energies of solution of the reactants cannot be ignored in interpreting activation data; and it provides the information necessary to correct activation energies so that valid conclusions can be drawn.

This has immediate value to chemical engineers. In designing commercial processes, they must be able to calculate quite exactly the amounts of heat which will be given off. They must also adjust the reaction conditions (including the type and amount of solvent) to obtain the maximum amount of product for the lowest cost. A detailed understanding of the interactions between solvents and reacting compounds can considerably reduce the need to get the necessary data for a specific process by trial and error methods, which are both costly and time-consuming.

The significance of these studies does not end here. One of the long-standing mysteries of chemistry is the structure of liquids, and particularly that of water. Many physical properties of water solutions are changed markedly by the addition of small amounts of alcohol. These variations have been analyzed by an English chemist, F. Franks; his recently published theory challenges some ideas which have been accepted for years. Arnett's results provide striking confirmation of Frank's interpretation, and may therefore contribute to the solution of one of the most fundamental problems in chemistry.

The foregoing account describes a method of understanding and controlling the reactions of large amounts of material, as one must when volume production is required. If one wishes really to understand what happens when two molecules come together, the following method has distinct advantages.

A New Technique for the Study of the Reactions Between Single Parts of Molecules—In most studies of the manner in which different chemical compounds react with one another, sizable batches of each compound (containing many millions of molecules) are allowed to react simultaneously with one another. Although each individual molecule reacts in some way with its neighbors, it was impossible to study the individual reactions. Instead, the scientist is limited to observing the total result of all the simultaneous reactions, such as the total heat given off and the chemical composition of the resulting product.

In recent years a new method which permits the study of reactions between single pairs of molecules has been developed. Batches of each type of molecule to be studied are first produced in the form of a gas. This gas is then allowed to escape from its container into a vacuum chamber through a series of fine holes, thus producing a thin beam of rapidly moving molecules. Two beams, each containing one of the two types of molecule to be studied, are then allowed to cross one another. At the intersection, collisions between molecules of the two types occur. As a result of the collisions, molecules are scattered out of the beams, sometimes without being changed physically, sometimes in a state of internal vibration, and occasionally with a different chemical composition from that which they had before the collision. By studying these collision fragments it is possible to obtain a great deal of detailed information about the individual molecular reactions.

Dudley Herschbach of Harvard University, a Foundation grantee, was one of the scientists who contributed materially to the development of the method. In 1965, he was given the American Chemical Society Award for Pure Research primarily in recognition of his work on molecular reactions.

By permitting beams of alkali metal molecules (sodium, potassium, rubidium, and cesium) to collide with beams of alkyl iodide molecules (where alkyl is a simple hydrocarbon group with 1 to 5 carbon atoms), he has made major progress in accounting for the distribution of the total energy of the reactions between the energy of motion and energy of internal vibration of the molecules scattered out of the beam.

Because of its complicated structure and specialized terminology, it is always very difficult to describe important results in modern mathematical research to a nonmathematical reader in a meaningful way. However, such research is important, and the following description of a case in which recent mathematics research has been able to assist communication engineers may be of interest.

The Mathematical Theory of Message Coding—The radio communication system which permitted photographs of Mars by the Mariner satellite to be relayed to Earth and reconstructed by computers in the form of high resolution photographs is based, in part, upon mathematical advances in information theory. Of particular importance has been the development of codes for use in transmitting the information in the pictures.

In communication channels, information is usually expressed as sequences of combinations of the binary digits 0 and 1 (BITS). However, noise and imperfections in the communication system may cause a "1" transmitted at a certain point in a message sequence to be received as a "0". The accuracy of each sequence must therefore be checked, and errors corrected, by transmitting with each message unit a sequence of check bits. The mathematical problem which arises is to devise check sequences corresponding to different messages in such a way that errors which are more likely to occur can be corrected or detected with the least amount of checking since transmission of any checking information is a very expensive matter. Codes of this kind due to R. W. Hamming, Bell Telephone Laboratory; J. E. Macdonald, IBM; R. C. Bose, University of North Carolina; D. K. Ray-Chaudhuri, IBM, have found important applications in modern communication systems.

It is characteristic of the nature of mathematical developments that sometimes seemingly unrelated areas of research find some point at which the basic problems to be solved turn out to be very similar. At such times the mathmatical tools developed in one area may become available to solve problems which had seemed insurmountable when attacked with the more limited insight of those working in the other area. Thus Bose has succeeded in showing the formal identity of certain problems which arise in information theory with certain problems in experimental design. However, it has also been recognized that problems in experimental design may be viewed as geometrical problems. In consequence, R. C. Bose and R. C. Burton have been able to answer an important question about properties of Hamming and Macdonald codes by noting the formal identity of this question to one which had already been solved concerning the characteristics of flat spaces in a finite geometry.

Engineering

The National Science Foundation supports a wide range of engineering research projects in many diversified areas, such as chemical and reaction kinetics and catalysis, solid and fluid mechanics, bio-medical engineering, dynamic behavior of structures, metallurgy and solid state materials, control and information theory, soil mechanics, electromagnetic phenomena, operations research, heat and mass transfer, and energy conversion.

Illustrative of the breadth of engineering research being supported by the Foundation are the following examples which describe important recent findings.

Parametric Pumping—Processes for the separation of mixtures into useful components have been of tremendous importance to the development of the chemical industry of the world. Many of the advances for making separations have been evolved during the twentieth century. For example, modern fractionation procedures used for the production of propane, gasoline, fuel oils, etc., are relatively recent developments. Processes for the separation of the isotopes of fissionable materials have been a new factor in the technology of atomic energy. More recently the development of chromatography into a useful technique for analytical separations has opened a host of new opportunities.

Currently a new and radically different process for separating fluid mixtures, such as saline water, has been devised by an NSF grantee, Richard Wilhelm of Princeton University. The feasibility of the process called parametric pumping, has been demonstrated in the laboratory, and research is now under way to determine circumstances where it can compete economically with such conventional separation processes as distillation and solvent extraction.

Parametric pumping is based upon the principle that the capacity of solids to absorb material from a solution varies with temperature. In the process a column containing a bed of porous, particulate, absorptive material, and a charge of fluid mixture is equipped at its ends with driving and driven pistons acting in tandem. The pistons in an alternating fashion move the fluid mixture through the particles of absorptive material. At the same time, a constant temperature difference is maintained between the ends of the column. This coupled heat and mass transfer process results in different solute concentrations at the column ends. This process is expected to provide a significant new separation tool leading to both basic research opportunities and industrial use.

Heat Transfer—Heat transfer is a broad subject which has applications in numerous engineering problems from the design of automobiles and household refrigerators to orbiting satellites and is important in extracting useful energy in nuclear fission or fusion processes. Numerous engineering devices involve some form of heat transfer for their successful operation.

For hundreds of years it has been known that the processes of boiling and condensation can be used to transfer heat at extremely high rates, yet it is only in recent times that some significant understanding of these processes has been achieved. Grants in this specific area of heat transfer research have been made to investigators at a number of leading universities in the United States. J. W. Westwater of the University of Illinois has developed unique techniques for taking high-speed motion pictures through a microscope in order to learn more about boiling and condensation phenomena. The results of this and other boiling-condensation research sponsored by the Foundation have led to smaller, lighter, less expensive, more efficient, and more reliable equipment utilizing boiling and/or condensation as the main heat-transfer mechanism.

Similarly, heat transfer by radiation has come into recent prominence. Applications of this mode of heat transfer are found in modern-day boilers, solar energy collectors, and the thermal design of manned and unmanned satellites. Here again, NSF grantees have been conducting both experimental and theoretical research. One particular group, at the University of California (Los Angeles), has studied the design of systems exposed to solar radiation and has concentrated upon the specification of surfaces which absorb, refect, and/or transmit solar radiation. Other subjects in radiation have been investigated, and the results have been published for use by design engineers in the above applications. The thermal comfort of astronauts and the satisfactory operation of electronic equipment in satellites are specifically influenced by research in radiation.

High-Resolution, Three-Dimensional, X-Ray Microscopy—In addition to support for radiation research in the long wave or heat range, the Foundation also has awarded grants for investigation in the short wavelength end of the spectrum. An example of this latter type of research is that dealing with holography, or wavefront reconstruction techniques, to overcome the inherent limitations of the conventional photographic process.

Holography is now being extended by NSF grantee, George Stroke of the University of Michigan, from the visible light spectrum to the X-ray range, heralding a possible fundamental advance in the optical aspects of photography. As a result of this new technique it may be possible to obtain three-dimensional micrographs of crystalline and amorphous materials with magnification of about 1 million diameters and resolution approaching 1 angstrom (100-millionth of a centimeter).

Unlike the ordinary photographic process, the image of an object is not recorded directly on the film in holography. Instead, the film records the interaction of the monochromatic light from the original source with the coherent light waves diffracted from the objects being viewed. Since each point on the film contains a record of what it sees from its specific position, the "negative" produced is made up of very fine interference fringes. By reversing the technique, it is possible to produce a visual image from the film and, just as perspective changes as a person moves his position, the resulting picture can be modified by changing the position of the light source, the film, or the viewer. In this manner it is possible to see objects which normally would be partially hidden by another object if the viewer were restricted to a single or unique perspective.

The discovery of the laser with its powerful coherent light source opened the way to new advances in holography. The investigator is extending the holography process from visible light frequencies to the X-ray range by developing techniques which permit the recording of information of dimensions 10,000 times smaller than the grain size of the best film now available. (In the past it was believed that the grain size was the limiting factor.) The net effect is to spread phase information in such a manner that it is no longer lost in the graininess of the film. He has also developed techniques which allow him to use a point source much larger than the resolution limit. In the X-ray range, it may be possible to obtain one angstrom resolution with a source size of 2,000 angstroms or more.

Biological and Medical Sciences

Basic research in the biological and medical sciences encompasses a variety of approaches to the problems of life, ranging from investigations into communities of whole organisms to attempts to understand the basic processes of life itself at the submicroscopic level. Current research support by the National Science Foundation provides help in every basic area of biological interest.

At the overall level of complete living organisms and systems are two fields of support. *Systematic biology* is concerned with organizing the knowledge of the diversity and variability among organisms, both recent and fossil, into a system that reflects evolutionary origins and relationships. The relationships between organisms and their environment are explored in the *environmental biology* program, which includes such fields of study as ecology, limnology, population dynamics, and biological productivity.

Physiological processes are examined in two programs. *Regulatory biology* is concerned with the general and organ physiology of plants and animals, including such aspects as neurophysiology, host-parasite relationships, and general aspects of animal and plant nutrition. Because an intact metabolism is mandatory for life, studies in *metabolic biology* involve all living organisms, and look into energy metabolism, purification of enzymes, nitrogen fixation, energy coupling factors, and other constituent parts of metabolic action. In addition, a special area of interest is *psychobiology,* which is concerned with human and animal behavior, and of the measurement and methods used in the study of behavior; research is conducted on vision, hearing, perception, motivation, and other aspects of behavior.

Research at the smallest, most basic levels of life, is that carried on at the molecular and cellular levels. *Molecular biology* encompasses investigations of the structure, organization, and interactions of constituent molecules and systems of molecules, and involves such phenomena as photosynthesis, vision, muscle contraction, and energy transfer. *Developmental biology* supports investigations at all levels of organization from the molecular to the organismal on problems of growth and cellular differentiation with considerable emphasis on the control of gene action in different developing systems. The nature of heredity itself is explored in *genetic biology,* which includes studies establishing the genetic basis for observed variation, finding new hereditary traits, and locating the genes on the chromosomes; studies of DNA, RNA, the genetic code, and nuclear cytology are included.

A discussion of research supported in all these fields cannot be complete in a single annual report. Because certain aspects of biology are at present advancing very rapidly, they will be given emphasis. The projects discussed are illustrative of the work supported by NSF in this highly important area of scientific endeavor.

Three times during the history of man and his civilization, human insight and understanding of biological systems have provoked a profound modification of human values, society, and culture. The primary revolution occurred in the dawn of history as man gradually understood the reproductive behavior of plants and animals. This led to their ultimate domestication with the consequent transformation of primitive man into civilized man within complex societies. A second revoluton occurred in the 18th and 19th centuries when the nature of infectious disease was established, with the subsequent development of methods of control resulting from giant leaps in medical knowledge. The application of these methods brought both sharp population increases and industrial expansion with a profound impact on technological development. In the middle 19th century Darwin's basic generalization of evolution, the third revolution, transformed man's image of himself and his place in nature leading to a moral and cultural reevaluation of Western civilization.

We are now immersed in a fourth biological revolution, the "molecular or genetic revolution" which will undoubtedly have social and cultural impact of far-reaching consequences probably greater than those resulting from the development of the cell and evolution concepts.

This has come about as a result of a fruitful fusion of physics, chemistry, and biology, reflecting biologists' efforts to understand underlying molecular mechanisms responsible for the myriad complexity of bioloigcal phenomena at all levels of organization, from the macromolecular to the level of populations and ecosystems. The Foundation is an active participant in this new explosion of biological information through its support of many of the most capable investigators in this area.

The Genetic Revolution.—We now know much about the manner in which hereditary information is transmitted from generation to generation and how this information is translated into the many cellular activities which characterize the living organism. Two classes of compounds found in all living organisms—nucleic acids and proteins—are key substances involved in the genetic process. The nucleic acids carry the hereditary information and provide the primary control over the activities and processes of all cells by specifying the proteins which the cell manufactures. Proteins are the substances which control the formation of most of the structural elements of the cell as well as the chemical reactions within it. All biological activity may be attributed to the behavior of proteins functioning as enzymes or as structural molecules within cells. In man there may be a million different kinds of proteins, many of which specify the particular behavior and function of the various cell types, such as muscle, nerve, and kidney.

One kind of nucleic acid, deoxyribonucleic acid (DNA) is found in the nucleus of the cell. It consists of a long double chain of thousands of small molecules (nucleotides) which attach to one another end-to-end to form the large helical DNA macromolecule. DNA is composed of only four different nucleotides in a practically limitless variety of sequences. A gene is now identified as a small specific sequence of nucleotides representing a portion of a much longer macromolecular sequence very much like the sequences of letters on a stock ticker tape designates a particular corporation. Each sequence of nucleotides defines a specific code word for a particular gene and each gene is distinct from every other gene by virtue of its characteristic nucleotide sequence. Each gene in turn determines the particular protein to be manufactured by specifying the order of combination of the 20 amino acids of which all proteins are composed. Man can now be defined genetically as 6 feet of a particular molecular sequence of carbon, hydrogen, oxygen, nitrogen, and phosphorus atoms—the length of DNA tightly coiled in the nucleus of an egg and in the nucleus of every adult cell, 5 billion paired nucleotide units long.

Cracking the genetic code in recent years has meant the deciphering of the direct relationship between the sequence of nucleotide bases in the nucleic acid code chain with a specific amino acid molecule of the protein chain. The triplet code, a sequence of three nucleotides, defines 1 of 20 amino acids. The DNA molecule does not of itself directly transmit the information for amino acid sequences to newly synthesized protein molecules; rather it transcribes its information by directed, enzymatic synthesis of another complementary nucleic acid chain known as RNA (ribonucleic acid) which differs slightly from DNA and is found in the cytoplasm outside the nucleus.

This messenger RNA conveys instructions for making the protein molecules from the gene to the protein-synthesizing machinery of the cell. Translation of genetic messages into protein molecules takes place on the polyribosomes which consist of a set of catalysts on ultramicroscopic particles (the ribosomes) held together by the long-chain messenger RNA. Specific carrier RNA molecules (transfer RNA) transport their respective amino acids to the messenger tape, read the RNA code words for each amino acid, line themselves up according to the coded sequence, and are zipped together into a protein chain.

This important generalization—"DNA makes RNA makes protein"—is the working hypothesis, the core around which much of biology currently functions.

It is interesting to note, however, that in the case of certain viruses which infect bacterial cells, the above generalization does not apply. These viruses, like other plant and animal viruses, have their genetic information coded into RNA macromolecules rather than DNA. Very recently, some exciting results were obtained in the laboratory of Sol Spiegelman, University of Illinois, which demonstrate a mechanism of viral RNA synthesis independent of DNA.

794-807 O—65——8

Dr. Spiegelman and his coworkers have isolated an enzyme from viral-infected bacterial cells identified as a "replicase" which is capable of catalyzing the test-tube synthesis of infectious viral RNA using a small amount of viral RNA as a primer plus the essential nucleotide precursors. The replicase is specific for each kind of viral RNA, since replicases isolated from one viral-infected bacterial cell cannot catalyze the synthesis of other kinds of viral RNA, nor can other RNA molecules serve as the primer for this enzymatic reaction. What is most exciting in these observations is the careful demonstration, by an elaborate dilution experiment (among other confirming experiments) that an infectious, biologically active RNA was synthesized in the test tube, probably the first successful experiment of this kind since Arthur Kornberg's demonstration of *in vitro* enzymatic synthesis of DNA in 1957. These observations will offer remarkable opportunities to manipulate a genetically active system and facilitate critical analyses of mechanisms involved in the fundamental biological process of genetic replication.

Although these studies represent major breakthroughs in molecular genetics, we are far from a complete understanding of the control mechanisms involved in gene function. What determines when a specific DNA sequence transcribes its message into RNA? Why do some genes function in some cells and not in others? This question of genetic regulation now represents a critical area of biological investigation. Work in microorganisms has demonstrated the existence of regulator genes—genes which turn other genes on or off, and this past year has seen a number of significant advances in our understanding of the genetic code and its operation.

One of the most fruitful biological approaches has been the analysis of the mode of action of suppressor genes. The phenomenon of genetic suppression has been known for many decades, but only recently has evidence been obtained indicating that suppression involved the genetic control of the cell's coding mechanism. Among the laboratories investigating this problem, that of A. Garen (Yale University) can be cited for contributing the most significant recent results. This group has been studying the suppression of "nonsense" mutations of the enzyme protein, alkaline phosphatase, in the bacterium *E. coli.* Nonsense mutations are genetic alterations that modify the normal course of protein synthesis by allowing only part of the protein chain to be formed. It is believed that the mutation generates a nonsense sequence that cannot code for any amino acid, causing the sequential growth of the protein chain to terminate prematurely on the polyribosome assembly line during synthesis. When a nonsense mutation is present in a strain that has an active suppressor gene, the coding defect is reversed and synthesis of the protein proceeds to completion.

To understand the mechanism of suppression, it is necessary to determine if the protein produced by suppression of a nonsense mutation is identical to the standard protein of the parental strain or if it differs by value of insertion of a new amino acid. Garen and his collaborators determined that the latter is the case by identifying and analyzing the effects of five different suppressor genes acting on the same class of nonsense mutations. By comparing the enzymatic characteristics of the *E. coli* alkaline phosphatases produced by the different suppressed strains, they determined that the suppression results in the formation of an altered enzyme and that each of the five different suppressor genes brought about a different kind of alteration in the enzyme's behavior. Apparently each suppressor gene causes the nonsense sequence to specify a different amino acid. That is, with one suppressor gene, the amino acid serine is specified; with a second, tyrosine is specified; and with a third suppressor gene, glutamine is specified. Thus, each suppressor gene can exercise control over the coding specificity of the nonsense sequence, and the same sequence can code for any of five different amino acids, depending upon which suppressor gene is acting. This represents an important first step

Figure 13.—***Strip of tape representing alanine RNA is examined by Cornell University scientist who, with aid of NSF grant, led a group that first determined the structure of a nucleic acid. Letters on the tape stand for the 77 nucleotides making up the RNA; twisted wires represent possible configurations of the RNA.***

in understanding the operation of intrinsic genetic control at the level of transcription of the genetic code.

A major breakthrough in our understanding of the genetic code and its transcription into RNA came as a result of the work by Robert W. Holley and his colleagues at Cornell University. They made the first determination of the structure or sequence of nucleotides in transfer ribonucleic acid (carrier RNA), 1 of the 20 transfer RNA's essential in protein synthesis. They determined the structure of alanine transfer RNA by identifying fragments found by complete enzymatic digestion, and subsequent careful reconstruction of the structure from small fragments. This relatively small nucleic acid molecule contains 77 nucleotides and represents the first time a known sequence of nucleotides has been specified, probably corresponding to a complementary sequence on DNA, the gene locus responsible for its synthesis. This means that techniques are now available for determining the sequence in all 20 transfer RNA's. In time, this may lead to a determination of the structure or nucleotide sequence in DNA and eventually the structure of specific genes.

From Egg to Man.—As genetics joins with cytology, embryology, and molecular biology in the search for understanding of growth, development, and cell differentiation in different biological systems, equally profound generalizations can be expected to emerge. Development is the translation of the genetic information stored in the egg into the ultimate unfolding of the adult organism.

The essential issue in development is the regulation and expression of the coded genetic information, particularly as it is illustrated in the synthesis of specific proteins characteristic of the orderly differentiation of specific cell types like muscle, nerve, kidney, skin, and red blood cells. Significant advances during the past year suggest that control of specific protein syntheses during the course of cell differentiation may operate through the translation mechanism on the polyribosome. From studies in a variety of differentiating systems—sporulating bacteria, germinating seeds, and maturing red blood cells—it is becoming evident that control of specific protein synthesis may also reside in the structural and functional relationships between the messenger RNA and the polyribosome.

An important advance in this area came from a continuing long-term study of the maturing vertebrate red blood cell in the laboratory of Paul Marks at Columbia University. The specific protein characterizing red cell differentiation is hemoglobin, the oxygen-transporting protein of the blood. In earlier studies this group demonstrated that polyribosomes are the site of protein synthesis in the intact immature red cell and it was further shown that the polyribosomes contain messenger RNA in a relatively stable form. By measuring the rates of incorporation of different amino acids, it has been shown that certain-sized polyribosomes are the site of globin synthesis. Studies with drugs which specifically inhibit protein synthesis have shown that the structure of the polyribosome may be altered in a manner suggesting that transferring RNA with the attached amino acid chain may also serve as an important factor in stabilizing polyribosomes. A more detailed analysis of polyribosome structure using combined techniques of electron microscopy and density gradient centrifugation have revealed polyribosomes which consist of as many as 20 individual ribosomes. The size distribution of polyribosomes was analyzed during the course of red cell differentiation. The immature, nucleated red cell is active in protein synthesis and contains virtually all ribosomes in the large polyribosome configuration. During differentiation to the nonnucleated, typical red cell, a decrease in protein-synthesizing capacity was observed associated with a fall in ribosome content and, more significantly, a decrease in the number and size of polyribosomes. Final maturation resulted in a progressive disaggregation of polyribosomes into smaller clusters and inactive ribosomes.

Although red cell differentiation is somewhat unique, the interesting observations reported here, relating structural configuration of the polyribosome to its function is of major importance as a control mechanism in differentiation and has been observed in other systems such as germinating plant embryos, developing lens, and differentiating feathers. For example, T. Humphreys at MIT reported that a compact quadripartite polyribosome found in maturing feather cells opens out into a linear structure when protein synthesis (keratin) becomes activated during the later stages of morphogenesis.

These interesting preliminary findings suggest that a number of different intracellular genetic control mechanisms are operating at different levels in the sequence "DNA makes RNA makes Protein" all of which require unravelling before we can fully understand embryonic development.

Molecular Evolution.—The advances in molecular biology have affected the entire range of the life sciences, even evolutionary biology.

A common assumption is that the classification of plants and animals should be based on evolutionary relationships. Of necessity past and present systems have relied solely on the outward expression of genetic information—how the organism looks in comparison with others. This is not always a good measure of relatedness, we know, because of convergence and other phenomena that result in distantly related organisms looking much alike. The best criterion would be a direct measure of genetic relatedness. Work begun in 1956 by Charles Sibley and his team at Cornell University has advanced to the stage where it is now possible to make this kind of measurement.

DNA molecules, which are the structural framework of chromosomes, normally exists as long-stranded double helices. When heated in the right environment the double helix unwinds and the strands separate. When cooled, they reform precisely as before. The "trick" that makes this phenomenon useful involves immobilizing the long, single, unwound strands in a porous gel matrix. Though cooled, they cannot reform. DNA from another organism is added. This DNA bears a radioactive label and mechanically is broken into tiny segments. The fragments slip through the porous gel and lock on to the entrapped whole strands. Only identical genetic components adhere. The unbound fragments are then washed away, and the remaining level of radioactivity is a direct numerical measure of comparability between the tested organisms.

Preliminary results show, for example, that man and mouse share about 20 percent identical genetic material, while man and monkey share 60 percent. Both man and mouse have about 10 percent in common with chickens, 5 percent with fish, and so far no measurable relationship with bacteria. With refinement, the technique should be sensitive enough to distinguish between closely related species, perhaps between the sexes of the same species. This quantitative system will open up heretofore scarcely imagined possibilities for understanding and manipulating evolutionary processes.

Social Sciences

The social sciences include several major disciplines—among them, anthropology, economics, economic and social geography, political science, social psychology, and sociology. All have the common purpose of scientific study of men in their relationships to one another, including the institutions and patterns of behavior that men have created. The specific techniques characteristically employed vary widely among these major disciplines, however, and among the growing number of specialized subdisciplines, such as psycholiguistics, demography, and others. Indeed, in training and in research techniques physical anthropologists typically have more in common with biologists than with economists; linguists may have had their basic training in social anthropology or in psychology; econometricians rarely have much in common with anthropologists, but they work closely with mathematicians and statisticians. The kinds of research problems typically chosen by each discipline tend to vary, too, as a result of the differences in investigators' backgrounds and their characteristic research techniques.

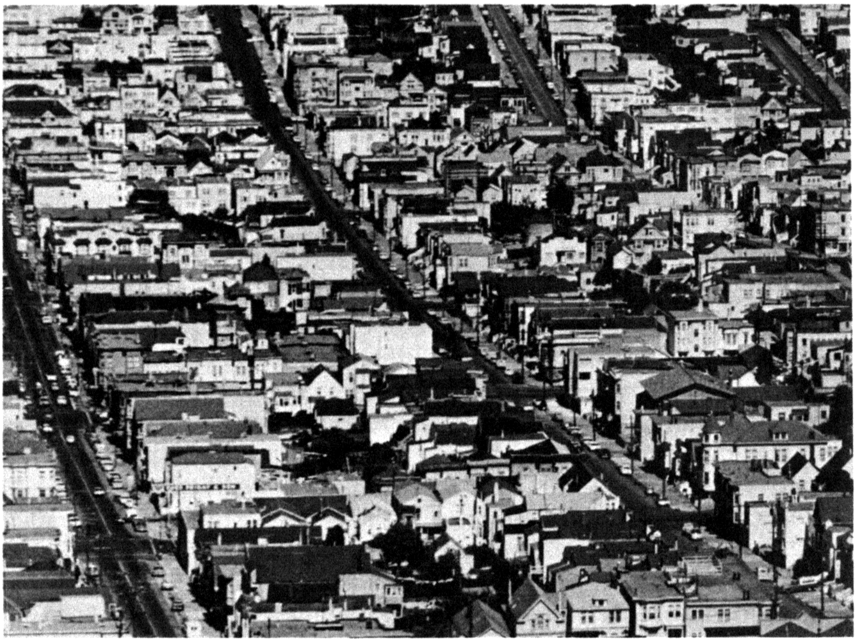
Nevertheless, because of their importance and susceptibility to many approaches, some subjects are being studied by almost the gamut of social scientists (often in collaboration with other scientists and engineers as well). As an illustration, the following paragraphs describe some of the recent and continuing work, aided by Foundation support, which touch on aspects of the general subject of urbanization.

Urbanization (Sociology).—Among the grants directly concerned with urban processes is an investigation recently begun by H. H. Winsborough at Duke University of the hierarchical relationship among cities, with one central city dominant and other cities as satellites, and the latter, in turn, as central places for smaller towns. Two different explanations of these hierarchical arrangements are being merged in an analysis which measures and analyzes the directions of communication flows among the cities, such as telephone messages, bank clearings and loans, and personnel exchanges.

A recent grant will support an effort by T. R. Anderson of the University of Iowa to describe and explain variations in characteristics of urban residential neighborhoods in terms of the spatial position of the neighborhoods (i.e., distance from major features of the urban environment, such as rivers and industrial locations). The analysis is based on a theory of dominance which holds that certain dominant features and facilities of a metropolitan area determine the distribution of residential neighborhoods and the character of their housing and population.

The transformation of the United States through migration from a society of isolated farms to one of interlocking systems of cities is being examined by a University of Wisconsin demographer, Karl Taeuber. A unique source of data for the investigation is available in the form of retrospective residence histories for a national sample of persons living in the United States in 1958, collected by the Bureau of the Census. These are the first migration data for the United States which permit tracing the pattern of successive moves within the lifetime of a person. Analysis of these data will answer many questions regarding both social change in the United States and changes in residential movements of individuals as they pass through various age periods. James Beshers, a sociologist at M.I.T., who is also concerned with the complexities of internal migration, received a grant to construct and test stochastic process models suitable for computer simulation of internal migration within the U.S.A.

Urbanization (Economics).—In an effort to develop better statistics for studying regional and area problems Karl A. Fox of Iowa State University has devised the concept of functional economic area (FEA). The U.S. Census Bureau has used the concept of standard metropolitan statistical areas (SMSA) each of which includes a central city of 50,000 population or more. The FEA, which includes the SMSA itself, takes cognizance of the impact of modern transportation and also includes any additional area within a commuting radius of 60 minutes from the central city. Extending the FEA scheme to cities of 25,000 to 50,000 which lie outside the 60-minute zone surrounding the central cities would enable a new pattern of area delineation for purposes of national statistics on population, national income and product, and employment. The vast majority (perhaps 90 percent) of the U.S. population and labor force would be included in statistical reporting units, every resident of which is within commuting radius of a central city of 25,000 people or more. At the center of each functional economic area would be the city or town which contains the largest cluster of economic activities and a large proportion of the population of the area. It is believed that this approach can serve the very important purpose of consolidating many different



Figures 14a–14b.—*Urbanization, in many forms and in many parts of the earth, is a subject of increasing interest to social scientists. Two forms of urban development well known in the United States, and now being studied in a variety of ways, are the crowded old cities (above) and the new suburbs (below).*

elements of our data systems on a basis which will be found a useful building block for all of them. Regional income and product accounts, labor market analysis, the need for transportation facilities and for public education and training could then be approached on a rational, functional basis rather than being divided into arbitrary units sometimes determined by happenstance.

Specific urban problems such as housing and transportation are receiving increased attention from a scientific point of view. Britton Harris of the University of Pennsylvania's Institute for Urban Studies is using data which were gathered for local planning purposes to test theories of the structure of housing markets by means of computer simulation. The anticipated outcome will be an operational model of the entire housing market, capable of predicting the costs and structure of residential accommodation in relevant detail and in a manner which can reflect changes resulting from factors such as transportation improvements, urban redevelopment, tax legislation, and the like. Walter Isard, of the Regional Science Research Institute, has been working on several aspects of urban place systems. One area of work has attempted to incorporate in one theoretical framework both the classical economic factors and the several noneconomic factors which influence decisions and behavior of individuals, firms, and other organizations. Current techniques emphasize efficiency and profit maximization. It is obvious, however, that such basic decisions as plant locations and the allocation of investment funds among regions involve many attitudinal factors and values which also restrict action. Development of an interregional theory and accounting framework which includes these kinds of considerations promises to advance our understanding of systems of urban complexes and the characteristics of metropolitan structure and function.

Urbanization (Anthropology).—Contemporary concern with urbanization and its effects is a worldwide phenomenon. Anthropologists have been working in Africa, Asia, Europe, and Latin America as well as in North America, on the effects of urbanization on traditional village life. Recent attention has been directed toward urban life itself where, in comparison with conditions found in primitive societies, individuals exist in a network which lacks the clearly demarcated units and boundaries of smaller societies. Among several recent grants on this subject is one to E. A. Hammel of the University of California who will study urban locations in Yugoslavia where the degree of industrialization, urbanization, and personal mobility has been very great since World War II and social networks are continually changing. These changes occur at least once for any peasant migrating to the city and constitute for many a continual series of shifting alliances. The research is directed toward understanding the process of personal adjustment necessary to urbanization and industrialization and, as such, has relevance to many emerging areas of the world.

And yet cities—and their attendant problems—are not new phenomena. Man's earliest civilization grew up around settled communities, and archeologists have attempted to reconstruct man's transition from primitive hunting-gathering bands to early agricultural villages to complex urban centers. The long-held hypothesis that man's earliest farming village communities appeared on the hilly flanks of the Taurus-Zagros arc in Iran and Iraq is now being questioned. Tentative hypotheses are now growing out of a reappraisal of the evidence for food production in early villages of the Mediterranean littoral and of inland Palestine and Syria. In particular the zone from Jordan to the Middle Euphrates is seen as the location of the development of the domestication of animals, independent of the development of the cultivation of cereals. Since prior theory had assumed that the growth of urban centers with their stratified society and specialized crafts was associated with the power and authority necessary for successful carrying on of irrigation, the new hypotheses raise many questions. M. N. van Loon of the University of Chicago is excavating in an area to be flooded by the Tabqa Reservoir in Syria where there are abundant remains of the early period of development. His findings should reveal data crucial to our understanding of the development of urban civilization in areas where irrigation was not a major factor in this step in human development.

It is also hoped that historical studies can add depth to our understanding of urban development. Charles Tilly of the Harvard-MIT Joint Center for Urban Studies, is conducting one such effort, focusing on available theory on the effects of urban concentration and attempting to test it by investigating the form and incidence of disorder over a 130-year period in France. The research asks where, when, under what conditions, and with what kinds of participants political disturbances occurred over a long period of urbanization, and what systematic changes in these characteristics appeared in the course of urbanization.

Archeological Anthropology.—A growing emphasis on the broader social and cultural significance of archeological research is reflected in recent and current research projects supported by NSF. In the United States, anthropology has traditionally embraced a number of fields. Archeology, linguistics, physical anthropology, and cultural anthropology have all been concerned with explaining man and his culture. However, despite a theoretical commitment to the whole, each discipline has tended to pursue its special interests with its own methodologies, making few notable contributions to the developing factual and theoretical base of its companions. Archeology has been no exception. Technical problems of excavation, of artifact analysis, of deciphering the internal chronology of sites, and of determining the time and cultural relationships between prehistoric societies have been of primary importance. However, as the substructure of archeological fact has become more firm, interest has quickened in the fashioning of interpretive techniques and in the application of these techniques to test constellations of raw data. In short, archeological statements now often move well beyond simple description.

Four important, and in some ways interrelated, areas of contemporary interest may be mentioned to illustrate this promising new trend.

One primary interest lies in the interpretation of the archeological remains of single prehistoric societies in broad social and cultural terms. Advancing well beyond the routine artifactual analysis, it is concerned with determining from these remains the social, economic, and religious systems of the society. For instance, at the prehistoric level, Paul S. Martin of the Chicago Natural History Museum has directed investigations in Arizona which have resulted in the reconstruction of the social structure of the peoples living at the Carter Ranch Site from 1100 to about 1250 A.D. The reconstruction is based on the assumption that patterns of behavior are reflected in patterned distributions of archeological data. "Behavioral meanings" can be determined with the aid of ethnographic and comparative evidence. For instance, some items are associated with certain economic, sociological, or religious activities, while classes of items reflect the composition of social segments, i.e., they may be used by men, women, hunters, housekeepers, and so forth. Thus it is possible, through sophisticated computer analysis, to interpret particular distributions of artifacts or style elements as reflecting the loci of particular activities or the loci of social segments.

The task of interpretation is somewhat different when records are available. A. Leo Oppenheim of The University of Chicago has been engaged in the translation and analysis of the information on more than 2,000 clay tablets recovered from the ancient city of Sippar in northern Babylon. This resulted in a careful tabulation of all specific features, from proper names to date formulas, from legal classifications to the names of fields, their dimensions, and their locations. The list of 20,000 names thus gathered did not constitute a representative cross section of the population of this large and important town of the middle third of the second millenium B.C. It clearly showed a twofold division: On the one hand were the ever-recurring names of an elite stratum consisting of officials, merchants, functionaries, and houseowners, and on the other, a large mass of names which appear rarely and represent the poorer inhabitants of Sippar. The texts give evidence of great municipal wealth, so much that it does not seem likely that it originated in agriculture. Since Sippar is situated at the border between the settled region of Babylonia and the "underdeveloped" region to the west, it is likely that its wealth originated in trade.

A second major interest of archeologists is the manipulation of data to derive generalizations of cross-cultural validity in regard to human behavior and the course of man's cultural development. The factors which influence, if not govern, culture change and the processes by which changes come about are being derived from the archeological record of specific prehistoric cultures placed in temporal and spatial relationship in order to discover the underlying principles of culture growth. For example, archeologists seek to isolate the factors prerequisite to the development of urban communities out of preurban settlement patterns. Donald W. Lathrap, Southern Illinois University, through intensive archeological investigation of the lowland and central highland areas of Peru is clarifying the complexities of contact between the sedentary, agricultural precursors of the high cultures of the Andes and the root crop economies of the tropical forests. His findings, coupled with the investigations at Dzibilchaltun (E. Wyllys Andrews, Tulane University) and Vera Cruz (James A. Ford, Florida State Museum), will contribute to our knowledge of the development and growth of civilization.

Another significant archeological interest focuses upon the details of the complex interrelationships prevailing between man's culture and his physical environment. Inquiry into how subsistence economics, settlement patterns, and other cultural complexes interlock as adaptations to specific facets of local environments, and how changes in one set of variables are responded to by changes in the other set are becoming of increasing concern to archeologists. David A. Baerreis (University of Wisconsin) is investigating the Oneota culture which appeared in the upper Mississippi River valley during the first millenium A.D. Interpretation of the changes in the culture has rested on a shift from dependence on agriculture to dependence on hunting associated with climatic change. Increasingly, archeological research is being conducted with the aid of teams of nonarcheological specialists, such as zoologists, botanists, paleoclimatologists, and geologists, not only to enrich the basic data but more especially to enlarge the scope of interpretation. In this instance, radiocarbon data, soil, pollen, and fauna provide evidence to test the hypothesis that the Oneota culture responded to cooler weather conditions and shorter growing seasons by turning to hunting, thereby losing much of its cultural richness and complexity.

Another study with ecological objectives is being carried out by Richard Woodbury of the Smithsonian Institution in which water management systems of both modern and ancient times are being compared and related to ethnographic information to draw broad conclusions about the relationship between water management, population density, settlement patterns, agricultural productivity, field patterns and social organizations. Systematic research provides the basis for inferences as to the levels of technological and social complexity associated with various types of water control systems.

Finally, a new and promising archeological interest joins forces with the biological anthropologist in attempting to comprehend more fully how human evolution came about. It has become increasingly evident that man's biological and cultural development for thousands of centuries proceeded hand-in-hand, exerting important influences on each other. As his early cultural and social behavior cannot be fully understood without reference to his biological structure, so the latter shows the effects of the former. A paramount issue in this regard is the effect of toolmaking and tool using on the biological evolution of man. Research which gives promise of shedding important light on this question is being conducted in Tanganyika, East Africa, by L. S. B. Leakey in his work on the early Pleistocene hominoids, the Australopithecus and *Homo habilis,* and by J. Desmond Clark (University of California, Berkeley) who is investigating in Nyasaland the development and variation of Pleistocene tools.

NATIONAL RESEARCH PROGRAMS

A number of widely varied research programs of particular significance to the Nation as a whole are the special responsibility of the Foundation. NSF's role varies with the nature of the individual program, but in each instance it stems from an assignment by the President, the Congress, or by agreement within the Executive Branch. For the most part these programs are maintained through grants to colleges and universities.

Six national research programs were in operation during fiscal year 1965.

United States Antarctic Research Program (USARP)

The Foundation funds, manages, and coordinates the national research program in Antarctica. Logistic support is provided by the U.S. Navy, using its own funds. Overall guidance of U.S. activities in Antarctica is provided by the Antarctic Policy Group, consisting of the Assistant Secretary of State for International Organization Affairs, the Assistant Secretary of Defense for International Security Affairs, and the Director of the Foundation. This Group was established during the past year.

The establishment in 1965 of the new Palmer Station on Anvers Island off the Antarctic Peninsula provided impetus particularly to biological investigations. With the closing, in February 1965, of Hallett Station, the United States now maintains a total of five year-round stations: Eights, Byrd, McMurdo, and Pole, in addition to Palmer. The USARP research vessel *Eltanin* provides a platform for work in atmospheric and marine sciences in the oceanic belt surrounding Antarctica.

The 14th major U.S. oversnow traverse was initiated to investigate the interior of East Antarctica, the last unexplored expanse of the continent. The 4-year South Pole-Queen Maud Land Traverse commenced with a first leg of 800 nautical miles, ending at the unoccupied U.S.S.R. station located at the "Pole of Inaccessibility," the point far-

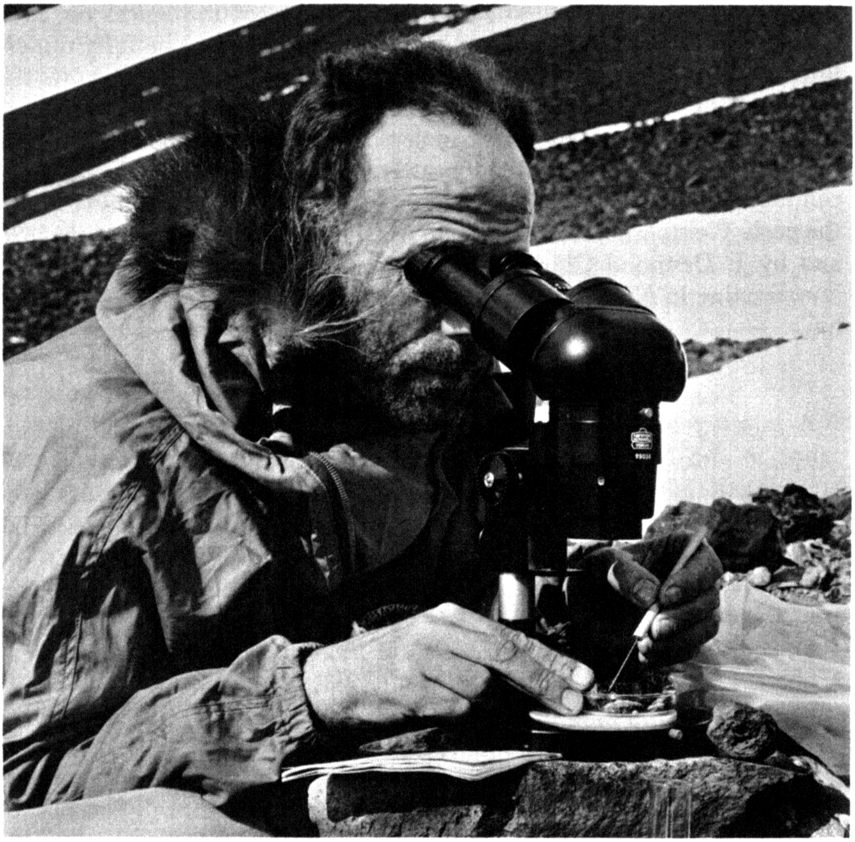


Figure 15.—***Scientist from Bishop Museum, Honolulu, examines soil in Antarctica for evidence of tiny insects and mites.***

thest from the sea. Seismic sounding measurements made at 29 stations, supplemented by gravity observations at 180 stations, showed a rugged subglacial topography near sea level in an area where elevations of the snow surface range from a minimum of 2,500 meters (8,200 feet) to about 3,700 meters (12,150 feet) at the traverse terminus. Indirect methods of determining annual snow accumulation gave tentative results varying from about 5 to 10 centimeters (2–4 inches) of water equivalent per year. A radar sounding device for determining ice thickness continuously from moving vehicles was tested over several areas in anticipation of its use on the traverse during the 1965–66 season.

Observations on the behavior and physiology of the Weddell seal were advanced during the 1964–65 Antarctic summer through the use of Scuba diving equipment and a sub-ice observation chamber especially constructed for the purpose. This chamber, the first device of its kind to be employed in the Antarctic, has opened up many possibilities for research *in situ* when suspended beneath the sea ice of McMurdo Sound.

Other summer programs in biology included research on fish, terrestrial arthropods, parasites, mosses, terrestrial and marine algae, the Adélie penguin, and egg proteins. The discovery of DDT (but no other pesticides) in McMurdo Sound seals, penguins, and fishes testified to the worldwide distribution of this insecticide, which was first released for civilian use in 1945.

A substantial cooperative program between New Zealand and the United States was successfully carried out in the Balleny Islands group from the icebreaker *Glacier*.

The *Eltanin* completed the work initially scheduled for the Scotia Sea and Drake Passage and turned her efforts to cruises across the South Pacific Ocean between Chile and New Zealand. Continuing her multidiscipline research program, the *Eltanin* steamed almost 35,000 nautical miles and completed oceanographic measurements and observations at 124 locations. During overhaul of the vessel in December-January, equipment for seismic and magnetic profiling was added.

Antarctic bottom cores obtained by the *Eltanin* are proving of great value in unraveling the glacial history of the Antarctic through studies of the planktonic radiolaria (microscopic animals found in ocean waters) which show contrast in type related to environmental factors. The pres-

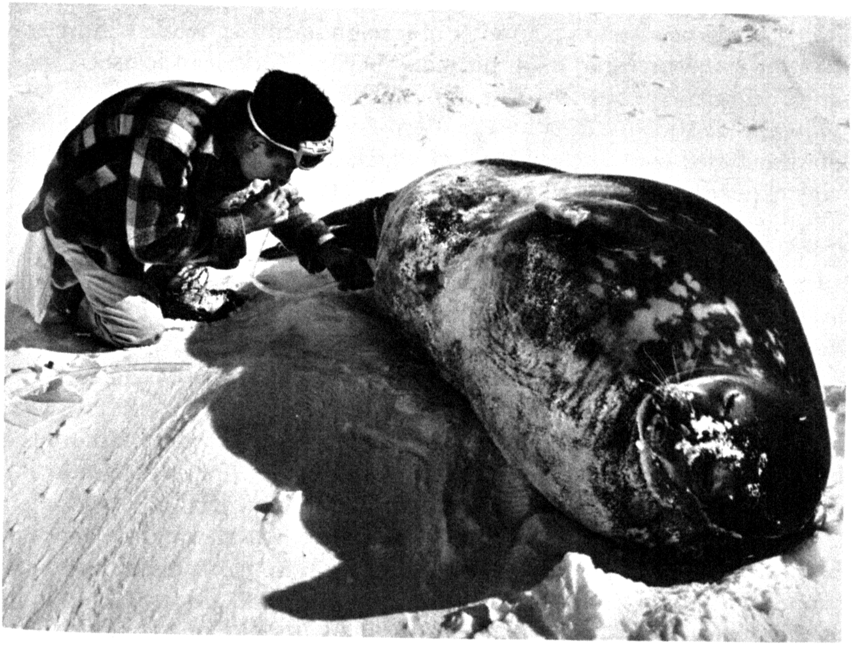


Figure 16.—***Laboratory technician at McMurdo Station, Antarctica, takes milk sample from Weddell seal, for use in University of Arizona project on the physiology of these deep-diving, cold-adapted mammals.***

ent location of the Antarctic Convergence, for example, marks a boundary between two distinct surface radiolaria types. Changes in the radiolarian grouping in sediments cored elsewhere under these waters are believed to represent past shifts in the position of the Convergence and the beginning of the glacial age in Antarctica at the end of the Tertiary period (about 70 million years ago).

Two satellite-monitoring projects were introduced into Antarctica in the past year. At Byrd Station a readout facility for ionospheric sounding satellites collects data for determining the diurnal, seasonal, and latitudinal variations of electron density along orbital paths. A Doppler-tracking system installed at McMurdo Station monitors geodetic satellites for data used in calculating the earth's gravity field and the shape of the geoid.

The world's longest antenna (21 miles) was laid out on the snow along a geomagnetic meridian at Byrd Station for upper atmospheric studies, principally of whistlers [1] and other very low frequency phenomena. In the past summer, the local field strength in the area for different antenna lengths was measured on the surface and from the air.

The number of U.S. scientific workers in the Antarctic in the 1964–65 summer increased by 14 over the previous summer to a total of 131. Again this year more than half of the scientists were engaged in biological and geological research. The 1965 wintering personnel numbered 38, 6 more than the low of 32 in the 1964 winter. As in previous years, the United States was host to a number of foreign scientists, while U.S. scientists were given access to areas normally beyond American logistic capabilities through the courtesy of foreign expeditions.

Fiscal year 1965 funding for the scientific work proper totaled $7,868,000 distributed over 134 projects, of which 53 were field projects. The Navy expended about $19.5 million for logistic support.

Deep Crustal Studies of the Earth (Project Mohole)

Project Mohole involves drilling at sea over the deep ocean basins through the earth's crust into the mantle. It is but one aspect of a much broader program for exploring the sea floor by deep drilling in as many of the world's oceanic regions as possible. Thus, Project Mohole should lead the way toward opening the deep portion of the earth to direct scrutiny and analysis by scientists. It has the broad and important objective of studying the earth directly as a planet rather than as a continent, an ocean, a deep sea canyon, or a high mountain peak.

Eighty-five percent of the earth by volume lies in the mantle beneath the crust. By studying the mantle—the forces at work there, chemical composition, age, origin—it will become possible to begin understanding the earth.

[1] So named because of its sound when converted to audible energy; it is an electromagnetic signal generated in the atmosphere in association with a stroke of lightning.

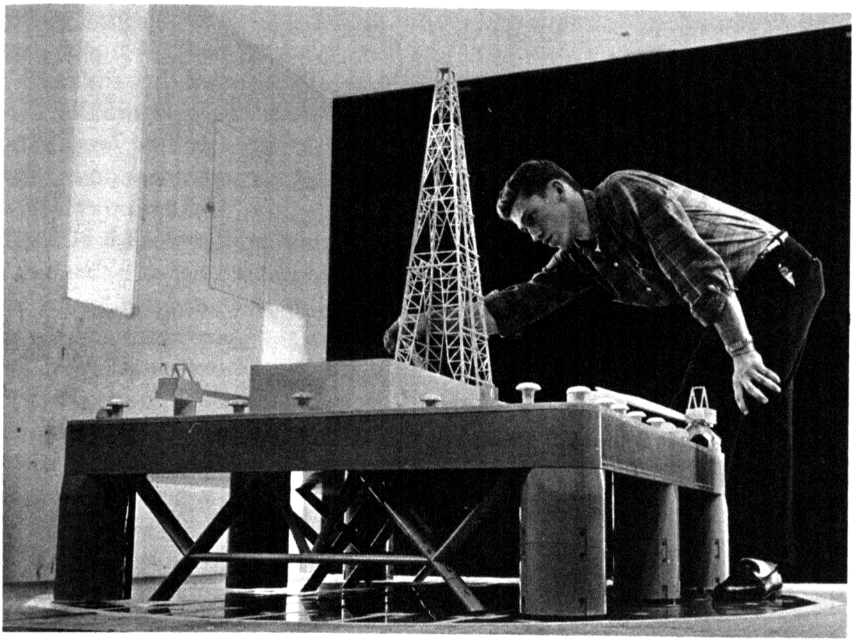


Figure 17.—*David Taylor Model Basin technician adjusts wind tunnel model of Project Mohole drilling platform, a part of the extensive testing program carried out on the conceptual design of the platform.*

Three years of intensive research and development have produced the design and specifications for equipment that can be used to sample the earth's oceanic crust from top to bottom. Where the earth's mantle is within reach (35,000 feet) it can also be sampled.

Design and specifications for a floating, unanchored drilling platform were completed in December 1964. The design work was done by Gibbs & Cox, Inc., in conjunction with the prime contractor for Project Mohole, Brown & Root, Inc., of Houston, Tex. Invitations for bids were sent to prequalified shipyards in March 1965.[2]

In addition to the above important development, a Mohole drilling site was recommended by the National Academy of Sciences Site Selection Committee and was approved by the National Science Foundation in January 1965. The site lies about 120 miles northeast of Honolulu, at approximately 22°22′ north and 155°28′ west; the depth to the mantle is between 28,000 and 31,000 feet (about 6 miles) below sea level, with the water depth being 14,000 feet. It is at the edge of the Hawaiian Arch which forms the basement complex of the Hawaiian Island Chain.

The Barracuda Fault Zone, lying about 200 miles to the east of the Caribbean Island of Antigua, was also thoroughly surveyed in late 1964.

[2] The successful bidder was National Steel and Shipbuilding Co. of San Diego, Calif., and the construction contract was awarded in October 1965.

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The most modern magnetic and seismic techniques were employed by the Offshore Exploration Co. of Houston, Tex., working under a subcontract with Brown & Root. An analysis of the results revealed that the earth's crust in that locality is considerably thicker than at the Hawaiian site; consequently, the site has been rejected as a Mohole drilling possibility.

Drilling to test various bits, coring devices, instrument packages, and logging equipment was completed at Uvalde, Tex., in December 1964. The drilling was carried out in a basaltic, volcanic plug which is believed similar to some of the rock expected to be encountered beneath the ocean floor. The hole was completed to a depth of more than 3,400 feet at an average drilling rate of about 5 feet per hour. Improvements made in the turbocoring equipment resulted in doubling the expected life of the turbocorer bearings and approximately doubling the drilling speed.

During drilling, cores were taken from the test hole over a large proportion of the distance, and samples were distributed to more than 30 scientists for analysis by a National Academy of Sciences Committee advising on the Project.

Twenty active research, development, and fabrication subcontracts are currently in progress. Thirty-eight subcontracts have been completed.

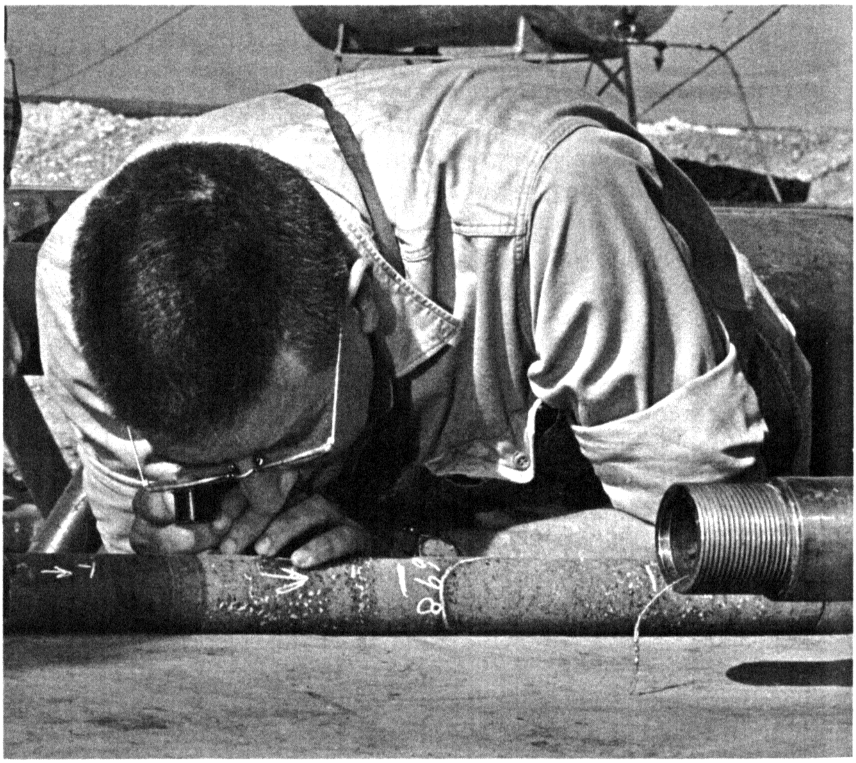


Figure 18.—***Scientist from U.S. Geological Survey examines core from Project Mohole test drilling at Uvalde, Tex.***

Approximately $24,700,000 was committed for Project Mohole during fiscal year 1965.

International Indian Ocean Expedition (IIOE)

This expedition has involved about 25 nations and 44 vessels and was originally sponsored by the nongovernmental International Council of Scientific Unions. Seven American institutions—the University of Hawaii, Woods Hole Oceanographic Institution, the University of Rhode Island, the University of Michigan, Stanford University, Columbia University (Lamont Geological Observatory), and the University of California (Scripps Institute of Oceanography)—have directly participated in major aspects of this expedition. In addition, meteorologists and oceanographers from more than 40 other American universities, institutions, and Government organizations have taken part in some aspects of the research activities. Government organizations participating include the Weather Bureau, Office of Naval Research, Bureau of Commercial Fisheries, and the Coast and Geodetic Survey. Furthermore, scientists from more than 30 countries have conducted investigations at U.S. installations and aboard the nine U.S. research vessels that have carried out major cruises into the Indian Ocean. Field observation began in July 1962 and was scheduled to end in December 1965. Data processing and analysis will of course extend beyond this period.

Geological and geophysical investigations in the Indian Ocean included thousands of miles of precision depth recordings. These will permit the mapping of the vast Indian Ocean basin. As a result of such depth recordings, it has now been confirmed that a mid-oceanic ridge with an associated rift valley, similar to the mid-Atlantic ridge, exists in the Indian Ocean. The presence of such ridges and rift valleys, found both on land and now on the ocean floors, is directly related to the forces that are shaping the earth. Submarine canyons and deep ocean trenches have also been discovered. Many gravity readings now exist in areas where there were no prior measurements. This has permitted numerous additions to the world gravity network and enhanced our knowledge of the earth's gravitational field. It has also been found that the general magnetic relief of the Indian Ocean is similar to that of the Atlantic and Pacific Oceans. This, in conjunction with data obtained from physiographic and magnetic studies of the ocean bottom, will make possible the delineation of geologic structures and systems not otherwise revealed. In the areas of intersecting ridges and rises, exceedingly complex heat flow patterns exist and support the concept that the detailed structure of the Indian Ocean basin is perhaps far more complicated than that of the other oceans. Seismic refraction and reflection profiles, along with sediment cores now under study, will also assist in unraveling the complex history and structure of the earth and its

Figure 19.—***Scientist from India and U.S. colleague, lowering a dredge from the*** **Anton Bruun,** ***U.S. biological research ship during the International Indian Ocean Expedition.***

ocean basins. Meteorological and biological investigations were also continued.

During fiscal year 1965, approximately $3.5 million were committed for IIOE projects.

Weather Modification

The drought in the East, the floods in the western plains, and the severe winter storms in the West during 1965 have again emphasized the need for developing useful techniques for modifying the weather. But even the most advanced seeding techniques cannot induce rainfall when water vapor is not present. Conversely, the large energies involved in severe storms when they gain momentum and maturity exceed the ability of man to cope with them. Means must be found to identify such storms while they are still in the nascent state and to apply some artificial mechanism which will inhibit their growth. Mitigating storms or increasing water vapor content requires basic knowledge which mankind does not yet possess. The goal of the National Science Foundation program in weather modification is to encourage research on a broad front directed toward understanding the pertinent atmospheric processes.

During fiscal year 1965, a total of $2 million was allocated by this program to universities and research institutes to initiate 28 projects. An additional $20 million was expended for basic research in the atmospheric sciences; of this amount $7.8 million was allocated to the National Center for Atmospheric Research. (See page 120.) The Foundation's Special Commission on Weather Modification formed working groups and held symposia and workshop sessions to study social, economic, statistical, ecological, legal, and international aspects. The National Academy of Sciences' Panel on Weather and Climate Modification has issued a preliminary report on the scientific aspects of weather modification. The Interdepartmental Committee for Atmospheric Sciences established a Select Panel on Weather Modification, and recommendations have been made by this group in the areas of fog dissipation and hail suppression. The Bureau of Reclamation initiated a program to develop an engineering approach to the artificial stimulation of

Figure 20.—***Multiple lightning strokes, photographed by University of Arizona scientist investigating atmospheric disturbances under NSF grant from the Weather Modification program.***

precipitation in order to increase the natural water resources of the Western States.

There is increasing evidence that many convective cloud systems over the Midwestern States contain an abundance of ice crystals in their natural states; however, radar evidence indicates that seeding these clouds with artificial ice-forming nuclei may stimulate additional rainfall within a 40-mile area downwind of the seeding line. Aircraft penetrations and radar studies indicate that the coagulation of many small cloud particles into larger raindrops often takes place in some supercooled clouds in the same way that rain is produced from warm tropical clouds. This has focused attention upon the internal turbulence and coagulation forces between cloud droplets rather than on the ice-forming mechanism, and opens a whole new approach to convective cloud modification. The role of cloud electrification as a possible coagulative mechanism has now assumed much greater importance.

United States-Japan Cooperative Science Program

This unique bilateral program in scientific cooperation was started in 1961 by conversations between President Kennedy and Prime Minister Ikeda. A Joint Committee, consisting of distinguished scientists from both countries, was formed to give scientific guidance to the program, to recommend areas for bilateral cooperation, to review and evaluate the projects underway, and to serve as an annual forum for discussion of problems common to science in the two countries. The National Science Foundation was asked by the Department of State to administer the program in this country. The program is cooperative both scientifically and financially, with each country supporting the activities of its citizens in the program. Three types of activities have been initiated—cooperative research projects; visits by scientists of one country to the other for purposes of research or lecturing; and scientific seminars, conferences, and planning meetings. During fiscal year 1965 this program involved approximately 300 American scientists and 320 of their Japanese colleagues.

This year 19 cooperative research projects were started, bringing the total since the beginning of the program to 53. Projects now going forward include research in earthquakes; deep sea seismic studies, hurricanes and typhoons; paleomagnetism—the determination of the magnitude and direction of magnetic fields in the past; clouds, and rainfall mechanisms; origins of volcanoes and hot springs in both countries; effect of ocean ice on weather; oceanographic studies; biological relationships between the fishes of the two countries; the relationship between fauna and flora of the United States and Japan and possible migration of plants and animals across the Pacific; wild monkey breeding habits; systematic studies of Pacific area insects; and luminescent marine organisms.

The 26 meetings and conferences held this year included a wide range of subjects such as wheat genetics, rainfall mechanisms, the molecular basis of infectious heredity, bioclimatology, narcotics and drug abuse, satellite data analysis, solar atmosphere, physical organic chemistry, pesticides, scientific information, and mechanical translation. Because of the importance of science education in both countries, and a feeling that exchanges of information and experience in this field would be important, conferences were held to discuss the teaching of mathematics, chemistry, and engineering.

One of the purposes of the program is to stimulate a wider knowledge of Japanese scientific activity and scientists by their U.S. colleagues. A strong effort has been made to send American scientists to Japan for varying periods of time to visit Japanese laboratories, give lectures, and do research. Last year the program sponsored 14 visits of this sort; the research interests of the visitors included subjects, such as ocean bottom sediments, mammalian cells and tissues, astrophysics, wave dynamics and their application in building coastal facilities, and ferroelectric crystals. In addition, 5 scientists visited Japan to prepare specific reports for the American scientific community on electron microscopy, colloid chemistry, plant physiology, rumen microbiology, and solid state physics.

Fiscal year 1965 funding amounted to $725,245. The program is now entering its fifth year, and is attracting increased interest both in this country and Japan.

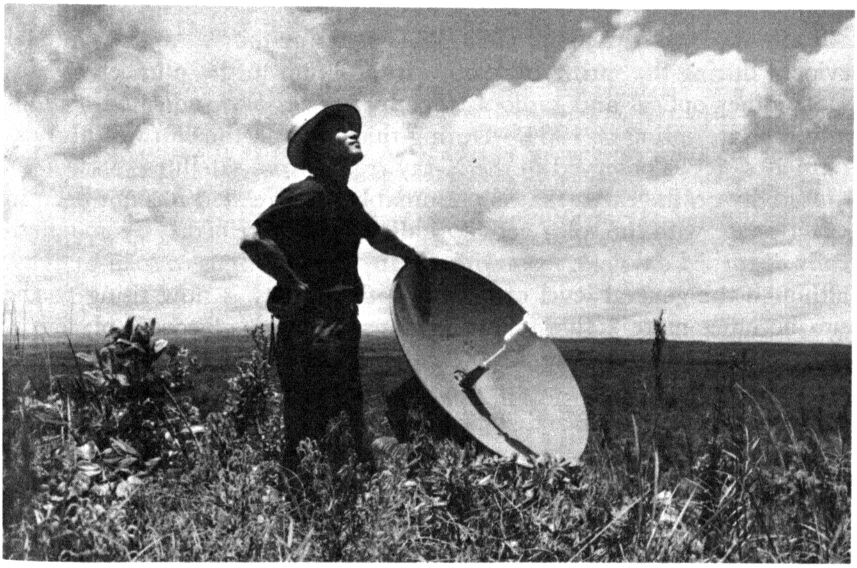


Figure 21.—***Japanese radiosonde receiving antenna being used on Mount Mauna Loa, Hawaii, as part of a joint study by United States and Japanese scientists of warm rainfall mechanisms. This research was carried out as part of the United States-Japan Cooperative Science Program.***

International Years of the Quiet Sun (IQSY)

The IQSY is a program of global geophysical observations designed to take advantage of the time of the sunspot minimum and to permit observations of phenomena which are more simply studied in the absence of disturbances produced by solar activity. The key point is that the observations are synoptic, implying simultaneous measurement of related phenomena over the globe. This is accomplished through international agreements to make observations in coordination, and to forward them to World Data Centers established for the purpose so that they may be available to all scientists. The international arrangements are primarily nongovernmental, arranged by the National Academy of Sciences with its counterparts in other countries on behalf of the scientific community The National Science Foundation provides governmental coordination for the U.S. part of the program, and is a major source of financial support for its special projects. These are reviewed and funded in response to proposals in the same way as support of other basic research.

The first full year of the IQSY program was completed during the fiscal year 1965. The observational program will end December 31, 1965. The emphasis to date has been on assembling the observations; an interval of analysis will follow during 1966 and 1967.

It has been established in retrospect that solar minimum actually occurred during the first part of 1964. The minimum of the sunspot cycle is in reality the low point between two overlapping cycles which can be distinguished by the magnetic polarity of the spots and their latitude on the sun. Thus, for example, the first spot of the new cycle was already observed in August 1963, while spots of the old cycle were still evident during the spring of 1965. In addition to the number of sunspots, other optical and radio astronomy indices also indicated a minimum in late spring of 1964. During this interval, the sun was also extremely quiet as observed in the X-ray region from satellites.

Activity on the earth that is presumably solar-related has not been in exact phase with the solar activity indices just described. Geomagnetically disturbed days can exist without any obvious signs of solar activity, although the general level of geomagnetic activity is now rising as the sun becomes more active following the minimum. Records of cosmic rays, ionospheric structure, and whistlers which travel through the magnetosphere, have in general responded as expected to the decline and subsequent rise in solar activity. However, the interaction is a complex one and not all indices move in unison. Detailed studies of data acquired during intervals of especially high or especially low activity during the IQSY are still to be undertaken.

Two special IQSY expeditions were undertaken during the year. The Equatorial Balloon Expedition involved launching high altitude balloons in India for about 10 universities, primarily for cosmic ray studies near the geomagnetic equator. The expedition was managed by the National

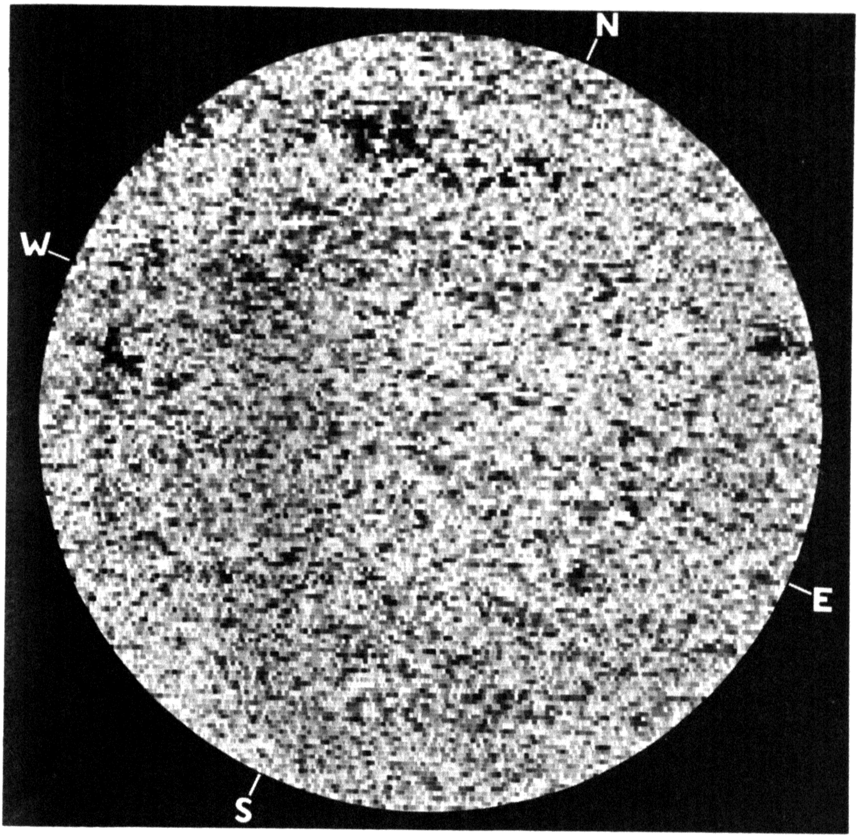


Figure 22.—*Magnetic structure of the quiet sun: reproduction of a color map of magnetic fields on the solar surface for November 5, 1964, produced by the Kitt Peak National Observatory. Each square represents 4,500 square miles; magnetic intensity is indicated by shades of gray, with white to black corresponding to a range of zero to more than 30 gauss (the earth's magnetic field averages about ½ gauss). Information provided by the map shows a noticeable bipolar general field of south polarity in the north, and north polarity in the south; and bipolar fields for the old-cycle sunspot fields in the south, and several new-cycle sunspot fields at high latitude in the north.*

Center for Atmospheric Research. The second expedition was to observe the solar eclipse of May 30, 1965, both from the astronomical and atmospheric sciences point of view. The ground-based activities of this expedition were coordinated by the Kitt Peak National Observatory and were centered on two islands in the South Pacific—the atoll of Manuae in the Cook Islands and the island of Bellingshausen in the Society Island group. Although the group on Manuae was clouded out, those on Bellingshausen were able to make useful observations. In addition to these ground-based groups, four jet aircraft equipped with optical windows and loaded with spectrographs and other optical instruments flew at altitudes up to 42,000 feet, rising above the clouds and extending the duration of totality by chasing the shadow. For the observers in one of these aircraft, totality lasted more than 9 minutes, the longest interval of total eclipse ever achieved. While the data secured from these expeditions have not yet been completely evaluated, it is clear that we now have an exciting new approach to use for such observations.

Including continued funding of projects started in the preceding year, 48 IQSY projects were funded during fiscal year 1965 at a cost of $3.6 million.

SPECIALIZED RESEARCH FACILITIES

As science progresses, the tools required—facilities and equipment—become more and more complex and expensive. At the same time, the financial capacity of the universities to provide these facilities is becoming more and more overtaxed. The Foundation, therefore, has been providing a limited amount of support to these institutions for the acquisition of facilities considered most essential to the advancement of basic research.

During fiscal year 1965, the Foundation made the following number and amount of grants for specialized research facilities.

	Number	Amount
Specialized Biological and Medical Sciences Research Facilities	22	$3, 750, 100
University Atmospheric Research Facilities	17	600, 050
Specialized Social Science Research Facilities	4	225, 000
University Computing Facilities	20	4, 515, 000
Oceanographic Research Vessels and Facilities	12	2, 966, 675
University Nuclear Research Facilities	3	11, 526, 600
Chemistry Research Instruments	56	1, 432, 500
Specialized Engineering Research Facilities	48	1, 174, 995
University Astronomy Research Facilities	2	1, 821, 000
Total	184	28, 011, 920

Of these 184 grants, two are of particular interest and are discussed in some detail.

Interferometer for Radio Astronomy—The resolution of the finer details of celestial radio sources requires the use of antenna systems having very large linear dimensions. For high resolution studies using radiowave lengths of the order of inches or tens of inches, the most economical antenna system has been found to consist of two or more steerable parabolic dishes that operate electronically as a single antenna, so arranged that the horizontal spacing between the dishes can be changed between sets of observations on a single object. Combining the successive sets of data thus obtained provides results in many ways similar to what might have been obtained had a single enormous steerable dish been used instead.

Groups of steerable dishes, such as those described, when used as a single unit are called interferometers. One of the first such radio interferometers to be built consists of a pair of steerable dishes, each 90 feet in diameter, located at the Owens Valley Radio Observatory of the California Institute of Technology. With the aid of this instrument the staff of the Observatory has made many outstanding contributions to astronomy, ranging from the discovery of the magnetic field of Jupiter to the determination of radio positions of quasars.

Despite its unique capabilities, this interferometer is severely limited in the rate and efficiency with which it can collect astronomical data by the size and number of component dishes. In response to the recommendations of the Whitford Report ("Ground-Based Astronomy, A Ten Year Program," National Academy of Sciences, 1964) the Foundation has made a grant of $1,645,000 to the California Institute of Technology for construction of a third steerable dish to be used as part of the interferometer. This dish, presently under construction, will be 130 feet

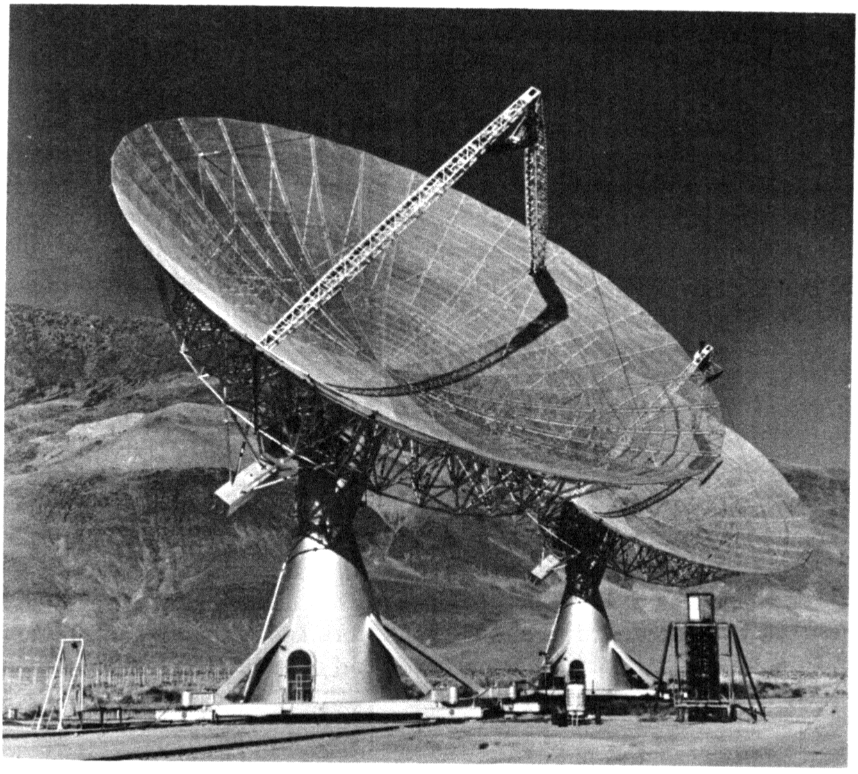


Figure 23.—*Twin 90′ radio telescopes used as interferometer, at California Institute of Technology; the NSF research facilities program is supporting addition of a 130′ dish to this array.*

in diameter. The newly established interferometer system at the National Radio Astronomy Observatory provides a complementary facility in the East available to the whole community of radio astronomers. (See page 107.) As presently constructed, the NRAO interferometer has much the longer base-line; it is expected, however, that the base-line of the Owens Valley interferometer will eventually be much increased.

Accelerator with Energy of 10 Billion Electron Volts—The interactions of electrons with other charged particles, such as those present in the nuclei of atoms, are governed by electromagnetic forces of a kind relatively well understood by theoretical physicists. Therefore, to determine the internal structure of a complex nuclear particle, it is often useful to bombard the particle with electrons and to observe the result of the collisions. The manner in which the collision fragments are dispersed after impact depends on the force between the electron and nuclear particles during impact and on the details of the structure of the target nucleus. Since the impact force is known, the nature and scattering pattern of the collision fragments gives clues to the structure of the original target nucleus.

To promote studies of this type, and on the recommendation of scientists including those of the Ramsey Panel (Report of the General Advisory Committee of the President's Science Advisory Committee Panel on High Energy Accelerator Physics, 1963) the Foundation contracted with Cornell University to build an electron accelerator with an energy of 10 billion electron volts (BeV) at an estimated cost of $11,300,000. During the several years prior to the signing of this contract, design studies had been carried out under two successive grants which totaled about $1.5 million. Of this about $1.06 million is attributed to the detailed design and preliminary costs of the accelerator and the remainder was for general studies of accelerator techniques.

With the exception of the Stanford University Linear Accelerator (Linac) which is designed to operate initially at 20 BeV, the Cornell machine will produce the highest available electron energies. Because the Cornell machine is of a design which produces electrons more nearly in a steady stream than does the Stanford Linac (which produces electrons in concentrated bunches), it has distinct advantages over the Linac for those types of experiments in which observation of detailed effects of individual collisions is required.

The design of the Cornell machine is well along, many components have been ordered, and preliminary site work and excavation of the tunnel to house the accelerator began at the end of June 1965. Completion is planned for 1968.

NATIONAL RESEARCH CENTERS

Each national research center maintained by the Foundation is essential to the Nation's basic research effort in a specific area of science. The Centers have been established because the cost of facilities and other requirements of their scientific programs render them unsuitable for operation by any single academic institution. Use of the facilities at the Centers is available to all qualified scientists without regard to their institutional affiliation, subject to priorities based on scientific merit and feasibility of the proposed research. These facilities are also used by resident staff scientists as well as by a limited number of graduate students.

The Centers are four in number—National Radio Astronomy Observatory (Green Bank, W. Va.), Kitt Peak National Observatory (Tucson, Ariz.), Cerro Tololo Inter-American Observatory (Chile), and the National Center for Atmospheric Research (Boulder, Colo.). These are Government-owned installations and are managed by independent nonprofit corporations composed of associations of universities.

NATIONAL RADIO ASTRONOMY OBSERVATORY

The National Radio Astronomy Observatory (NRAO), established in 1956 at Green Bank, W. Va., is a center dedicated to the study of the external universe through use of radio telescopes. NRAO is operated by Associated Universities, Inc., under a contract with NSF.

Facilities and Instrumentation

Research at the NRAO is centered on the use of large radio telescopes and the specialized auxiliary equipment used in conjunction with them. The principal telescopes in operation during fiscal year 1965 were the 300-foot diameter transit paraboloid and two 85-foot diameter fully steerable paraboloids. The two 85-foot telescopes are operated together as a variable baseline interferometer. (See page 104 for a discussion of a similar interferometer at the Owens Valley Radio Observatory of the California Institute of Technology.) These instruments were in use 24 hours per day throughout the year aside from minor interruptions for maintenance by visiting and staff scientists. Several smaller, special-purpose instruments, including 40-foot and 30-foot diameter paraboloids and a 120-foot calibration horn, were also in use.

The 140-foot diameter radio telescope, which has been under construction since 1958, was completed in June 1965. It is a fully steerable, solid surface paraboloid of high precision, capable of operating at wave-

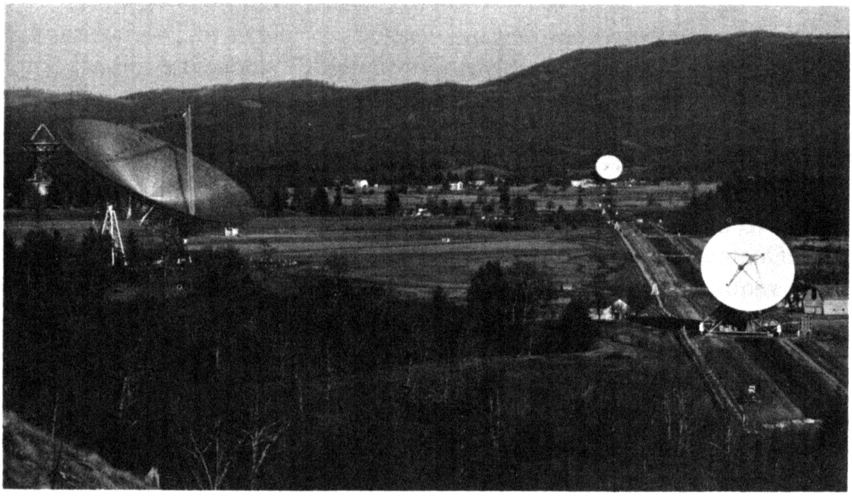


Figure 24.—***The four major instruments of the National Radio Astronomy Observatory, Green Bank, W. Va.—the 140′ dish (far left, pointing toward the zenith), the 300′ antenna, and the two 85′ radio telescopes, here being used together as an interferometer.***

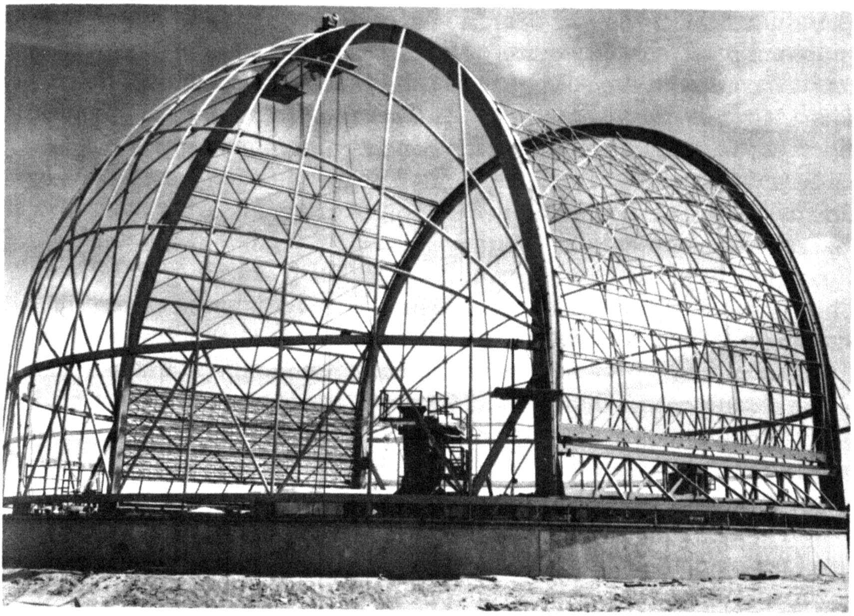
lengths down to about 1 cm. Preliminary tests of the instrument indicate that its performance is excellent.

Construction was begun during the year on a 36-foot diameter millimeter-wave telescope that should be capable of making significant scientific contributions at wavelengths as short as 1 mm. This telescope is expected to go into operation in fiscal year 1966. Because millimeter-wave observations require dry atmospheric conditions, the telescope will be located at the Kitt Peak National Observatory in Arizona. It will be operated as a field station by the NRAO, with the close cooperation of the Kitt Peak National Observatory.

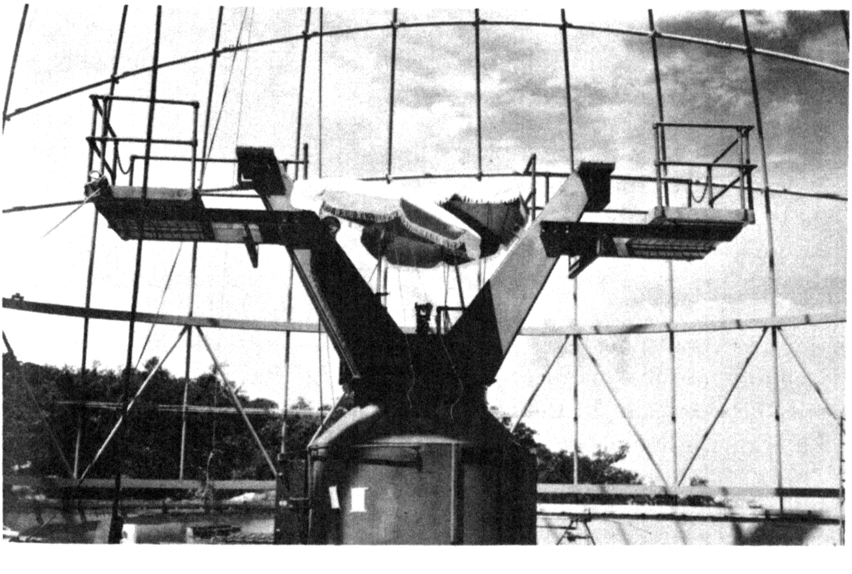
A number of additional radiometer systems were developed for use with various NRAO telescopes. Particularly noteworthy is the 100-channel autocorrelation receiver for hydrogen-line studies which went into routine operation in October 1964. This receiver, used with the 300-foot telescope, has already produced more than one-third of a million hydrogen-line velocity profiles for analysis by visiting and staff scientists.

The Observatory's computing facility was expanded during the year to meet the increased need for data processing and analysis being generated by users of the NRAO telescopes.

Very Large Antenna Array (VLA) Project. The Observatory is undertaking the design of a very large array of antennas, with the advice of a number of radio astronomers throughout the Nation. Being investigated are various array configurations that operate at an 11-cm. wavelength (usable also at 3 and 21 cm.), have a resolution of 10 arc



Figures 25a–25b.—*Installation for the 36′ millimeter-wave radio telescope, to be operated on Kitt Peak by the National Radio Astronomy Observatory. Above—steel dome structure; below—alt-azimuth mounting.*



seconds, a field of view of 5 arc minutes between grating lobes, and a minimum detectable flux density of 0.02 flux units. These specifications are in accord with those suggested in the National Academy of Sciences report, *Ground Based Astronomy, A Ten Year Program* (the Whitford report). The design will be greatly dependent upon the experience now being gained with the NRAO long-baseline interferometer that has already indicated the feasibility of constructing an array with those characteristics.

Largest Feasible Steerable Paraboloid Telescope (LFSP) Project. The Whitford report also suggested the need for a large steerable, filled-aperture telescope. More than a dozen of the Nation's leading radio astronomers met at NRAO to determine in a preliminary manner some of the characteristics that such an antenna should possess. Most of the participants agreed to the following characteristics: The telescope should have a nearly circular beam and as large a declination coverage as possible—at least 70°. To permit reasonable integration times, the antenna should track in hour angle for at least 1 hour, although full azimuth coverage is not mandatory. The telescope should be reasonably efficient down to 10-cm. wavelength, but should be fully operable at 18 cm. Consensus was reached that since telescopes of diameters up to 400 feet are well within present-day technology, the feasibility study should concern itself with instruments considerably larger than this. A small engineering group was formed to investigate a number of design concepts. Although this project has priority second to that of the array, a large antenna having the aforementioned characteristics could probably be constructed within 8 to 10 years.

Research Programs

A wide variety of research programs was carried out in fiscal year 1965 by visiting and staff scientists with the principal observations being made on the 300-foot transit telescope. Investigations using the 21-cm. hydrogen line are developing a detailed, high-resolution picture of the distribution and motion of neutral hydrogen in the Milky Way and surrounding galaxies. These studies are leading to greatly increased understanding of the dynamics and evolution of galaxies, and of the interactions between stars in the interstellar gas. Of particular interest are the absorption line observations by T. K. Menon (NRAO) and D. R. Williams (University of California, Berkeley) which suggest that a significant fraction of the interstellar gas may consist of very dense clouds. Such a conclusion would require a major revision in current estimates of the total mass of neutral hydrogen in the Milky Way system.

Significant results were also obtained from studies of the discrete sources of radio emission. A catalog of more than 700 sources, giving intensities at 2 frequencies and positions accurate to about 20 arc seconds, was completed with the aid of observations made with the 300-foot telescope. This catalog comprises the most extensive list of accurate positions yet available, and as such is of great value in connection with many other studies of these discrete sources. A positional accuracy of about 1 arc second has been achieved with the NRAO interferometer for a smaller number of sources. The interferometer has also yielded details of the structure of a number of sources, with a resolution never before achieved.

On July 9, 1965, B. Hoglund, a visiting scientist from Sweden, and P. G. Mezger (NRAO) discovered a new emission line of atomic hydrogen, thus confirming the discovery by two Soviet groups in 1964 of the probable existence of a whole system of such emission lines. Their observations open up a new area of radio astronomy research, which will yield new information about the clouds of ionized hydrogen gas in the galaxy.

M. S. Roberts has derived the radial velocity map, rotation curve, and neutral hydrogen distribution for a number of extragalactic systems using the 21-cm. line receiver on the 300-foot telescope. The velocity distributions in many galaxies, notably the Andromeda Nebula, are very com-

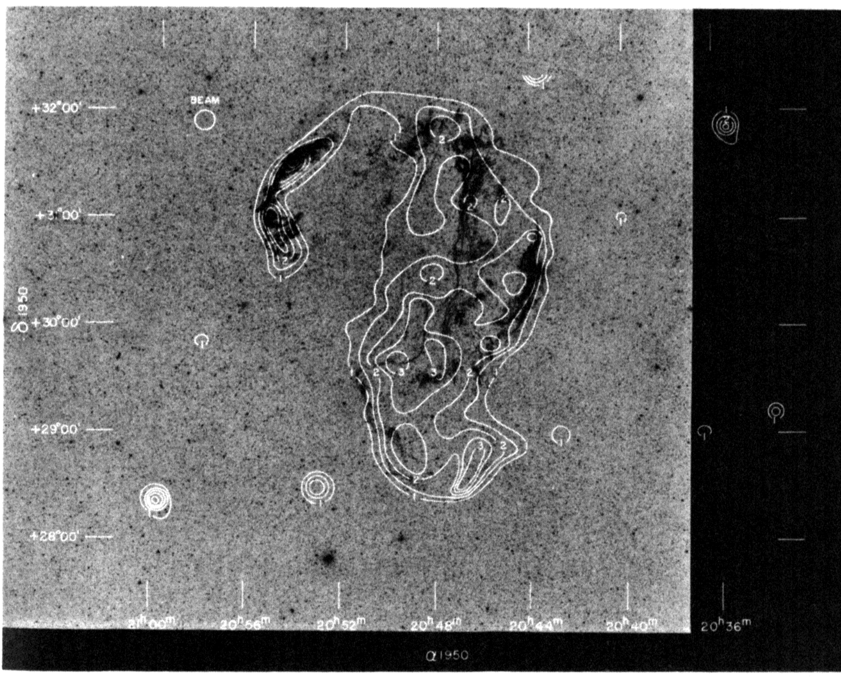


Figure 26.—*A radio contour map of the region of the Cygnus Loop, superposed on a Palomar Sky Survey photograph of the same region. The white lines are contours of equal radio frequency intensity, obtained with the NRAO 300′ telescope at 21 cm. This object is believed to be the remnant of a supernova explosion. The close correspondence between radio and optical emission gives astronomers important clues about the nature of the physical processes at work.*

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plex, and some galaxies appear to have hydrogen "companions" located well away from the main body of the galaxies and having no apparent optical counterpart.

W. E. Howard (NRAO) and G. Westerhout (University of Maryland) have undertaken a study of the neutral hydrogen distribution in galactic clusters using the autocorrelation receiver on the 300-foot antenna. First results show that about two-thirds of the clusters contain measurable amounts of hydrogen and that nearly all young clusters contain hydrogen.

Observations of a large number of planetary nebulae have been completed at 750 and 1,415 MHz (megacycles per second) by T. K. Menon and Y. Terzian (Indiana) and by M. Kaftan-Kassim, using the 300-foot antenna. While most of these nebulae have thermal spectra, as expected, a few do not; these few will be promising objects to observe in the future by both optical and radio techniques.

B. Burke and K. Turner (both of Carnegie Institution of Washington) made observations with the 300-foot antenna to derive low frequency flux densities of discrete sources and to investigate the galactic halo. They found no evidence for such a halo, in contrast to other observations at somewhat higher frequencies.

A major long-term intensity calibration program involving the source Cas A has been completed by Findlay, Hvatum, and Waltman, using the 120-foot horn. They have accurately determined its flux density to be $2370 \pm 7 =$ flux units at 1,440 MHz in 1963. The source is decreasing in intensity at a rate of 1.75 ± 0.50 percent per year.

Visitors, Students, and Staff

Approximately 30 visiting scientists from 18 different institutions made use of the NRAO facilities during the course of the year. This high rate is consistent with observatory policy which ensures that at least 60 percent of the observing time on each telescope be available to visitors. More than 70 percent of the 300-foot telescope observing time, for example, was utilized by visitors.

The Observatory encourages the use of its facilities by graduate students engaged in thesis work. Normally they work under the general direction of both a staff member and their academic advisor at the home institution. During fiscal year 1965, seven graduate students from as many universities did Ph. D. thesis work at the Observatory. During the summer the Observatory attracts approximately 25 graduate and undergraduate students who work under the direction of the scientific staff and attend an extensive series of lectures on all aspects of radio astronomy. This year the Observatory received more than 70 applications for these summer positions.

In addition to observing time on the telescopes, visitors and students have free use of the Observatory's laboratory, library, and computer fa-

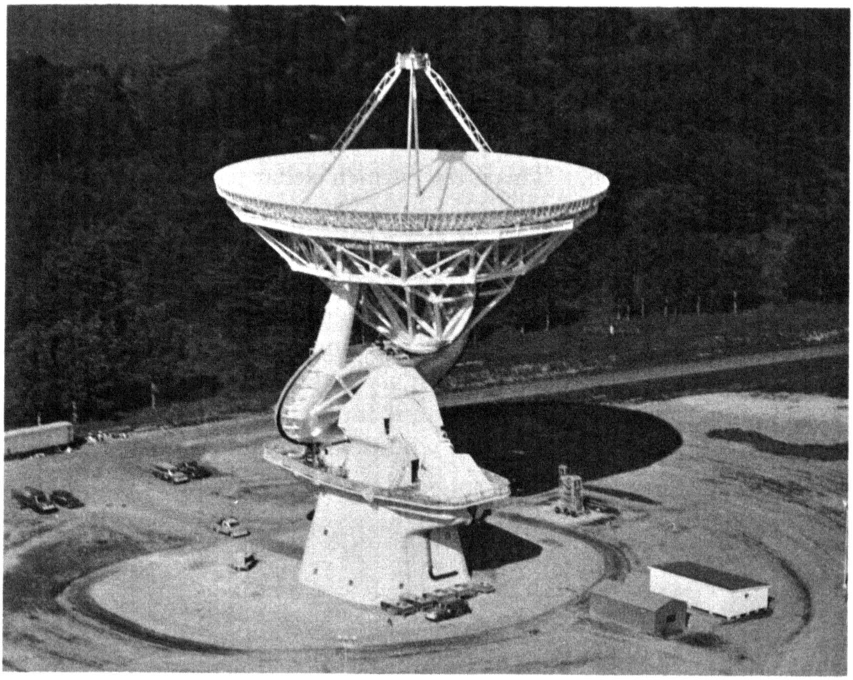

Figure 27.—*NRAO's 140′ fully steerable, high precision radio telescope, completed in 1965.*

cilities. They also receive technical assistance, as needed, from the Observatory technical staff.

The Observatory has a full complement of telescope operators to run the telescopes; an electronics and engineering staff to plan, build, and maintain the equipment, and programers and computer operators to assist in the data reduction and analysis. Experience has shown the need for capable supporting personnel to service, assist, and participate in the scientific activity of the Observatory, particularly to facilitate the use of the NRAO equipment by visitors who are often not well acquainted with the details of the operations. At the end of fiscal year 1965, the scientific staff consisted of 15 scientists on the permanent staff, 11 on temporary appointments, and 10 structural, mechanical, and electronic engineers. The total permanent NRAO staff was 180.

KITT PEAK NATIONAL OBSERVATORY

The second national research facility established by NSF is the Kitt Peak National Observatory (KPNO), which exists to provide optical astronomers with modern telescopes at an excellent site in a good climate. The Observatory is located 45 miles southwest of Tucson, Ariz., on Kitt Peak which is 6,875 feet high. The KPNO administrative headquarters are in Tucson. KPNO is managed by the Association of Universities for Research in Astronomy, Inc. (AURA) for the Foundation.

Instrumentation and Associated Research Programs

In September 1964 the Observatory's second major instrument came into regular operation. This is the 84-inch stellar telescope, the world's fifth largest. The optical performance of the telescope was critically tested by observations of close double stars and surface features on the moon and the planets. It was concluded that the resolving power and the concentration of light into a sharp image are excellent and approach the limit to be expected during the best atmospheric conditions.

Toward the end of the fiscal year, a very large and powerful spectrograph at the coudé focus came into use for high-dispersion spectroscopic programs. These are concerned with determination of stellar physical

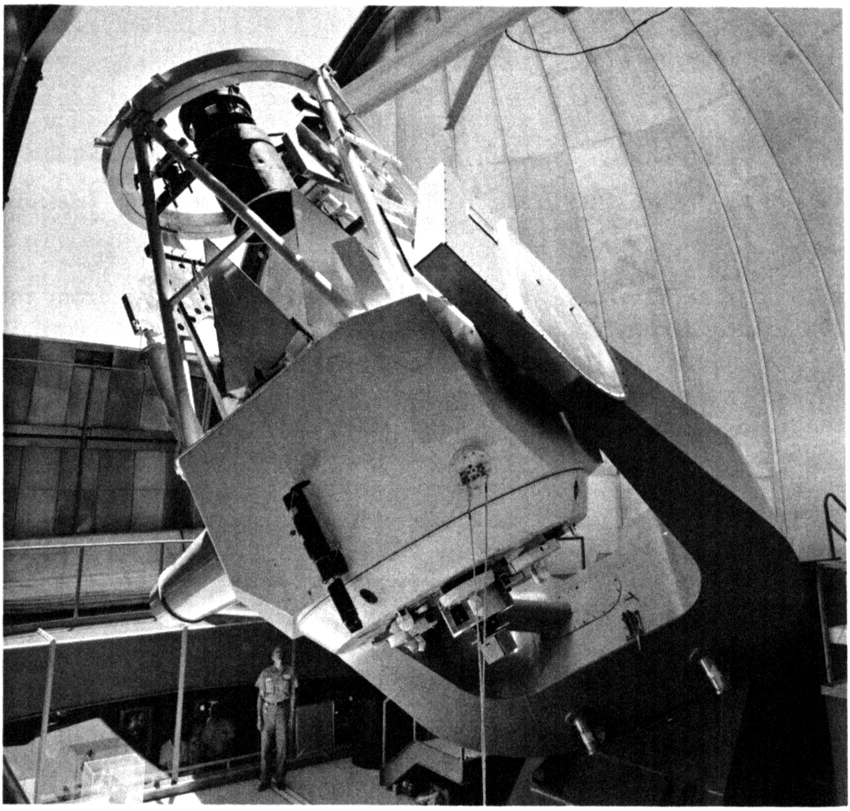

Figure 28.—*The second major instrument of the Kitt Peak National Observatory, the 84-inch stellar telescope. The resolving power and light concentration capabilities of this precise new instrument have already enabled astronomers to make significant observations of such phenomena as quasi-stellar radio sources.*

and chemical composition, element abundances, intrinsic brightnesses, and motions of celestial bodies.

Unconventional observational work carried out with this telescope included measurements in the far infrared spectral region (7.5 to 14 microns), and the use of an electron-image tube for observations of the newly discovered and very puzzling quasi-stellar radio sources.

The infrared work was carried out by G. P. Kuiper and F. J. Low, visiting astronomers from the University of Arizona, with highly sensitive detectors of their own design that permitted, for the first time, observations with adequate resolution of the planets and stars. New spectral features have been found in the radiation from the planets Venus, Mars, and Jupiter, as well as evidence for infrared-emitting material surrounding several of the brightest supergiant stars. This circumstellar material appears to vary in density and size, and its study promises to furnish a new insight into one of the least understood phases of stellar evolution.

The image tube spectrographic work by C. R. Lynds and W. Livingston of the resident staff has given results in an exciting field that has so far been studied systematically only with the use of the world's largest telescope. Measurements of red shifts and identifications of new spectral features in the spectra of quasars has been made possible by the high quality of the optics of the 84-inch telescope and the high photon efficiency of the image tube detection system.

An important new development at the Observatory occurred when a contract was concluded with the General Electric Co., Cleveland, Ohio, for the production of a 150-inch diameter mirror blank of fused quartz. This will be the major optical element of a 150-inch telescope that is planned for construction at Kitt Peak. Progress has been made on the design of its mechanical mounting, and on the fixed and rotating dome structure. With construction funding to be requested in fiscal year 1967, this telescope, as the world's second largest, will provide a means for many more U.S. astronomers to work on the most challenging astronomical problems of our times.

The McMath Solar Telescope, the world's largest, has continued to be used by both visitors and resident staff on research programs that can be carried out only with an instrument with its great light-gathering and resolving power. As in previous years, use of the solar telescope for observing objects other than the sun has occurred and on an increasing scale. For example, it has been used for infrared spectroscopic studies of Mars, lunar mapping, and photography, and very high-dispersion stellar spectra. In effect, it is a 24-hour per day telescope and is doing work in fields not foreseen when it was originally planned.

Among the important auxiliary instrumental additions to the telescope is an on-line computer that can command the telescope to follow the sun, moon, and planets, to scan across these objects in various patterns, as well as to correct for atmospheric refraction and any flexure in the mounting of the large heliostat flat mirror. The computer also can receive and process data, and display its output in various ways, such as on paper or magnetic tape, or by means of a typewriter, line-printer, or a two-coordinate plotter.

The second major auxiliary instrument is the magnetograph, by which the pattern of the sun's magnetic field may be studied in great detail; new evidence for the existence of local field isotropy has been found from these observations by W. Livingston of the resident staff.

The vertical vacuum spectrograph has continued to produce results of much significance for solar physics, because of its great dispersive power. Used with the newer techniques of rapid scanning, photon pulse counting, and digital data output and processing, this spectrograph during the past year yielded the following new results: A much lower limit for the maximum possible abundance of lithium in the sun's photosphere, a tentative identification of boron, and evidence for convection in the solar granules; these results were obtained, respectively, by C. R. Lynds, J. Waddell III, and J. Kirk of the KPNO staff.

It is fortunate that the solar telescope is in operation with its magnetograph at a time which is close to sunspot minimum when there is the least amount of solar activity; thus these studies are providing much new information about the sun during its quiet state.

Activities on Kitt Peak involving cooperative programs with outside groups include: The National Bureau of Standards aurora and airglow installation that is monitoring the night airglow during the International Years of the Quiet Sun, and the installation of a 36-foot millimeter-wave radio antenna by the National Radio Astronomy Observatory. This radio telescope will be used in an important program to fill the gap existing between optical and radio astronomy. Recent development of very sensitive infrared detectors indicates that this telescope will open up a whole new field of astronomical investigation for planetary and stellar research programs. When completed in the fall of 1965, this 36-ft. radio telescope will be the largest of its kind; it was located on Kitt Peak because of the excellent dry weather conditions, and availability of maintenance from the physical plant support already there. But most importantly, it will help to encourage cooperative scientific programs among radio and optical astronomers.

In the Observatory's Space Division, the Aerobee rocket program continued with successful launchings of three payloads during the year at White Sands. The experiments were: (1) To measure the brightness and polarization of the zodiacal light, (2) to extend the limit of the spectrum of the daytime airglow, and (3) to photograph the quiet sun in the soft X-ray region. In the last flight on June 23, 1965, a new development in rocket stabilization designed by Observatory space engineers was used for the first time with considerable success. With this

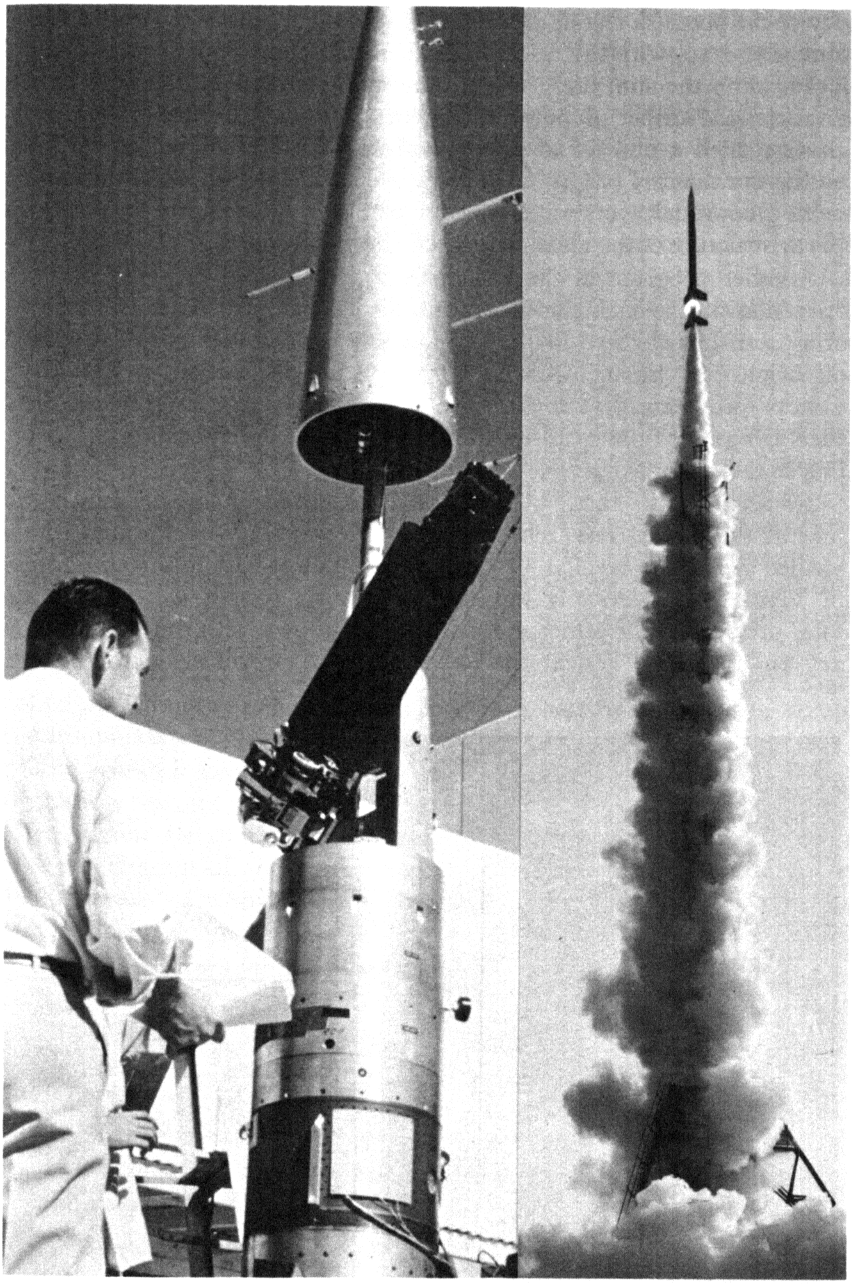

Figure 29.—*Prelaunch testing of Aerobee rocket payload (left) designed to investigate solar X-rays. The nose cone is elevated, and the instrument package pointed at the sun, simulating flight conditions. The instrument package consists of 84 image-forming pinhole cameras with a variety of filters. At right, Aerobee rocket launch which carried this instrument package to a height of 95 miles, part of the space program of the Kitt Peak National Observatory.*

device the precession cone of the slowly spinning rocket was rapidly closed almost to zero, with the result that when the solar sensors in the payload locked onto the sun, there was a minimum rotation in the solar images given by a number of pinhole cameras. Successful recovery by parachute yielded a number of photographs on film that show several areas on the sun that are bright in the X-ray region. The success of the experiment gives much encouragement for planning later flights in which the X-ray structure of the inner-corona can be investigated.

Another program in the Space Division included bringing into test operation the 50-inch remotely controlled telescope. After the Observatory staff has checked its performance with a number of test programs on bright-star photoelectric photometry, it will become available for visitors' programs that require the collection of large amounts of data, such as repeated observations in many colors of variable stars at various phases in their light curves.

In addition to these observational programs in space astronomy, several theoretical research programs on planetary atmospheres have yielded significant results: (1) The abundance of CO_2 in the atmosphere of Venus is considerably less than previously supposed, and (2) the total pressure in the atmosphere of Mars is known with much less accuracy and probably is near the lower range of previously accepted esti-

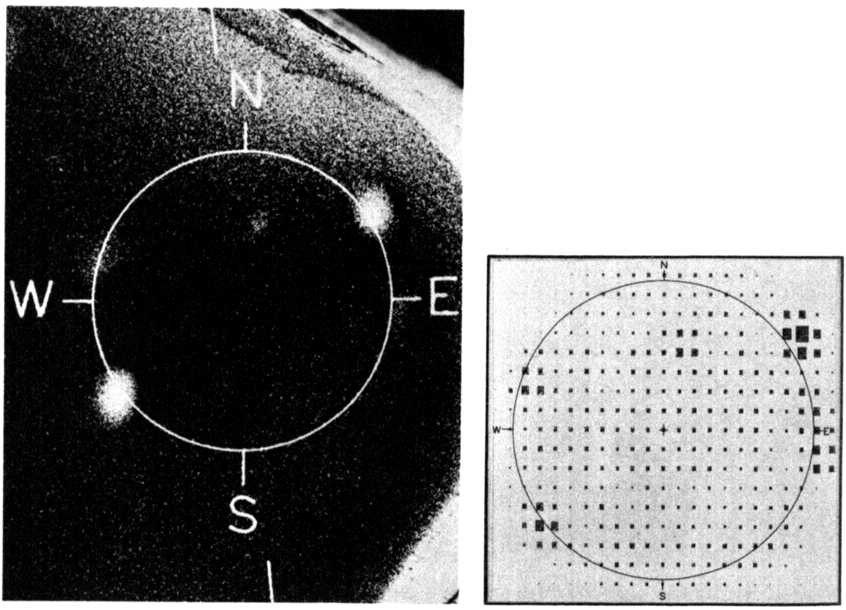

Figure 30.—*An X-ray image of the sun (left) produced by one of the pin-hole cameras shown in figure 29, compared with a 9.1 cm. spectroheliogram obtained with a radio telescope. The circle (right) represents the limb of the solar surface. The five intensive X-ray sources correspond closely with the active regions on the spectroheliogram.*

mates. This last result is of importance for the proposed Voyager series of "soft landers," because it means parachute braking would be ineffective.

In another significant theoretical investigation, Richard Goody of Harvard University, a consulting astronomer to the Space Division, carried out a program of analysis of the dynamics of the Venus atmosphere. After separating the effects of limb darkening, solar rotation, and other phenomena from recent thermal emission measurements made with the 200-inch telescope, a model of Venus atmospheric circulation was developed that seems to account in a natural way for the planet's high surface temperature.

Solar Eclipse Expedition

A major part of the Observatory's solar research program during the year was the expedition sent to the South Pacific under the direction of A. K. Pierce of the KPNO Staff to observe the total solar eclipse of May 30, 1965, as part of the International Years of the Quiet Sun Program. (See page 102.) At the request of the National Academy of Sciences, the Observatory assumed the responsibility for making all the necessary arrangements for the several U.S. groups that wished to observe the eclipse. The 300-ton auxiliary-powered sailing schooner *Goodwill* was used for transportation. Groups of scientists were stationed at Bellingshausen in French Polynesia and Manuae in the Cook Islands mandate of New Zealand.

The research involved spectroscopy and photometry of the corona which was scanned rapidly by a rotating mirror, and the use of sophisticated digital electronic instrumentation which measured the intensity and polarization of the corona at 40,000 points out to a distance of 5 solar radii. The group on Manuae was completely clouded out, but that on Bellingshausen obtained useful data through thin clouds.

This expedition required a major logistic effort in refitting the ship, unloading all of the heavy gear into small boats that had to be manhandled through treacherous coral reefs, and finally returning in a hurricane-like storm. At the end of the 12,000-mile voyage, all personnel and equipment were safely returned to the United States. Much of the same instrumentation will be used at an eclipse that will occur in Peru in November 1966, for which the experience in the South Pacific has been invaluable.

Visitors, Students, and Staff

An indication of the interest of university astronomers in the new 84-foot telescope may be gained from the fact that, in its 9 months of operation during the fiscal year, 25 visiting astronomers and 10 graduate students from 20 institutions throughout the United States used it for about 60 percent of its available research time.

During the year 19 visitors, including 3 from abroad, used the solar telescope; Ph. D. thesis material was obtained by 5 graduate students.

As of the end of the year the Observatory staff consisted of 217 full-time employees, of whom 41 were scientists and engineers.

In addition to scientific visitors, the Observatory welcomed more than 41,000 tourists and public visitors, and in April 1965, opened an astronomical museum on Kitt Peak to serve as an information center for them.

CERRO TOLOLO INTER-AMERICAN OBSERVATORY

From locations in the Northern Hemisphere it is not possible to observe some of the most important and interesting astronomical objects, such as the southern part of the Milky Way and the Magellanic Clouds (which are the two nearest external galaxies). The Cerro Tololo Inter-American Observatory, now under construction on a mountain top 7,400 feet high on the western slope of the Andes, will meet the needs of U.S. astronomers who wish to study the southern sky. The administrative headquarters building of this new Observatory, located in the coastal city of La Serena about 300 miles north of Santiago, is now completed and occupied. On the mountain, about 60 miles southeast of La Serena, two domes have been completed which will house one 16-inch telescope each. Construction has started on two more buildings, one for a 36-inch and one for a 60-inch telescope; these instruments are being manufactured in the United States and will be delivered to Chile early in the year 1966.

Astronomical research has been carried out by the staff and visitors using one of the Kitt Peak 16-inch telescopes housed in a temporary shelter. This instrument is equipped with a photoelectric photometer and a photoelectric scanner. The spectra of many hundreds of stars have already been studied. Many photoelectric measurements of stellar brightness have also been made in four different colors with the cooperation of several Chilean astronomers. The Observatory will have only a small permanent staff because most of the observing time will be made available to visiting astronomers from both North and South America.

NATIONAL CENTER FOR ATMOSPHERIC RESEARCH

As a result of scientific and technical advances made during the past two decades, the possibility is coming in sight of understanding the large-scale behavior of the atmosphere, including its general circulation, the global energy budget, and the influences on the atmosphere from the sun and space above and from the land and ocean surfaces beneath. This understanding is essential to the achievement of improved long-range prediction, for understanding the near-space environment, for assessing the merits of possible methods of human control over the atmosphere, and for understanding the effect man is already having on the atmosphere by massive injections of fossil fuel exhaust and through other means.

The National Center for Atmospheric Research (NCAR) was established by the Foundation in 1960 to augment and supplement the national effort to gain this knowledge. It is operated by the University Corporation for Atmospheric Research, a 21-university nonprofit corporation, on contract with NSF.

The Center's primary activities are: (1) conducting a broadly based, interdisciplinary research program in pursuit of a fundamental understanding of atmospheric processes, to encourage postdoctoral education, and to attract talented students to the atmospheric sciences; (2) serving as a research and facility planning center for the atmospheric sciences; (3) managing and operating joint-use research facilities where a clearly established national need exists and where no other institution is in a position to provide such facilities more efficiently.

Facilities

NCAR's joint-use facilities in ballooning, aviation, and computing represent not only sites and equipment but also a staff to provide technical assistance and information to visiting scientists. The plans and performance of each facility are reviewed by an advisory panel of non-NCAR scientists to assure its continuing response to the developing needs of the scientific community.

During the year the *NCAR Scientific Balloon Facility* attacked a number of technical problems, with special emphasis on discovering why so many large polyethylene balloons fail as they rise through extremely cold regions of the atmosphere. A double-balloon experiment produced the first downward-looking photographic record of a balloon disintegrating in such a region. Such data constitute a first step in developing balloon designs that will be more failure-proof.

The facility is also developing a "superpressure" balloon that will float at a given density-altitude, carrying a very light weight radio transmitter and instrument package. This system will be part of a worldwide weather observing experiment now being cooperatively planned by a number of U.S. agencies and by the World Meteorological Organization. It is to be tested in flights around the Southern Hemisphere in a joint NCAR-U.S. Weather Bureau experiment during fiscal year 1966.

The NCAR Scientific Balloon Flight Station at Palestine, Tex., was the site of approximately 100 balloon flights carrying experiments for scientists from more than 20 institutions. The station, operated by private industry under the supervision of NCAR staff members, serves both as a facility for the use of the scientific community and as a laboratory for improved techniques for launching, tracking, controlling, re-

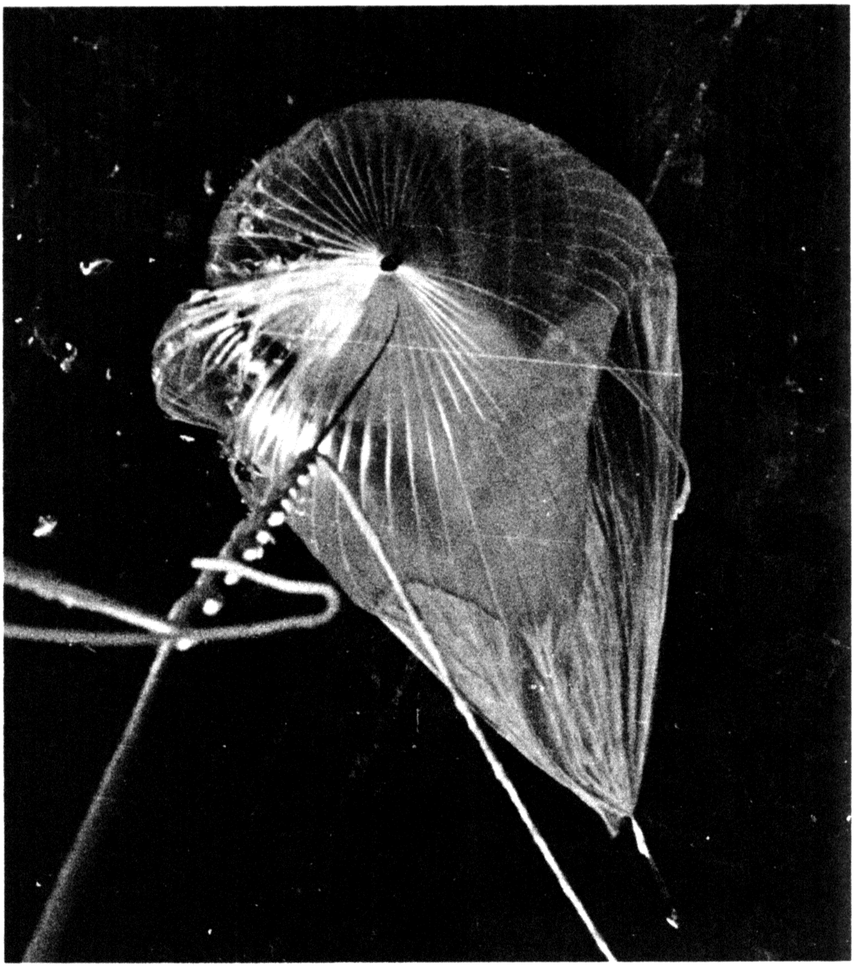

Figure 31.—*"Successful failure" . . . One of a series of photographs of the failure of a 2.94-million cubic foot balloon at 46,800 foot altitude. The launch and down-camera study were made to obtain information on design and manufacturing factors that contribute to balloon failures, part of the NCAR Scientific Balloon Facility effort to improve balloon reliability.*

covering, and receiving telemetered information from balloon systems, and for improving their altitude and weight-carrying capabilities. A secondary site at Page, Ariz., is operated during the winter.

During the winter of 1964–65, at the request of NSF, the facility managed the ballooning phases of the IQSY Equatorial Expedition. The flights, carried out in India with the cooperation of the Tata Institute of Fundamental Studies of Bombay, made possible the first successful high-altitude cosmic ray measurements near the Equator.

The *NCAR Aviation Facility* purchased its first airplane, a Beech Queen Air 80, whose capability falls between that of the typical light plane which may be available to a university department and the heavy, high-performance airplanes which prove to be costly to operate when used for atmospheric research. During the year, the plane provided more than 350 hours of research flight time for a variety of NCAR projects and for a project of the University of Wisconsin. During fiscal year 1966, a second Queen Air 80 is being leased to provide support to approximately 10 projects of scientists from NCAR and from outside research groups. The facility also provides technical assistance, liaison, and information services, and conducts a program in the development of sensing and data-handling devices that will be of use to a variety of experimental projects.

The *NCAR Computing Facility* provided more than 500 hours per month of computing on its Control Data 3600 machine, for both NCAR and university scientists. The bulk of the machine's time was devoted to fundamental atmospheric science problems that require vast amounts of computation. NCAR will replace its present computer with a Control Data 6600 in fiscal year 1966, in order to provide additional computational capacity economically for increased use by outside scientists, and to make it possible to handle theoretical problems in greater detail and hence with greater realism.

NCAR support facilities were further developed in fiscal year 1965—library, shops, and field observing. The latter support facility also served as a national spare-parts depot for M–33 radars operated by universities, and also supplied technical services upon request. A complete M–33 set was provided to the United States-Japan Cooperative Program in cloud physics on the island of Hawaii.

Research Programs

NCAR research programs are carried forward in two operating research laboratories, the Laboratory of Atmospheric Science (LAS) and the High Altitude Observatory (HAO).

The LAS program emphasizes three areas of research:

The general circulation of the atmosphere.—Understanding of this complex subject holds the key to long-range weather prediction and to understanding the potential for, and implications of, weather and climate modification (intentional as well as inadvertent). The central activity of this area of research at NCAR during fiscal year 1965 was the development of a versatile numerical model of the general circulation under the direction of Akira Kasahara and Warren M. Washington.

The life cycles of the trace gases and aerosols in the atmosphere.—It is now clear that air pollution, cloud modification, the radiative balance of the atmosphere, and many other atmospheric problems and processes depend on understanding the nature and role of trace gases and particulates.

Research during fiscal year 1965 in this area included projects such as development by James P. Lodge, Jr., of improved methods for measuring the minute but critically important quantities of trace gases and aerosols found in the natural and polluted atmosphere; development by Jan Rosinski of techniques for measuring changing concentrations of freezing nuclei that may have a direct bearing on variations in rainfall rates; and determination by Richard D. Cadle of reaction rates of methane and atomic oxygen in the stratosphere and mesosphere.

Cloud physics and dynamics.—Many knowledge gaps exist in this area, especially in cloud dynamics. Some of these gaps are no doubt in part responsible for the indifferent history of attempts at weather modification.

During fiscal year 1965, a new type of dropsonde was developed by Robert H. Bushnell. These dropsondes are to be released from airplanes to measure the dynamic structure of large convective clouds. In related studies, J. C. Fankhauser, a visitor from the U.S. Weather Bureau, and Chester W. Newton have shown how the movement of thunderstorms in the mean wind field is determined by their sizes.

During fiscal year 1965, LAS scientists also contributed to programs of applied research upon request. Included in these activities were: (*a*) consultation with the Bureau of Reclamation on weather modification activities; (*b*) a project to sample trace gases and aerosols in Panama to assist the U.S. Army Tropical Research Center in a study of corrosion rates of materials in the tropics; (*c*) assistance to the National Academy of Sciences in its study of requirements for a worldwide meteorological observing system.

The High Altitude Observatory, founded in 1940 and merged with NCAR in 1961, is a long-established research laboratory that concentrates mainly on solar physics and the interaction between the solar and terrestrial atmospheres. Outstanding achievements during fiscal year 1965 include photographs of the sun's outer atmosphere to a distance of five solar radii—on two occasions spaced by one solar rotation; observations of the solar eclipse of May 30, 1965, that may shed light on the electron density of the solar atmosphere; progress toward duplicating solar plasma processes in the laboratory in order to study them in detail; and improvements in observing and recording devices at HAO's Climax Observing Station, near Fremont Pass, Colo., used by both NCAR and visiting scientists.

The photographs of the outer solar atmosphere were taken by a balloon-borne coronagraph system called Coronascope II$_B$. This is an instrument that creates an artificial eclipse in order to observe the sun's outer atmosphere, the corona. Under the direction of Gordon A. Newkirk, Jr., and John A. Eddy, the design and construction of a similar coronagraph system to be flown in a satellite is already underway in cooperation with NASA. The frequent and regular observations thus

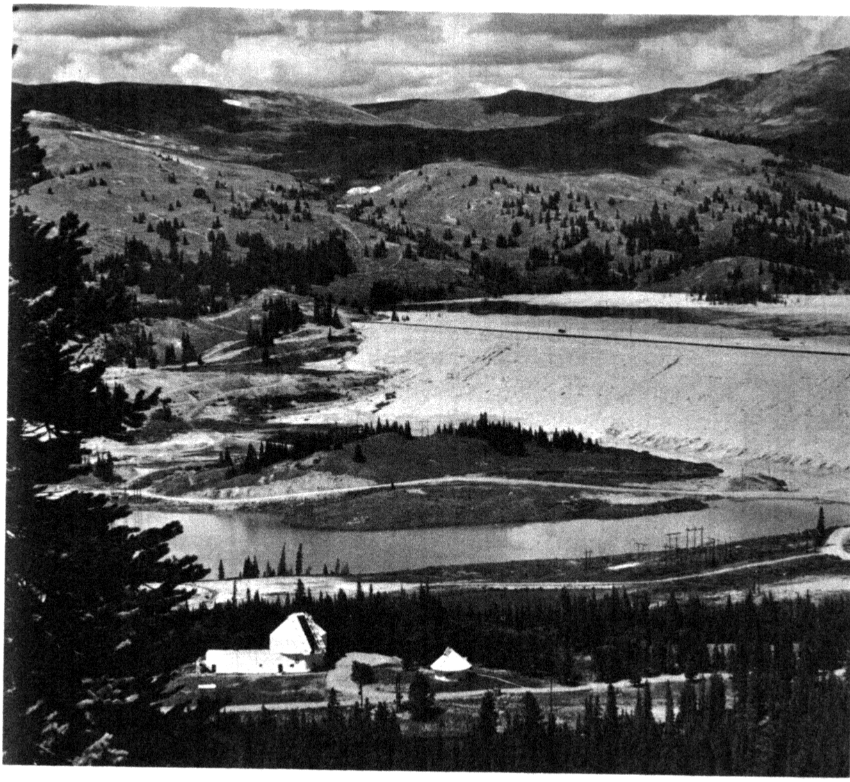

Figure 32.—***The High Altitude Observatory at Climax, Colo.; larger dome houses a new 16-inch coronagraph, while smaller dome contains older 5-inch coronagraph and the H-alpha flare patrol telescope that operates constantly during clear daylight hours.***

obtained will contribute significantly to our knowledge of the solar corona and solar activity.

The solar eclipse, observed from Bellingshausen Island in the South Pacific by Eddy, John M. Malville, and David Hultquist, as part of the International Years of the Quiet Sun Program, provided new data on two emission lines of Iron XIII, which arise out of the excitation of iron atoms in the intense heat of the solar corona. These observations are now in the process of analysis.

At the Climax Observing Station, a spectograph and a magnetograph for use with the 16-inch coronagraph (one of two such instruments in the world) were completed and installed, along with the necessary highly complex data recording system. This work makes Climax a truly multipurpose solar observatory for the use of the scientific community.

Considerable theoretical work was also completed at HAO, including a model of the solar atmosphere by R. Grant Athay that for the first time correctly predicts the intensity of some of the various solar emissions.

Visitors, Students, and Staff

Through postdoctoral appointments, seminars, and special study groups drawn from the scientific community at large, NCAR's Advanced Study Program promotes and fosters the broad view of the atmospheric sciences essential to the solution of many basic problems, and helps define specific problems (e.g. the theory of turbulence) that are of first-priority urgency for the general progress of the atmospheric sciences.

In its first year three postdoctoral appointments were made, and several series of small, highly informal seminars were conducted by the resident and visiting scientific staff at a postdoctoral level. In June 1965, a 6-week seminar on Extraterrestrial Influences on Atmospheric Circulations began, with some 20 scientists from the United States and abroad meeting in intensive sessions to pinpoint problems in this area that appear most likely to produce new knowledge about cosmic influences on the earth's atmosphere.

During fiscal year 1965, some 200 scientists visited NCAR to discuss scientific problems with the NCAR staff and with each other, and to pursue research projects on their own or within NCAR research programs. They came from 32 U.S. colleges and universities, 26 private or Government laboratories, and from 21 foreign countries.

Meetings hosted or sponsored by NCAR during the year included an International Symposium on Research and Development Aspects of Long-Range Forecasting (with the World Meteorological Organization and the International Union of Geodesy and Geophysics), a Symposium on Natural Ultra-Low-Frequency Electromagnetic Fields (with the Central Radio Propagation Laboratory of the National Bureau of Standards), and a Conference on Atmospheric Limitations of Optical Propagation (also with CRPL).

Two additional activities related to exchanges with the universities should be noted. First, the NCAR Fellowship Program, funded through private foundation grants, supports graduate students at universities of their choice in disciplines within, or allied with, the atmospheric sciences. During the summer preceding and following the academic year of the grant, they work in established research groups at NCAR.

Second, a "reverse" visitor program was inaugurated during the year—a program under which NCAR staff members may establish "affiliate professor" relationships with universities. Two NCAR staff members have established such relationships—Patrick Squires at Coloradio State University and Bernhard Haurwitz at the University of Texas. The affiliate professorship program is in addition to more informal ad hoc arrangements under which many NCAR scientists have visited universities to give series of lectures and seminars and, in some cases, to teach for a full semester.

Seven universities have recently joined NCAR's management corporation, bringing the total membership to 21 universities, located in 18

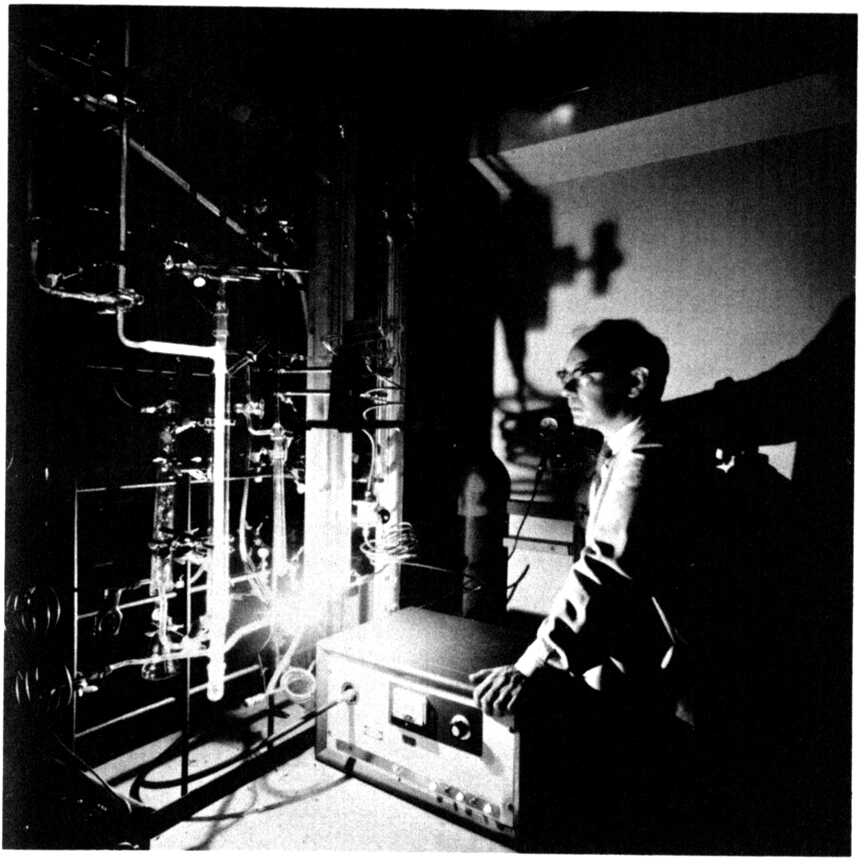

Figure 33.—*Ripon College chemistry professor and 1964 Post-Doctoral Fellow at NCAR, shown with apparatus used for investigation of the reactions of atomic oxygen with various gases present in the atmosphere.*

different States. The corporation has been active in its fellowship program, in fostering ties between NCAR and the universities, and in funding certain NCAR projects.

The NCAR staff, calculated on a full-time equivalent basis and including visitors at NCAR for 4 months or more, reached 368 at the end of fiscal year 1965, including 74 at the Ph. D. level. The Center is now housed in four buildings in which space is leased from the University of Colorado. The first buildings of NCAR's permanent laboratory on a 529-acre tract southwest of Boulder given to NSF by the State of Colorado, will be ready for occupancy in mid-1966.

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INSTITUTIONAL PROGRAMS

In recent years the need to supplement the traditional individual project grants with more broadly based institutional grants for strengthening science activities at colleges and universities has become increasingly apparent. Although the use of Federal funds for institutional support is not new, only recently has broad action been taken to apply institutional development concepts. Examples of such action by other Federal agencies include the massive support provided by the Office of Education through grants for facilities, the sustaining university program of the National Aeronautics and Space Administration, and the National Institutes of Health general research support program and health facilities programs. These various institutional support programs have at least one element in common—each acts to encourage autonomy in institutional planning, while protecting the scientist's freedom in conducting his research.

The National Science Foundation has inaugurated several institutional programs in recent years. These programs recognize that the responsibility of planning for strong science activities must be assumed more and more by the institutions themselves.

GENERAL FACILITIES FOR GRADUATE SCIENCE

The General Facilities for Graduate Science Program is primarily for support of facilities for research and graduate education. This program is similar to the other programs discussed in this section in that funds granted are managed on an institutional basis; it differs from the others, however, in that the grants awarded are not for broad-based scientific activities but rather for the construction or renovation of specific facilities.

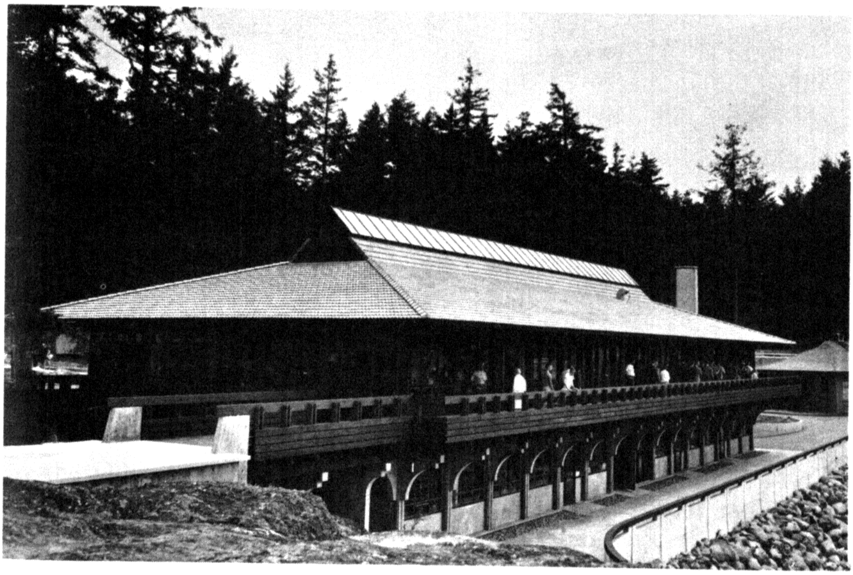
The support provided through the General Facilities for Graduate Science Program continues to be of importance in maintaining the scientific strength of our Nation's colleges and universities. The availability of science laboratory facilities in adequate quantity and high quality is essential to the training of future scientists and the advancement of basic research activities. The shortage of new laboratory space, as well as the inadequacy of much existing space, is a major deterring factor in achieving national scientific goals.

Requests to the Foundation for matching funds to support graduate science facilities were less in fiscal year 1965 than in previous years. Nonetheless, requests for support of nearly $59.0 million were received. The initiation of the Foundation's Science Development Program and the Higher Education Facilities Program (Public Law 88–204) of the

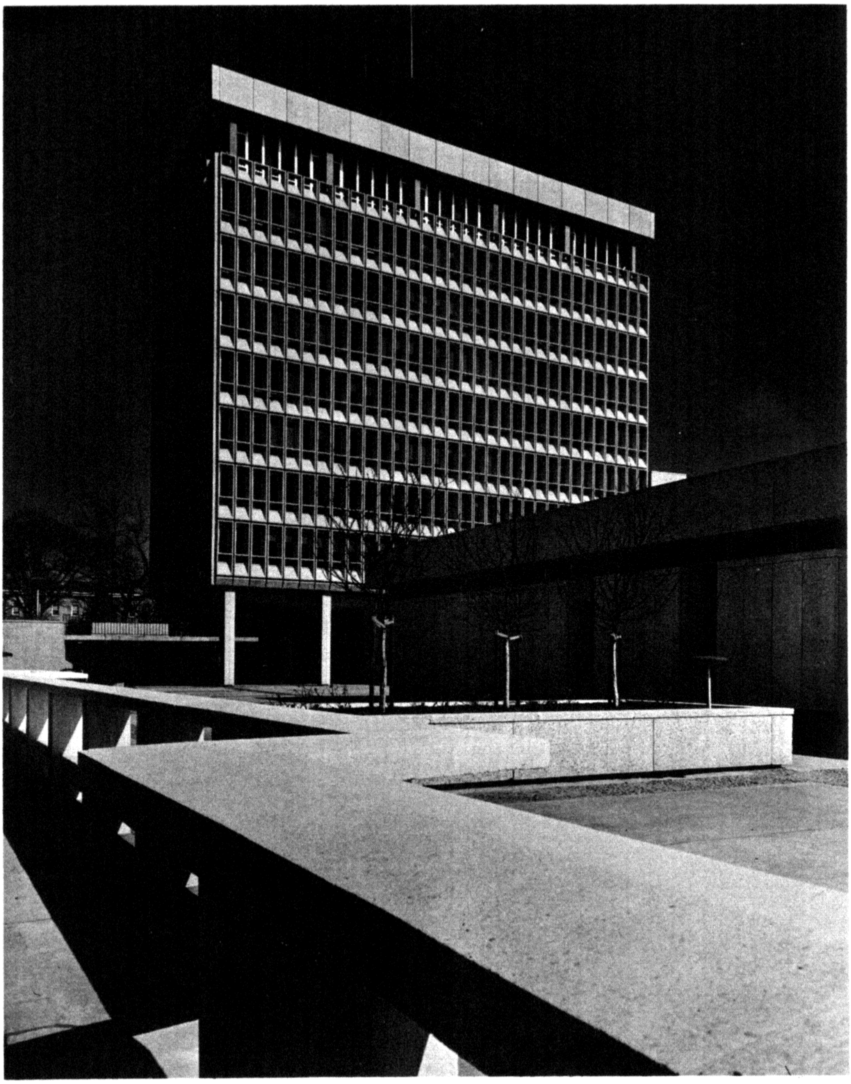
Office of Education, both of which contain provisions for Federal support for graduate science facilities, undoubtedly played a strong role in the reduction of requests to the General Facilities for Graduate Science Program.

Requests for funds from this program have been reduced about 50 percent, measured both in number and dollar value. Conversely, however, the average dollar value of the requests continues to rise—about 10 percent during fiscal year 1965. This helps substantiate the concept that the trend is directed toward long-term planning for larger facilities. Grants awarded during 1965 were the smallest in number since 1961 and totalled the least in dollar amount since 1962. Nonetheless, through the infusion of $28.3 million in Federal funds, the program assisted educational institutions substantially in providing science and related facilities valued well in excess of $58.6 million.

The predominance of graduate science facilities support for the physical sciences continued during 1965. This is a steadily growing upward trend. Support in the life sciences declined sharply to 17 percent during 1965, from 40 percent during 1960–64. The predominance of support to the physical sciences may, in part, be attributed to the emphasis given.



Figures 34, 35, 36, and 37.—*As classrooms and laboratories are built to help satisfy the growing demand, architects constantly seek to create useful and imaginative structures that will both enhance the campuses and be of maximum use. This selection of photographs shows a small sample of new campus architecture, where the science portion of the buildings was aided by NSF grants. They are the Friday Harbor Marine Laboratory of the University of Washington, Van Vleck Hall of the University of Wisconsin, the physics building (and auditorium) at Rutgers, and William James Hall at Harvard.*



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in the Gilliland Report[1] to the urgent needs in engineering and the physical sciences. In addition, there have been significant and notable increases in national activity in space and the related efforts in astronomy and atmospheric sciences which undoubtedly have had an effect upon the increase in demand upon the Foundation in the physical sciences area.

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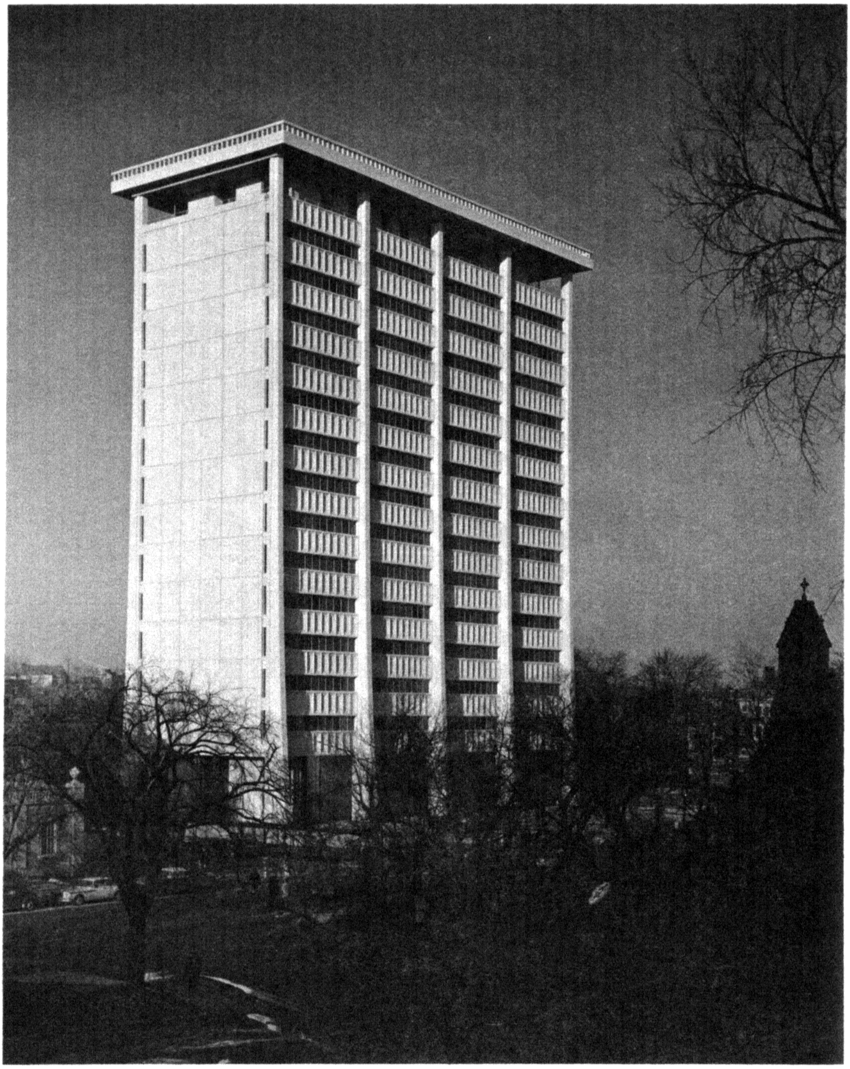
[1] *Manpower Needs in Science and Technology. Report No. 1: Graduate Training in the Engineering, Mathematics, and Physical Sciences.* A Report of the President's Science Advisory Committee, December 1962. U.S. Government Printing Office, Washington, D.C. 20401.



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SCIENCE DEVELOPMENT PROGRAM

Science Development Program grants are designed to assist selected academic institutions in strengthening significantly their activities in science and engineering. They are not intended to replace existing programs or to consolidate grants for administrative convenience. Rather, the program's primary purpose is to accelerate improvement in science by providing funds to be expended only in accordance with carefully developed master plans. Such plans must be designed to produce significant upgrading in the quality of the institution's science activities. A small number of grants are made each year to academic institutions judged to have good science programs at present and to have great potential (including financial resources) for moving upward to a high level of scientific quality and for maintaining this quality. A proposal may be submitted for strengthening a single academic science activity, a group of related science activities, or the entire science program of the institution; it may include the establishment of a new academic unit.

One of the key stimuli in developing the Science Development Program was the President's Science Advisory Committee statement of November 15, 1960 (the Seaborg Report), which identified the need for an increase in the number of high-quality graduate centers. However, a Foundation review of the strengths and weaknesses of a selected sample of colleges and universities showed that broad new approaches to the support of science should not be limited to graduate schools. Therefore, even though most of the funds during the first years will in all probability to go institutions having graduate programs, grants may be made to any U.S. institution of higher education that grants baccalaureate or higher degrees in science or engineering. The important criteria are the presence of sufficient scientific strength at the institution to serve as the base for the proposed development plan, and the availability of adequate financial resources to give reasonable assurance that the institution's goals can be achieved and maintained.

Although outstanding institutions have not been specifically excluded from participation, the announcement makes it clear that this program was not initiated to overcome any weaknesses they may have. A variety of existing programs provides for the continued development of such institutions.

Since March 1964, the Foundation staff has conferred with representatives from nearly 200 colleges and universities. The first four grants were announced on April 30, 1965, by President Johnson; and six additional grants were announced on June 30, 1965.

A wide range of institutions is represented among the proposals submitted. Most are from institutions having graduate programs and are generally recognized to be in the second and third echelons from the standpoint of Federal funds received for research and from the numbers of Ph. D.'s granted per year in science and engineering. Most of the institutions submitting proposals believe that they can make certain of their programs outstanding within a period of 3 to 5 years. A few have overestimated their present scientific qualities and have little chance of receiving a grant under the program as it is now constituted. Although the needs for funds by these institutions are great and the plans for development are realistically presented, a program is required covering a longer period of time than currently allowed under the Foundation's Science Development Program.

The total amount requested in the 68 proposals received to date is approximately $275 million. An analysis of these proposals shows that 55 institutions have requested funds for facilities, 62 for personnel (including faculty, graduate students, and nonacademic), 58 for equipment, 21 for libraries, and 26 for miscellaneous purposes. Of the funds requested, 39 percent were for facilities, 33 percent for personnel, 22 percent for equipment, 2 percent for libraries, and 4 percent for other purposes.

From the proposals, it appears that the greatest institutional needs are in the physical sciences and mathematics. About 80 percent of the institutions requested funds for physics; 77 percent for chemistry; 63 percent for mathematics; 5 percent for astronomy; and 17 percent for earth sciences, mainly geology. Approximately 50 percent of the proposals requested funds for various departments in engineering; 54 percent for biological and life sciences; and 24 percent for social sciences, including psychology, sociology, anthropology, and economics.

Many proposals show a similar pattern. Combinations of three to five broad science areas were most common. Only five of the proposals requested funds for one science area only. A very common combination is physics, chemistry, and mathematics. Proposals requesting funds for engineering often include requests for mathematics and physics. It appears that institutions interpret this program as a means of helping them strengthen basic science areas and are presenting plans for building upon present strength as opposed to improving weak science areas. They tend to omit items for innovation.

Of the first 10 science development grants announced, 8 were funded with fiscal year 1965 funds, for a total of $27,394,000. The following table shows the amount granted for each science area in 1965 and the number of institutions receiving such support.

Science area	Total amount	Percent of total amount	Number receiving support
Chemistry	$7,358,000	26.9	8
Physics	5,590,000	20.4	6
Engineering	4,624,000	16.9	5
Interdisciplinary programs	3,538,000	12.9	5
Mathematics	3,015,000	11.0	4
Biology	1,770,000	6.5	5
Social sciences	1,025,000	3.7	3
Astronomy	474,000	1.7	2
Total	27,394,000	100.0	....

Of the five interdisciplinary programs, two are in materials sciences and comprise the fields of chemistry, physics, engineering, and metallurgy; a third encompasses the areas of chemistry, physics, and biology. Another university is developing two interdisciplinary institutes: one in molecular biology comprising the areas of biology, physics, and chemistry, and a second in theoretical sciences, including physics and mathematics. The fifth interdisciplinary program supported is a complex one in systems engineering and research and comprises the fields of chemical and electrical engineering, economics, mathematics, psychology, chemistry, and biology.

By categories of use the funds awarded in the first eight grants were about evenly distributed: personnel, 34 percent; equipment and other, 31 percent; and facilities, 35 percent.

In October 1964, the Director of the Foundation appointed a Science Development Advisory Panel. These eight nationally known persons, from academic institutions that are not competing for awards, from industry, from private foundations, and from private life, advise him on selection of institutions to receive this type of grant. The evaluation process is comprehensive and extends over several months. It involves the use of staff from all divisions of the Foundation as well as non-NSF personnel for assistance in undertaking site visits.

As a result of the experience of the Foundation during the first year of this program, it became obvious that certain kinds of institutions need assistance that the present Science Development Program is not designed to provide. Representative of these are institutions in isolated geographic regions or in thickly populated urban areas, or in areas where minority groups have been deprived of good institutions of higher education. Possibly an extension of the formula type institutional grant would meet some of this need. Also, evidence overwhelmingly points to the need for institutional support for institutions that cannot realistically be expected to take their place among the best in the Nation, but have the capability for major improvement on a relative basis—institutional support programs, that is, which would have as a criterion the ability to improve and which would be directed at the 500 or 600 "third and fourth echelon" colleges and universities widely scattered throughout the Nation.

The Science Development Program is a most important departure from existing programs. It is setting patterns and plotting directions for additional ways of strengthening science. It is too early for an assessment of programmatic impact. However, the program has stimulated extensive institution-wide planning beyond expectations.

INSTITUTIONAL GRANTS FOR SCIENCE

Through its program of Institutional Grants for Science, the Foundation supports scientific research and education in a large number of colleges and universities. During the 5 years in which these grants have been made, more than 500 institutions of higher education have received about $35 million for strengthening their scientific activities.

Colleges and universities may use Institutional Grant funds only for direct costs of scientific activities and must account for their use, but institutions are otherwise free to determine how they will use the funds. Such autonomy, the Foundation believes, strongly encourages flexibility in the allocation of these funds, and permits the institution to make decisions relative to assuring balanced growth of its scientific research and education effort.

Because the program is "Institutional"—that is, concerned with the total scientific strength of the grantee college or university—a grant is made through its president to the institution, not to individual professors or departments. Prudent stewardship of Federal funds is assured through the Foundation's reporting and accounting requirements, while administrative procedures and reporting requirements are designed to be not burdensome to the institutions. Although none of the grants are overly large, their value to institutions, as reported by university officials, far exceeds that which is generally expected from an equal amount of restricted funds.

Institutional Grants for Science are made once a year to higher educational institutions that apply for them and that have received NSF grants for basic research, for undergraduate research participation, or for research participation for college teachers. The amount of each grant is computed by applying a tapered arithmetical formula to the amount of applicable grants an institution has received from the Foundation during the period April 1 to March 31. The formula used for computing the grants in fiscal year 1965 was: 100 percent of the first $10,000 of applicable grants received; 10 percent of the amount from $10,001 to $1,000,000; 3 percent of the amount from $1,000,001 to $1,500,000; 1.5 percent of the amount from $1,500,001 to $2,000,000; 1 percent of the amount from $2,000,001 to $2,500,000; and 0.5 percent of the amount above $2,500,000.

In fiscal year 1965, Institutional Grants totaling $11,417,659 were made to 376 colleges and universities in all 50 States, the District of Columbia, and Puerto Rico, ranging in amount from $600 to $146,624. Table 1 shows the distribution of Institutional Grants and number of recipients, by size of grant.

As shown in table 1, 50 institutions in 1965 received grants of $75,000 or more. Nearly four-fifths of the grants were for $10,000 or more, and over one-third were for $20,000 or more. Although no institution received the maximum allowable grant of $150,000, 42 institutions had grants of $100,000 or more, as compared to 33 institutions in 1964.

Colleges and universities receiving the grants report annually on the uses they have made of the funds. Annual reports covering the period

Table 1.—*Distribution of Institutional Grants for Science, 1965*

Size of grants (in dollars)	Funds		Institutions	
	Amount	Percent	Number	Percent
Less than 2,500	$18,455	(1)	10	2.7
2,500 to 4,999	73,899	0.6	20	5.3
5,000 to 9,999	361,903	3.2	49	13.0
10,000 to 19,999	2,140,896	18.8	169	44.9
20,000 to 29,999	782,592	6.9	32	8.5
30,000 to 49,999	1,346,919	11.8	33	8.8
50,000 to 74,999	761,127	6.7	13	3.5
75,000 to 99,999	693,962	6.1	8	2.1
100,000 to 124,999	2,464,443	21.6	22	5.9
125,000 to 149,999	2,773,463	24.3	20	5.3
Total	11,417,659	100.0	376	100.0

[1] Less than one-half of 1 percent.

Table 2.—*Distribution of Institutional Grant Expenditures by Use, Fiscal Year 1964* [1]

Use	Amount	Percent
Equipment	$2,028,389	44.5
Faculty research projects	689,741	15.1
Faculty salaries	451,235	9.9
Library resources	391,595	8.6
Computers (equipment, operations, etc.)	316,789	7.0
Facilities	293,236	6.4
Student stipends	202,313	4.4
Miscellaneous (travel, visiting lectures, curriculum development, etc.)	184,760	4.1
Total	[2] 4,558,058	100.0

[1] Latest year for which breakdown is available.

[2] Total reported expenditures were $5,783,212; of these, $1,225,154 are not included in the table because their use could not be assigned with the same degree of precision as those tabulated.

July 1, 1963–June 30, 1964, show that institutions used the funds for a variety of scientific purposes. These uses are summarized in table 2.

The principal use of Institutional Grant funds continued to be the purchase of research and instructional equipment. Liberal arts colleges awarding only bachelor's degrees spent nearly three-fourths of their Institutional Grant funds for equipment. Institutions awarding the doctorate in science spent larger proportions of their grants for faculty research projects (especially of young faculty members), for books and periodicals for science libraries, and for student stipends than did institutions awarding the bachelor's or master's as their highest degree. Nevertheless, the reports show that there are great differences in the ways in which institutions, even of the same general type, use their Institutional Grant funds. These differences are indicative of the diversity of needs and opportunities for scientific education and research among the higher educational institutions of the Nation.

SCIENCE INFORMATION

The major news in the field of science information is that national science information systems now appear to be within reach, and significant progress has been made in the past year toward achieving this goal. The progress so far achieved results from a decade of research and experimentation. Many problems remain to be solved, including the adjustment of traditional library, publication, and communication systems and processes to new or changing requirements. But certain fields have been chosen and information systems are being developed; the first part of this chapter will discuss the systems development now under way. The remainder of the chapter will describe research and experimentation in science information, and coordination of science information activities.

NATIONAL INFORMATION SYSTEMS AND SERVICES

Selection of disciplines for development of national information systems was based both on the needs so far exhibited for national information systems, and the prospect within the discipline for contributing to that successful development.

Progress in Selected Scientific Disciplines

Over a period of years, the Foundation has supported work of the Chemical Abstracts Service (CAS), as well as other groups, on techniques and concepts necessary for the mechanization of a chemical information service capable of coping with the increasing flow of information in this discipline. The findings demonstrated the feasibility of a large-scale effort to develop an operational mechanized system for the registration of chemical compounds and for search and retrieval functions based on such registry. The Office of Science and Technology organized a task group to guide this developmental phase after securing agreement from the National Science Foundation, the Department of Defense, and the National Institutes of Health, to cooperate in its support. NSF agreed to manage this cooperative enterprise, and during 1965 contracted with the American Chemical Society for a 2-year developmental program of a registry system, along with research on selected problems of chemical information automation.

This contract provides for the first phase in a major experiment with a computer-based national information system that involves cooperation between a scientific society and the Federal Government. Such an arrangement may well be a prototype for future Government-scientific society relationships.

The American Chemical Society was selected to conduct the initial work both because of its resources and because of provisions in its Federal charter—unique for a scientific society—under which the Society makes investigations and reports on chemistry at the request of the Government.

Other scientific societies and non-Government organizations will be involved in the broad program to ensure that the system will be responsive to all needs.

The major task in the American Chemical Society contract is to build upon the state of the art in the mechanized handling of structural information about organic chemical compounds by conducting the necessary large-scale pilot trials of the registry itself. To this end the Chemical Abstracts Service will utilize its information resources to provide some 800,000 chemical references, of which about 150,000 are expected to be structural information dealing with chemicals being reported for the first time. Information stored in the computers will include a tabular representation of the compound's chemical structure, its molecular formula, names (systematic, trivial, or trade names) as well as any laboratory codes assigned in the open literature and bibliographic references to the Chemical Abstracts volume in which the compound may be found and the journal article on which the abstract was based.

The registry system will assign a unique identifying number, much like a chemical "social security number," to each compound put into computers. The number can be used to locate information about the compound stored in other computer files.

An essential feature of the registry system will be its ability to identify a compound which has previously been processed and to assign the same number to the compound each time it appears. Compounds new to the file automatically will be recognized and assigned their own unique number.

Most of the 800,000 chemical references processed during the term of the contract will be taken from current chemical publications—making the latest information the most immediately available to the chemists in automated forms. Computer programs are being developed to search the file to identify compounds or parts thereof that have particular structural features of interest.

The large-scale testing of these techniques will be conducted first on the system developed at CAS through research supported largely by the National Science Foundation. Additional substructure searching techniques will be explored fully, as this research capability will help chemists to relate structure to chemical activity, and perhaps even design chemicals. The system is designed to help answer certain types of chemical questions that defy existing information systems or now require a great deal of time and effort.

Later phases of the chemical information program call for a series of research and developmental activities by a number of agencies and institutions aimed at establishing the technical and economic feasibility and the optimum usefulness of mechanized chemical data services.

The continuing support by the Foundation of a documentation research project under the auspices of the American Institute of Physics has stimulated an inquiry into the requirements of working physicists for the indexing of the literature of physics. The results of this inquiry led to experiments with new forms of subject indexing, including some in which the author of the journal article was himself involved in the indexing process. This research is continuing; it has permitted the American Insitute of Physics to take a new look at the preparation of *Physics Abstracts,* which is produced by the Institution of Electrical Engineers in Great Britain. NSF is supporting a series of meetings between American and British physicists and information experts to develop this service in a manner that is responsive to the requirements of American physicists.

U.S. engineers have initiated an inquiry into the effectiveness of traditional information patterns and services in the field of engineering. The development of a thesaurus of terms for the indexing of engineering literature has permitted NSF to support experimental indexing in plastics and electronic engineering, in cooperation with the *Engineering Index.* The possibility is now open for the development of sections of the *Engineering Index* in other areas of engineering. Similarly, this common engineering vocabulary has made possible cooperation between the *Engineering Index* and the American Society for Metals in an attempt to achieve better coordination between their respective information services; NSF is supporting this cooperation.

These two activities are only a small segment of a larger enterprise, the development of an engineering information system. This enterprise has a number of challenging problems that demand ingenuity in their solution. Significant among these problems are those of interrelating the information services for the many fields of engineering and of relating an overall engineering information system to those in other disciplines, such as chemistry and physics.

Support from a number of agencies has been provided for several years to the American Meteorological Society for the production and distribution of *Meteorological and Geoastrophysical Abstracts.* Here, also, a need for coordinated support and coherent development of the abstracts service led to the acceptance by the Foundation of the coordinating role. With the advice of the Interdepartmental Committee for Atmospheric Sciences, and with funds contributed by the Weather Bureau, the Department of Defense, the National Aeronautics and Space Administration, and the Foundation, a contract was entered into with the American Meteorological Society to provide indexing and abstracting services.

In other fields, particularly, the biological, earth, and social sciences, a trend toward national systems is neither as apparent nor as clearly indicated. The Foundation has been in active contact with the pertinent societies, in part on behalf of the Committee on Scientific and Technical Information. (See page 145.)

Libraries Within a National Information System

The research library community is showing increasing signs of energy and willingness to exploit contemporary technology to improve information services. The activation of the Association of Research Libraries, with partial NSF support, has contributed to this movement. Foundation support has made possible experimentation with computer applications to internal library operations, including the development of mechanized serial records and mechanized production of book catalogs. Support has been concentrated on projects whose results could be applied to other libraries. The promise of computer technology, with its potential for applying timesharing to library operations by means of remotely installed terminals or consoles, has thus suggested a new level of operations for the library of the future.

The relationship that now exists between librarian and user may, in the future, become a relationship between computer and user. An NSF-supported project to explore certain characteristics and implications of such a relationship, through the development of an experimental catalog, is one of a series of similar experiments that will engage the concern of the library community. Grants have also been made to study the optimal size for academic working collections, to apply operations research and systems engineering techniques to the analysis of university libraries, and to develop a machine-readable form of library shelf list.

RESEARCH AND EXPERIMENTATION

Communication Patterns

The science information research program of the Foundation has continuously sought a deeper understanding of the communication patterns and information needs of the scientific community. The problem has been not only to recognize patterns and needs as they are expressed or exhibited, but also to predict what these needs might be if improved or different information systems and services are developed. User studies have produced some interesting and unexpected results, not necessarily conclusive, but indicative of the need for future research.

For example, study of information exchange in psychology has found that information exchange through formal published channels represents but a fraction, and perhaps not the most significant fraction, of the total information exchanged by scientists. The role of informal exchange through reprint, preprint, oral communications, and communications at conferences, therefore, requires closer scrutiny. As a result of the study, the American Psychological Association is experimenting with such innovations as the provision of published lists of papers just as soon as they have been accepted by APA journals, and the distribution of conference papers in advance of annual conventions. This latter change may alter the traditional format of the APA convention and increase the time available for discussion of research results.

The study has also raised questions as to whether the findings are unique for the psychological community or are applicable to other disciplines. It has stimulated the interest of other societies in similar approaches to the problem of the information exchange within their own disciplines. NSF has been exploring this subject with professional organizations in mathematics, biology, and the earth sciences. Also, a grant was made to Columbia University for a review of the results of studies already completed. On the basis of this review, the investigators will attempt to provide a framework for further efforts.

Organization of Information

Intimately related to the problems involved in assessing the communication patterns of scientists and in evaluating the merits of systems is the problem of organizing information for retrieval. Traditional modes of organizing book collections in libraries by means of hierarchical classifications, or of describing their contents through standardized subject headings, have been supplemented by indexing applied to journal articles and the technical report literature. Controlled vocabularies, thesauri, permuted title indexes, rudimentary machine-generated indexes, and citation indexes have all been the subject of both experimentation and development. Because NSF has not yet been able to identify any single approach to the organization of information that is clearly superior, it has encouraged studies and development in almost all of these areas.

One example of this support is a grant to the Technical Information Project at the Massachusetts Institute of Technology, in which an information system has been designed as a test environment within which processing techniques and experimental services can be tried and evaluated. Data describing the significant literature of physics are generated exclusively through clerical or nonprofessional efforts, so that the system can, if desired, be economically expanded. The data involved include the author, title, and the bibliographic citations of the article. The availability of Project MAC (Multiple Access Computer and Machine-Aided Cognition) at MIT provided a computer base for this project, together with simultaneous access by a community of users through remote terminals.

Network and System Relationships and Evaluations

Information systems or centers that provide documents, secondary indexing and abstracting, or other information services, and libraries that

794-807 O—65——12

store and make available the literature of science, are interdependent. The relationships involve connections between Federal services and those provided by State, local, or private agencies; between services that are universal in scope and those that are subject-specialized; and between those that provide a variety of services and those that concentrate on a particular kind.

An approach to the understanding and consequent manipulation of service and user patterns has been attempted through the development of analytic tools based on mathematical modeling techniques. A contract with the Information Dynamics Corp. has yielded a mathematical model that will allow computer simulation of different network characteristics and configurations. At present, the testing of the model has been limited to hypothetical situations. Planning is underway to support application of this technique to actual situations.

A conference organized by NSF in 1964 on the subject of evaluation of document-searching systems and procedures concluded that considerable efforts still need to be expended in the development of: effective measures of system performance, objective criteria for evaluation of such performance, improved experimental design for test and comparison of systems, and improved methods of reporting the results of such experiments to facilitate comparability. NSF is, therefore, providing support for a critical review of experimental designs for system testing and evaluation and for empirical studies of relevance assessments by users of information services.

Automatic Language Processing

Research in machine-aided language processing has followed two paths. One seeks solutions to information retrieval problems through machine manipulation of English language texts; the other concentrates on manipulation of foreign languages to achieve a translation capability. The first path has led to experimental computer programs that have begun to serve the research community. In the parallel path, mechanical translation projects have in the past few years completed preliminary versions of automatic sentence analysis programs, similar to programs for the English language. NSF support has stressed research on those aspects of machine translation that offer promise of ultimate application and is therefore interested in encouraging research dealing with the application of currently available techniques to aid the human translator. There is evidence that, under proper conditions, man-machine translation can be produced at higher quality, lower cost, and greater speed than translation produced by unaided translators.

Scientific Publications

Experimentation and development with a computer-aided publication system has been pursued with NSF support by the American Mathematical Society. Such computer-aided typesetting is expected both to increase the speed of mathematical publication and to reduce its cost. Similar experiments have proceeded toward the development of effective techniques for the photocomposition of chemical structures. The American Chemical Society undertook, with NSF support, to develop a test matrix disk of chemical structural characters for a photocomposing device. Work is now under way looking toward an improved matrix disk and toward tying this procedure into the total information system provided under the aegis of the American Chemical Society.

More general application can be expected from work conducted by Inforonics, Inc., on a method for computer-controlled printing of journal articles that will permit the automatic generation of bibliographic information and indexes. NSF is supporting trials at the American Chemical Society.

Although such experimentation looks toward application of new technologies to the publication process, the present information needs of the scientific community must still be met through traditional publication media. Many of these are not self supporting and require the aid of Federal funds for their continued existence. NSF has met this requirement by supporting the publication of journals, monographs, abstracting and indexing services, and translations of foreign scientific literature.

This effort represents the single largest science information service investment by the Foundation over the past several years. It has provided support for publications in all the major disciplines with varying and changing emphasis among types of publications. In 1965, 86 percent of the nearly $3 million expended in the support of publications was equally divided between translations and abstracting and indexing services. NSF support for publications is viewed as support for the initial establishment of a service that should eventually attract funding through the sale of subscriptions and copies to a point where the publication would become self-sufficient. Such indeed has been the case with respect to the translations published by the American Institute of Physics.

SCIENCE INFORMATION COORDINATION

The National Science Foundation is represented on the Committee for Scientific and Technical Information (COSATI), which provides a forum for the discussion of interagency problems and activities in the area of scientific and technological information. This committee reports its views and recommendations to the Federal Council for Science and Technology, which serves both an advisory and coordinating function to the President's Office of Science and Technology.

By virtue of a COSATI recommendation and a decision of the Federal Council on Science and Technology, the Foundation has assumed responsibility for the funding and policy direction of the Science Information Exchange (SIE) administered by the Smithsonian Institution. The SIE collects information on active federally conducted or supported research projects. During 1965, considerable attention was given to increasing SIE coverage of such research. The expansion of coverage into the physical and social sciences required not only adjustments on the part of the SIE but also on the part of agencies hitherto not accustomed to reporting in these fields.

NSF continued its support of the National Referral Center for Science and Technology in the Library of Congress. Emphasis during the year was given to developing working relationships with the Clearinghouse for Federal Scientific and Technical Information in the Bureau of Standards, as well as spurring the Center's attention to the analysis of national information resources in its growing files.

NSF worked with, and contributed to, a number of subcommittees and task groups of COSATI concerned with specific problems of interest to the member agencies. Particular contributions were made to the study of translation of foreign scientific and technical literature by Government agencies, and to the development of compatible vocabularies among the varied indexing services offered by these agencies.

As COSATI became more concerned with the national patterns and needs respecting science information, a special task force was organized under the chairmanship of the Head of the Foundation's Office of Science Information Service to develop recommendations on the problems and relationships associated with the traditional scientific journal.

FOREIGN SCIENCE INFORMATION

From its inception, NSF has recognized the geographic indivisibility of science and the need for effective access to the results of scientific research wherever such research may be pursued. One of the barriers to foreign scientific literature is the problem of language and the fact that only a small percentage of American scientists can effectively read journals and reports written in languages other than English. NSF attempts to ease this problem by supporting translation programs in this country as well as by the Special Foreign Currency Science Information Program (Public Law 480) overseas. Under the latter program NSF serves all agencies of the Government in utilizing counterpart funds in specific countries (presently Poland, Yugoslavia, and Israel) to pay for requested translation of scientific and technical materials mainly in Russian and East European languages. In addition to providing translations to these agencies, the program makes copies available to the Clearinghouse for Federal Scientific and Technical Information for sale to the public.

During fiscal year 1965, 53 foreign journals were being translated. In pages these amounted to 77,650 in the Slavic languages, 2,400 in Japanese, and 3,400 in Chinese.

Much of the effort in making foreign scientific literature available to the American scientists involves the establishment of international cooperative arrangements. The Foundation has encouraged the activities of the International Council of Scientific Unions (ICSU) and the ICSU Abstracting Board in the area of documentation and of the International Federation of Documentation (FID) in its association with the community of professional documentalists. The ICSU Abstracting Board has undertaken studies comparing the services of the several national indexing and abstracting publications, and their coverage of the scientific literature. NSF's contributions to the efforts of ICSU and the FID have benefited from the assistance and cooperation of the National Academy of Sciences, both through its Office of Documentation and through the active interest of the Academy's Foreign Secretary and his staff.

In addition to continuing the support of the National Federation of Science Abstracting and Indexing Services to secure Chinese scientific journals, NSF in 1965 contracted for the completion of a comprehensive directory of mainland Chinese research organizations and institutes. This is similar to a directory of East European research institutes now in press.

INTERNATIONAL SCIENCE ACTIVITIES

International activities supported by the Foundation have the same basic intent as all other Foundation activities—strengthening U.S. science. Many regular NSF programs, such as those dealing with research that may take place abroad, exchange of scientists, and scientific meetings, involve international activities in the usual course of business. Other programs are specifically designed and administred as international projects. These include such activities as the United States-Japan Cooperative Science Program and certain science education programs. Additionally, NSF administers certain AID-financed projects beneficial to developing countries.

NSF maintains two overseas offices—Tokyo, Japan, and San Jose, Costa Rica—to support certain of these activities.

RESEARCH

Research grants to foreign institutions in fiscal year 1965 amounted to $637,000, which is less than half of 1 percent of total funds expended by NSF for support of basic research during the year. Grants to such institutions are made only in exceptional circumstances—typically when the research cannot be carried out in the United States because of geographic or environmental factors. Examples of such support are grants to the University of Nigeria for an archeological survey of East Nigeria, and to the University of Sidney (Australia), for observations of galactic and extragalactic radio emission of the Southern Hemisphere.

A number of NSF grants to U.S. institutions involve work done abroad; research and science information projects are most frequently involved. An illustration of this type of grant is in the field of anthropology, where major attention to foreign cultures (both modern and ancient) has been traditional.

The National Science Foundation supports in varying degrees the participation of U.S. scientists in many international programs. Among the current programs are the International Indian Ocean Expedition, the International Year of the Quiet Sun, the United States-Japan Cooperative Science Program (all of which are discussed in the *National Research Programs* section of this report, beginning on page 91).

SCIENCE EDUCATION

The Foundation's regular science education activities from time to time have international aspects. In 1965, for example, of the 4,993 fellowships awarded by NSF to U.S. citizens, 247 provided for tenure at a foreign institution.

Of more direct international impact, however, are the education programs designed specifically as international or carried out by NSF at the request of other agencies dealing with foreign affairs. Programs of the latter type are frequently funded by money transferred from the requesting agency to NSF.

Programs that were specifically international in nature included, in fiscal year 1965, providing travel support to help 71 young U.S. scientists attend short-term advanced study institutes sponsored in Europe by the North Atlantic Treaty Organization, and administering the Senior Foreign Scientists Fellowship Program by which 49 distinguished foreign scientists came to study, lecture, or do research in universities in this country.

At the request of the Department of State, NSF again awarded North Atlantic Treaty Organization fellowships to U.S. citizens—71 during the last fiscal year—to enable them to study in NATO countries.

The Associated Colleges of the Middle West, working in cooperation with the University of Costa Rica, was given support for the development in Central America of a training program in the environmental sciences. Support was also given to U.S. institutions and organizations to enable foreign scientists and science educators to participate in U.S. educational and training activities; in the seventh year of a program conducted in cooperation with the Department of State and a number of organizations with international interests, 134 teachers from foreign countries were placed in NSF-sponsored teacher institutes held at U.S. university campuses.

In a parallel development, U.S. professors of science, experienced in running NSF-supported institutes, are being called on to teach and help develop similar activities in a number of foreign countries. For example, there is a large program in India where in the summer of 1965 about 200 U.S. scientists helped with the operation of 90 institutes financed by AID funds.

A great deal of interest has been shown by foreign countries in NSF-sponsored course content development activities, as well as in the teacher training institutes. Representatives of U.S. course content study groups have been associated with a variety of science education projects throughout the world—projects which have been modeled to a large extent after U.S. efforts. Various high school course materials, developed with NSF support, have been translated into Spanish, Japanese, Chinese, Portuguese, Thai, Hebrew, Norwegian, Swedish, French, and other languages, and have been used as text or resource materials in more than 40 countries. The existence of these various NSF programs has stimulated similar programs in the more advanced countries which are in turn benefiting science education in the United States. The developing countries have also shown great interest in these programs, and the Foundation has been asked to provide assistance in many parts of the world. (See section on Development Assistance Programs, page 152.)

ECONOMIC AND MANPOWER STUDIES

In pursuit of its mission to develop policy recommendations for the improvement of U.S. scientific resources, the Foundation conducts and supports economic and manpower studies, primarily on U.S. resources, but including foreign resources as well. It is attempting to obtain data on manpower, facilities, and funds devoted to science activities in many foreign countries and to analyze the effect of these activities on technology and economic growth.

The Foundation has participated in projects of the Organization for Economic Cooperation and Development (OECD) which resulted in the establishment of standards in methodology for the survey of national scientific resources and manpower. It has also supported U.S. studies of science in the U.S.S.R. and Red China.

INTERNATIONAL CONFERENCES, TRAVEL AND EXCHANGE

Another NSF activity of substantial benefit to the American scientific community is attendance by U.S. scientists at meetings abroad, and participation by foreign scientists in professional conferences in the United States. During fiscal year 1965, more than 600 travel grants were awarded to U.S. scientists primarily to permit them to attend international scientific meetings.

Some of the funds supplied by NSF for scientific conferences are used to make possible the participation of foreign scientists whose contribution to the conferences are essential in assuring maximum scientific benefit to the U.S. participants.

SCIENCE INFORMATION ACTIVITIES

A key mission of the Foundation is to improve the availability to scientists and engineers in the United States of the results of worldwide scientific and technical research. The Foundation is, therefore, involved in making translations of foreign scientific and technical literature available in the United States through translation programs carried on abroad and through support for publication within the United States.

The past year has witnessed an increased interest on the part of many countries in the developments within the United States designed to satisfy requirements for improved scientific and technical information services. This interest is manifested directly and through international organizations—both governmental, such as the Organization for Economic Cooperation and Development (OECD), and nongovernmental, such as the International Federation for Documentation (FID). The Foundation provides both advisory and liaison services to programs of the international governmental organizations. Fiscal support serves to improve the capability of nongovernmental groups to facilitate the flow of science information across national boundaries.

The United States-Japan Scientific Cooperation Program has involved meetings of groups from both countries concerned with improving research on mechanical translation and the publishing of scientific and technical journals.

Science information activities of the Foundation are discussed in detail beginning on page 139.

EXCHANGES WITH EAST EUROPEAN COUNTRIES

NSF has since 1959 supported a program of the National Academy of Sciences for the exchange of scientists between the United States and the U.S.S.R. In fiscal year 1965, 43 Soviet scientists visited the United States for a total of 105 man-months, and 34 American scientists visited the U.S.S.R. for a total of 91 man-months. (Comparable figures for the preceding year were 15 Soviet visitors for 24 man-months and 13 Americans for 52 man-months.) The agreement calls for 55 visits from each country totaling 180 man-months for the two calendar years 1964 and 1965.

The Academy is also carrying out exchanges with the Polish Academy of Sciences and the Yugoslav Council of the Academies, and exchanges are contemplated with comparable bodies in Czechoslovakia, Hungary, and Rumania. Under an NSF grant, an NAS delegation visited Poland in May 1964, and Yugoslavia in May 1965. It is anticipated that further scientific exchanges will take place with Poland, Yugoslavia, and Rumania during fiscal year 1966 under this program.

INTERNATIONAL COOPERATION YEAR

On October 2, 1964, President Johnson issued a proclamation stating that the United States would participate in the International Cooperation Year 1965, an event established by the United Nations. The prime purpose of this Year was to publicize the immense amount of cooperation in all fields which is now taking place among nations, as well as to develop new programs.

Of the 31 committees established by the Government to explore various aspects of the International Cooperation Year, two—Science and Technology, and Manpower—were chaired by NSF personnel. Staff personnel were also members of several other committees. A White House Conference on the International Cooperation Year, from November 30 through December 2, 1965, considered the committee findings.

INTERNATIONAL ORGANIZATIONS

OECD—The Organization for Economic Cooperation and Development (OECD), which started as a mechanism for making North American financial and technical assistance available to Europe, is gradually evolving into a unique association of the 21 most advanced nations in the free world devoted primarily to their own economic development. At the request of the Department of State, NSF has for several years assisted in science activities of the OECD.

In fiscal year 1965, there were some 53 OECD meetings in which 83 U.S. citizens took part. NSF, with the help of other Federal agencies, selected these participants, briefed them, and in many cases prepared relevant documents for the meetings.

UNESCO—NSF cooperates with the UNESCO science program staff, particularly in the areas of science teaching and science information. UNESCO is undertaking a large program for the development of new science teaching materials and courses in the developing countries, and there has been considerable interaction between the UNESCO secretariat and NSF staff in this field.

DEVELOPMENT ASSISTANCE PROGRAMS

The many new high school science text books and courses that have been prepared over the past 7 or 8 years with NSF support have attracted considerable attention abroad; they may turn out to be one of America's most popular and useful exports. The developing countries have been particularly interested in these new courses because in them they see a way of obtaining the best and newest methods of science instruction for their schools. The Agency for International Development (AID) has asked NSF to help countries in translating and adapting these text books for local use. Because of legislative restrictions, NSF could not use its own funds to support such activities. However, funds provided by AID made possible two NSF science education assistance programs directed to the improvement of instruction in science and mathematics in the secondary schools and at the lower levels in the universities of Latin America. Competent Latin American scientists and mathematicians are supported and encouraged in their efforts toward curriculum reform, teacher improvement, and development of modern course materials. Technical assistance and guidance are provided by U.S. scientists who have participated in such projects in the United States. The programs provide assistance in the selection of laboratory equipment and in the design of facilities. There is made available demonstration quantities of new course materials developed in the United States, and some opportunity for advanced training of faculty in the United States.

To ensure maximum benefit through these programs, leading scientists of the region have met in planning and evaluation conferences and seminars, and have defined regional objectives and national needs. New course materials have been developed in Spanish and Portuguese. Special attention has been paid to tropic zone biology. Institutes for the training and upgrading of teachers have been organized, and NSF/AID assistance has been provided for participation in these institutes by faculty and trainees from remote areas.

The larger of the two assistance programs is directed to the improvement of science and mathematics instruction throughout Latin America, principally at the level of the secondary school. Cooperating Latin American organizations include the Argentine National Council for Scientific and Technical Research, the Peruvian Institute for the Promotion of Mathematics Education, and the Brazilian Institute for Education, Science, and Culture.

The second program, undertaken in cooperation with the Superior Council of Central American Universities, is directed to the integration and regional accreditation of science and mathematics training in the schools of general studies (i.e., the lower university level) of the national universities of Costa Rica, Nicaragua, El Salvador, Honduras, and Guatemala.

Both programs are coordinated with related programs of the Ford Foundation, the Organization of American States, the Inter-American Development Bank, and UNESCO.

SCIENCE POLICY PLANNING

The Nation has become increasingly dependent upon science to achieve its goals. The investment of public funds in the support of basic research and education in the sciences has mounted rapidly and sharply. The contributions of private funds to scientific activities have risen absolutely but declined in relative importance; and the Nation's total scientific enterprise has expanded enormously and altered significantly in form. As a result of these developments in recent years, the questions and issues faced by those who seek to plan for the continuing health and vitality of science and who are compelled to reach decisions on problems of science policy have grown in number, scale, complexity, and difficulty.

In the final analysis, the planning activity of the Foundation is defined by the issues, questions, and problems of science policy. Consequently, this activity seeks to: (1) understand their purport and relative importance; (2) cast them in meaningful and manageable forms; (3) discover effective ways of illuminating and clarifying them; (4) secure the relevant data, information, knowledge, and insight required for effective policy analysis and formulation; and (5) anticipate the emergence of new issues and problems of science policy in the future.

Within the last two decades a new partnership has been fashioned between the Federal Government and the U.S. science community. This partnership has emerged from the dependence of the Government upon science, and from the growing realization that it is in the national interest to encourage and sustain the health, vigor, and growth of the scientific enterprise, broadly conceived. In consequence, there is now a clear-cut, continuing commitment on the part of the Federal Government to provide support for research and education in the sciences.

For scientific research alone (basic and applied), Federal obligations were estimated at around $5.1 billion in fiscal year 1965. For research and its technological counterpart, development, annual Federal expenditures (including R&D plant) increased from $74 million in fiscal year 1940 to an estimated $15.4 billion in fiscal year 1965. Today, the Federal Government provides about two-thirds of the dollars used in the performance of research and development throughout the Nation. In large measure this support stems from specific Federal requirements for national defense, health, and space technology. To a lesser degree it is also support for non-mission-related basic scientific research and graduate education in science to provide the manpower and fundamental knowledge that will be needed later.

Because the Nation's goals are related to and dependent upon scientific and technological progress, these expenditures of public funds are an investment in the Nation's future. To make this investment both prudent and fruitful, the Nation must find appropriate ways of foreseeing the needs of research and education, and of planning to meet these needs.

PLANNING A NATIONAL POLICY FOR SCIENCE

Within the Federal Government, national science policy planning is shared by the legislative and executive branches. Examples of congressional involvement are seen in the annual budget review and in special reviews conducted by various committees and subcommittees from time to time. The creation of a Science Policy Research Division within the Legislative Reference Service of the Library of Congress is a recent important example of congressional interest in science policy.

The annual review of the budget of each executive department or agency, by aprropriate committees in the House of Representatives and Senate, has led, over the years, to continuing analysis of ongoing and proposed policies and programs. It has, consequently, been an important factor in the planning and formulation of policy. Furthermore, the policies and practices of each Federal agency are subject to congressional review by standing or specially created committees. Recently, for example, the Subcommittee on Research, Development, and Radiation of the Joint Committee on Atomic Energy considered the problem of funding and planning in the field of high energy physics. Decisions based on hearings such as this may have important effects not only on the agency most directly concerned—in this case the Atomic Energy Commission—but also upon a scientific discipline as a whole.

The extended hearings of the Subcommittee on Science, Research, and Development of the Committee on Science and Astronautics of the House (the Daddario Committee) is an example of major studies on the part of the Congress in its continuing evaluation of the Nation's scientific enterprise.

Another highly important contribution to the understanding of public policy problems in the field of science and to the assessment of the scientific enterprise, particularly of its academic component, was made by the House Committee on Science and Astronautics through a contract entered into with the National Academy of Sciences. This agreement resulted in a report to the Committee entitled *Basic Research and National Goals,* published in March 1965. This report represents a landmark in congressional assessments of science policy, and promises to exert a strong influence upon policy planning and formulation in the future.

Within the executive branch, science policy planning similarly takes place in different ways and at different levels. The President may seek advice on matters relating to science through his Special Assistant for Science and Technology, who in addition to serving as the President's personal science advisor is Director of the Office of Science and Technology and Chairman of both the President's Science Advisory Committee and the Federal Council for Science and Technology. The Office which he heads is responsible for evaluating and assisting in the coordination of the entire Federal scientific and technical establishment.

The Federal Council for Science and Technology, consisting of top policy-level representatives from each of the Federal agencies most heavily engaged in scientific and technological activities, is a coordinating mechanism for the entire Federal effort in these areas. The President's Science Advisory Committee, which consists of leading scientists and engineers appointed by the President from outside the Government, provides advice on a wide variety of subjects and policy problems involving science.

A significant factor in Federal policy planning and formulation is, of course, the Bureau of the Budget. In its analyses of the budgetary plans of the several agencies, the Bureau is concerned with projected levels of funding for scientific programs, and it inevitably plays a major role in determining the direction and the magnitude of Government involvement in science.

In addition to the interests and activities of the Federal Government, there are other diverse factors which affect, directly and indirectly, the level, substance, and conduct of research and other scientific activities in the United States; the opportunities for, and content of, education in the sciences; and the utilization and development of the Nation's resources for science. These influences are shaped by the policies of State and local governments and by the attitudes and actions of a variety of nongovernmental institutions and organizations. They are private as well as public in character. They are expressions of different goals, purposes, and emphases, and they rely upon different means to attain the particular ends they seek.

What is commonly spoken of as "national science policy," therefore, may be more accurately described as the sum of the public and private policies which contribute to the realization of four broad objectives:

(1) assuring the vitality of scientific research and other activities designed to push back the frontiers of knowledge;

(2) enhancement of the resources of manpower and institutions required to carry out those activities;

(3) diffusion and utilization of scientific information and understanding; and

(4) conversion of basic scientific knowledge to useful applications beneficial to the welfare of the Nation and its people.

The complexity and subtlety of planning policy for science pose a major challenge because of the very nature of the activities which seek to extend and deepen the store of human knowledge. The scientist can, and must, plan his approach to a research problem. Society, through its responsible elements, such as the Federal Government and the academic community, is also planning when it attempts to enhance the resources of science and sustain the conditions and climate conducive to the pursuit of free inquiry. But this does not mean that specific fundamental advances or basic discoveries in scientific knowledge can be planned. It would have been impossible, for example, to plan the discovery of the electromagnetic effect which Joseph Henry and Michael Faraday first observed in 1828, the observation of radioactivity by Antoine Becquerel in 1896, or the discovery of penicillin by Sir Alexander Fleming in 1929.

Clearly, responsibility for the substantive planning of research rests with the working scientist. Society, however, has a planning responsibility for the determination of policies which promote research and education in the sciences—policies which ensure the sound development of the necessary resources of manpower and institutions.

Government can aid basic research by planning and creating a policy framework within which research and science education can flourish. As new discoveries and insights lead to new opportunities and challenges, needs arise not only for adequate human and material resources but for policies that can encourage and support progress under new conditions. Thus the planning process must try to determine how, as well as how much, support can best be provided for:

(a) science as a whole (research, education, and information), as contrasted with research in particular;

(b) the different scientific disciplines with due regard to emerging cross-disciplinary research areas; and

(c) basic science, as compared to applied science and development.

Such choices among alternatives must be made constantly, for it is almost invariably true that our ideas, purposes, and objectives outreach our resources. Moreover, the results of earlier decisions—or lack of decisions—bring new difficulties, new opportunities, and new situations. To make valid choices, policies and plans must be very carefully conceived, for they involve such truly national purposes as increasing the Nation's defense capabilities, sustaining the health and well-being of the people, assuring continued success in space science and technology, encouraging steady industrial growth, developing an adequate pool of highly trained manpower, and achieving a satisfactory institutional and geographical distribution of science support funds.

Both the significance and the difficulties of planning with respect to science are further illustrated by the fact that there are many other areas of policy far less intimately linked to science—elimination of poverty, taxation, patents, immigration, and civil rights, for example—in which decisions may and do exert important influences on the scientific enterprise of the Nation.

In the presence of many policies dealing with science—which collectively may be thought of as "national science policy"—the role of the National Science Foundation in science policy planning spans both the Federal and non-Federal sectors, and is defined by the statutory responsibility to "develop and encourage the pursuit of a national policy for the support of basic research and education in the sciences," and ". . . to appraise the impact of research upon industrial development and upon the general welfare."

Within the executive branch, the National Science Foundation also has major responsibilities for developing, proposing, coordinating, or evaluating policies by which not only the Federal Government but also State and local governments and nongovernmental organizations and institutions can contribute to the enhancement of the health and vigor of research and education in the sciences.

NATIONAL SCIENCE FOUNDATION PLANNING ORGANIZATION

The importance of the planning function to the mission of the National Science Foundation is reflected in actions taken by the Foundation during fiscal year 1964 to expand and add increased responsibility to its own organization for planning. Three newly established offices and the Data Processing Center were placed in the Office of the Associate Director for Planning.

Office of Economic and Manpower Studies

The Office of Economic and Manpower Studies conducts factual and statistical studies designed to provide essential data and descriptive information on all facets of scientific research and development and science education. Fundamental data that are meaningful and comprehensive are essential to the decision-making process and policy formulation.

Office of Science Resources Planning

The Office of Science Resources Planning is concerned with long-range planning studies to assure the effective development and utilization of the Nation's resources for research and education in the sciences. It is also concerned with the structure and substance of broad policies and programs designed to optimize national resources. To this end, it seeks to develop and assess alternative policies which could be pursued in both the public and private sectors and to recommend preferred courses of action.

Office of Program Development and Analysis

The Office of Program Development and Analysis serves as a focal point for planning the Foundation's own future program activities. Its principal objectives are the improvement and strengthening of the Foundation's efforts in support of science and science education, and the coordination of ideas and concepts that are of concern to various Foundation offices and divisions. Continuing assessment of ongoing Foundation programs is conducted to assure their relevance and effectiveness.

Planning elements have also been established within the components of the Foundation specifically concerned with research and with education, in order to coordinate plans formulated in these areas and to provide continuing liaison with the Office of Program Development and Analysis.

Data Processing Center

Recent expansion in the Foundation's data-processing capability can be expected to make a significant contribution to the effectiveness of overall planning. Information on Foundation programs and activities will be more readily available and in greater detail than in the past, as will various bodies of data on significant aspects of the Nation's scientific enterprise. When fully operative, the Data Processing Center will have enhanced sharply the Foundation's capacity to conduct complex statistical and analytical studies.

Additional Planning Groups

As further evidence of the emphasis on both short- and long-range planning within the Foundation, it is notable that within the past year the committee structure of the National Science Board was reorganized so that one of its standing committees is now assigned specific responsibility for the Foundation's intermediate- and long-range plans. The work of this committee in particular, as well as of the others, augments and guides to a significant degree that of the planning staff, so as to strengthen the position of the Foundation as a whole with respect to planning and policy formulation.

In addition to the work of the National Science Board, and the important contributions made by the divisions and program directors within the Foundation, the planning and policy-making capability is further augmented by the Planning Council, a group consisting of the Foundation's top officials under the chairmanship of the Director. A final, and far from insignificant, factor in Foundation planning activities emerges from its wide-ranging formal and informal relationships with other agencies and governmental commissions, committees, and panels, with scientific and professional societies, academic and other institutions, as well as with individual scientists.

The current issues and questions raised with respect to science policy range from the impacts of the system of Federal support of academic research upon institutions of higher education to the allocation of Federal expenditures between the support of basic research, on the one hand, and of applied research and development, on the other; from the varied

794-807 O—65——13

long-range educational implications of improvements in science education in elementary and secondary schools to the effects of public expenditures on research and development upon the economic health and growth of a locality or region; and from the appropriate relationship between the level of Federal support of academic research and of graduate students to the sums devoted to the work of Federal research laboratories.

It is evident that the more fundamental problems of policy will endure. They will continue to be relevant and important problems because the policy decisions made with respect to them at one point in time do not solve them for all time.

In order to help the planning of sound, longer-range policies for the health of science and the development of viable programs for the support of research and education in the sciences, the Foundation strives to secure reliable information and data for establishing the parameters and describing the essential characteristics of the Nation's total scientific and technical enterprise. In line with this effort, a wide range of surveys and analytical studies, methodological as well as substantive, are conducted by the planning offices themselves as well as through grants or contracts.

The Foundation's annual survey, *Federal Funds for Research, Development, and Other Scientific Activities,* now in its fourteenth year, represents the only systematic and comprehensive compilation of obligations and expenditures of Federal departments and agencies in the support of research and development. The Foundation also gathers varied bodies of information from academic institutions, profit organizations, Government laboratories, and nonprofit, nonacademic institutions designed to throw light on the manner in which the Nation's resources for science and technology are distributed and utilized in all of its sectors.

Additional significant data are provided by The National Register of Scientific and Technical Personnel, which the Foundation is required by statute to maintain. Recent analyses of these data have, for example, provided fresh information on the mobility of scientists with respect to geographic location, field of science, type of employer, and work activity. Other studies and surveys focus on obtaining knowledge about the development of scientific and technical personnel through the processes of education and training. Also of major concern to the Foundation is a better understanding of the factors which affect supply of and demand for scientific and engineering manpower and, in particular, improvement in the techniques for forecasting future demands for such manpower.

Other study efforts are directed to illuminating the relationship of Federal research and development expenditures to the Gross National Product, to determining ways of assessing their economic and social implications, and to understanding the pattern of geographic distribution of these expenditures. A report prepared by the Foundation at the request of the Subcommittee on Science, Research and Development of the House Committee on Science and Astronautics, on *Obligations for Research and Development by Geographic Divisions and States by Selected Federal Agencies, Fiscal Years 1961–65,* provides key data and information on the geographic distribution of Federal research and development funds. Other NSF analyses deal with the patterns of the distribution of Federal funds for academic research on an institutional basis and with the implications of these patterns for governmental policies and programs. Among other problems connected with the economics of research under investigation is that of determining the rate of increase in the costs of conducting research.

Progress in policy planning for science depends upon an understanding of the implications of a pluralistic structure of goals and purposes for the availability and allocation of the resources for science. It depends also on learning how to identify emerging needs, how to assess with confidence the changing requirements within different fields of science, how to sustain research and educational excellence where they exist and at the same time identify and develop the potentialities for excellence, how to attain national purposes for science and through scientific activities while safeguarding the freedom and independence of scientific institutions and individual scientists, and, in sum, how to protect and make fruitful society's investment in science.

All of these objectives are reflected in aspects of the work of the planning organization other than those already mentioned. Thus, an analytical study is devoted to securing a more thorough and systematic understanding of the structure of diversified support for academic research and of the ways in which its component elements interact. Fundamental questions in connection with the problems of priorities in science and the determination and application of criteria for scientific choice are also being pursued, as is a systematic understanding of the processes and factors involved in the allocation of funds to scientific research within the Federal Government.

In connection with the future needs of the various fields of science, the Foundation supports the work of the National Academy of Science's Committee on Science and Public Policy. Under its auspices one report, *Ground-Based Astronomy: A Ten-Year Program,* has been published. Others on chemistry, physics, plant sciences, and computers have been launched, and studies on mathematics and biology are being planned. A related area of investigation involves an effort to work out the implications which alternative sets of assumptions with respect to the future have for science policy strategies.

A key element in the Foundation's concerns is the strength and health of the Nation's institutions of higher education. Consequently, the Foundation is also engaged in studying in a variety of ways the impact of its programs, as well as those of other Federal agencies, upon academic institutions. For sound planning of future Foundation policies and practices it is necessary to forecast with as much understanding as possible how they may affect scientific research. Hence it is important to be able to assess critically the consequences of support programs and policies upon the educational functions of academic institutions as well as upon their organization and structure. At the same time, it is essential to anticipate the quantitative and qualitative changes in higher education likely to occur in the future and the extent to which academic institutions may be susceptible to significant innovations and alterations.

During the past year the Foundation has intensified and deepened its examination of the Federal Government's role in academic research and graduate education. A new study, based on the Foundation's own data as well as information reported by other Federal agencies, is designed to develop a profile of academic science and technology that will be useful in assessing patterns and levels of Federal obligations for scientific programs at universities and colleges. The results of this study now available have pin-pointed a series of policy issues connected to the educational implications of existing patterns of institutional distribution of Federal funds.

There has been no intention to depict here every aspect of the work of the planning staff of NSF or to detail the variety of analytical studies and large-scale statistical surveys which it conducts. What has been sought is to convey a sense of the kinds of problems which must be faced and the range of study activities which must be pursued in order to contribute meaningfully to the planning function in connection with the formulation and implementation of sound and effective policies for science and with their critical and objective evaluation.

APPENDICES

A listing of grants, contracts, and fellowships awarded in fiscal year 1965 appears in a separate publication entitled "National Science Foundation Grants and Awards, Fiscal Year 1965," NSF 66–2. It is available from the Superintendent of Documents, U.S. Government Printing Office, Washlngton, D.C.

APPENDIX A

National Science Board, Staff, Committees, and Advisory Panels

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794-807 O - 65 - 14

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L. Quincy Mumford, The Librarian of Congress, Washington, D.C.

Derek J. de Solla Price, Avalon Professor of History of Science, Yale University, New Haven, Conn.

Ralph R. Shaw, Dean of Library Activities, University of Hawaii, Honolulu, Hawaii.

R. H. Shryock, Professor of History, University of Pennsylvania, Library, American Philosophical Society, Philadelphia, Pa.

Henry B. Steinbach, Chairman, Department of Zoology, University of Chicago, Chicago, Ill.

Don R. Swanson, Dean of the Graduate Library School, Harper Memorial Library, University of Chicago, Chicago, Ill.

Raymond K. Wakerling, Director, Technical Information Division, Lawrence Radiation Laboratory, University of California, Berkeley, Calif.

Thomas J. Wilson, Director, Harvard University Press, Cambridge, Mass.

Commission on Weather Modification

A. R. Chamberlain, Vice President for Administration, Colorado State University, Fort Collins, Colo.

William C. Colman, Executive Director, Advisory Commission on Intergovernmental Relations, Washington, D.C.

John C. Dreier, Visiting Professor of Latin American Affairs, School of Advanced International Studies, Johns Hopkins University, Washington, D.C.

Leonid Hurwicz, Department of Economics, University of Minnesota, Minneapolis, Minn.

Thomas A. Malone, Second Vice President, Research Department, Travelers Insurance Co., Hartford, Conn.

John Bardeen, Department of Physics, University of Illinois, Urbana, Ill.

Arthur W. Murphy, Professor of Law, Columbia University Law School, New York, N.Y.

Sumner T. Pike, Vice President, The Trident Packing Co., Inc., Lubec, Maine

William S. von Arx, Woods Hole Oceanographic Institution, Woods Hole, Mass.

Gilbert F. White, Department of Geography, University of Chicago, Chicago, Ill.

Karl M. Wilbur, Department of Zoology, Duke University, Durham, N.C.

Advisory Panel for Anthropology

Robert M. Adams, The Oriental Institute, University of Chicago, Chicago, Ill.

Harry W. Basehart, Department of Anthropology, University of New Mexico, Albuquerque, N. Mex.

Frederick Johnson, R. S. Peabody Foundation for Archaeology, Phillips Academy, Andover, Mass.

Herbert H. Paper, Department of Linguistics, University of Michigan, Ann Arbor, Mich.

Lauriston Sharp, Department of Anthropology, Cornell University, Ithaca, N.Y.

Raymond H. Thompson, Department of Anthropology, University of Arizona, Tucson, Ariz.

Advisory Panel for Astronomy

(Chairman: Dr. Geoffrey R. Burbidge)

Radio Astronomy

Frederick T. Haddock, Jr., The Observatory, University of Michigan, Ann Arbor, Mich.

A. Edward Lilley, Harvard College Observatory, Cambridge, Mass.

Edward F. McClain, U.S. Naval Research Laboratory, Washington, D.C.

Optical Astronomy

Russell Grant Athay, University of Utah, Salt Lake City, Utah

Geoffrey R. Burbidge, University of California, La Jolla, Calif.

Armin J. Deutsch, Mt. Wilson and Palomar Observatories, Pasadena, Calif.

Bengt G. Stromgren, Institute for Advanced Study, Princeton University, Princeton, N.J.

Merle F. Walker, Lick Observatory, University of California, Mt. Hamilton, Calif.

Marshal H. Wrubel, Geothe Link Observatory, Indiana University, Bloomington, Ind.

Advisory Panel for Atmospheric Sciences

Werner A. Baum, Vice President for Academic Affairs, University of Miami, Coral Gables, Fla.

George S. Benton, Department of Civil Engineering, Johns Hopkins University, Baltimore, Md.

Herbert Friedman, Atmosphere and Astrophysics Division, Naval Research Laboratory, Washington, D.C.

Richard M. Goody (Chairman), Department of Engineering and Applied Physics, Harvard University, Cambridge, Mass.

Francis S. Johnson, Graduate Research Center, Dallas, Tex.

Cecil E. Leith, Jr., Lawrence Radiation Laboratory, University of California, Livermore, Calif.

Advisory Panel for Chemistry

William G. Dauben, Department of Chemistry, University of California, Berkeley, Calif.

William Eberhardt, School of Chemistry, Georgia Institute of Technology, Atlanta, Ga.

H. S. Gutowsky, Department of Chemistry, University of Illinois, Urbana, Ill.

George S. Hammond (chairman), Department of Chemistry, California Institute of Technology, Pasadena, Calif.

Harold Hart, Department of Chemistry, Michigan State University, East Lansing, Mich.

Jacob Kleinberg, Department of Chemistry, University of Kansas, Lawrence, Kans.

Kurt Mislow, Department of Chemistry, Princeton University, Princeton, N.J.

George Morrison, Department of Chemistry, Cornell University, Ithaca, N.Y.

B. S. Rabinovitch, Department of Chemistry, University of Washington, Seattle, Wash.

L. B. Rogers, Department of Chemistry, Purdue University, Lafayette, Ind.

Harrison Shull, Department of Chemistry, Indiana University, Bloomington, Ind.

Henry Taube, Department of Chemistry, Stanford University, Stanford, Calif.

Advisory Panel for Developmental Biology

Robert Auerbach, Department of Zoology, University of Wisconsin, Madison, Wis.

Paul B. Green, Department of Cytology, Dartmouth Medical School, Hanover, N.H.

Paul A. Marks, College of Physicians and Surgeons, Columbia University, New York, N.Y.

Keith R. Porter, The Biological Laboratories, Harvard University, Cambridge, Mass.

David M. Prescott, Department of Anatomy, University of Colorado Medical Center, Denver, Colo.

John W. Saunders, Jr., Department of Biology, Marquette University, Milwaukee, Wis.

Herbert Stern, Department of Botany, University of Illinois, Urbana, Ill.

Alfred Sussman, Department of Botany, University of Michigan, Ann Arbor, Mich.

Advisory Panel for Earth Sciences

Bruce B. Benson, Department of Physics, Amherst College, Amherst, Mass.

Wayne V. Burt, Department of Oceanography, Oregon State University, Corvallis, Oreg.

Richard R. Doell, Geophysics Branch, U.S. Geological Survey, Menlo Park, Calif.

Albert E. J. Engel, Department of Earth Sciences, University of California, San Diego, La Jolla, Calif.

Richard H. Jahns (Chairman), Division of Earth Sciences, Pennsylvania State University, University Park, Pa.

J. Hoover Mackin, Department of Geology, University of Texas, Austin, Tex.

Jack E. Oliver, Lamont Geological Observatory, Columbia University, Palisades, N.Y.

Donald W. Pritchard, Chesapeake Bay Institute, The Johns Hopkins University, Baltimore, Md.

John F. Schairer, Geophysical Laboratory, Carnegie Institution of Washington, Washington, D.C.

Henry C. Thomas, Department of Chemistry, University of North Carolina, Chapel Hill, N.C.

George A. Thompson, Department of Geophysics, Stanford University, Stanford, Calif.

George W. Wetherill, Institute of Geophysics and Planetary Physics, University of California, Los Angeles, Calif.

Advisory Panel for Economics

Robert E. Baldwin, Department of Economics, University of Wisconsin, Madison, Wis.

Richard A. Easterlin, Department of Economics, University of Pennsylvania, Philadelphia, Pa.

William L. Garrison, Department of Geography, Northwestern University, Evanston, Ill.

John A. Nordin, Department of Economics, Kansas State University, Manhattan, Kans.

Roy Radner, Department of Economics, University of California, Berkeley, Calif.

Daniel B. Suits, Department of Economics, University of Michigan, Ann Arbor, Mich.

Advisory Panel for Environmental Biology

George Bartholomew, Department of Zoology, University of California, Los Angeles, Calif.

Edward W. Fager, Scripps Institution of Oceanography, University of California (San Diego), La Jolla, Calif.

Donald S. Farner, Department of Zoology, Washington State University, Pullman, Wash.

Robert F. Inger, Chicago Natural History Museum, Chicago, Ill.

D. A. Livingstone, Department of Zoology, Duke University, Durham, N.C.

Robert B. Platt, Department of Biology, Emory University, Atlanta, Ga.

Gordon Riley, Bingham Oceanographic Laboratory, Yale University, New Haven, Conn.

George Sprugel, Jr., Chief, Natural Sciences Division, U.S. National Park Service, Washington, D.C.

Robert Harding Whittaker, Brookhaven National Laboratory, Associated Universities, Inc., Upton, Long Island, N.Y.

Edward O. Wilson, Biological Laboratories, Harvard University, Cambridge, Mass.

Advisory Panel for Genetic Biology

Walter Bodmer, Department of Genetics, Stanford University Medical School, Palo Alto, Calif.

Sterling Emerson, Division of Biology, California Institute of Technology, Pasadena, Calif.

Ellis Englesberg, Department of Biological Sciences, University of Pittsburgh, Pittsburgh, Pa.

Samson Gross, Department of Microbiology, Duke University, Durham, N.C.

John Laughnan, Department of Botany, University of Illinois, Urbana, Ill.

Richard Lewontin, Department of Zoology, University of Chicago, Chicago, Ill.

Laurence Sandler, Department of Genetics, University of Washington, Seattle, Wash.

J. Herbert Taylor, Institute of Molecular Biophysics, Florida State University, Tallahassee, Fla.

Norton Zinder, The Rockefeller Institute, New York, N.Y.

Advisory Panel for Graduate Science Facilities

The Rev. Victor J. Blum, S.J., Dean, Institute of Technology, Saint Louis University, St. Louis, Mo.

Lawrence Bogorad, Department of Botany, University of Chicago, Chicago, Ill.

George E. Dieter, Jr., Drexel Institute of Technology, Chairman, Metallurgical Engineering Department, Philadelphia, Pa.

Malcolm Dole, Materials Research Center, Technological Institute, Northwestern University, Evanston, Ill.

Henry A. Fairbank, Chairman, Department of Physics, Duke University, Durham, N.C.

Chauncey G. Goodchild, Chairman, Department of Biology, Emory University, Atlanta, Ga.

John L. Kennedy, Chairman, Department of Psychology, Princeton University, Princeton, N.J.

David A. Lind, Department of Physics, University of Colorado, Boulder, Colo.

Richard S. Pierce, Department of Mathematics, University of Washington, Seattle, Wash.

Sydney C. Rittenberg, Department of Bacteriology, University of California, Los Angeles, Calif.

Paul E. Russell, Dean of Engineering, Kansas State University, Manhattan, Kans.

Albert C. Spaulding, Chairman, Department of Anthropology, University of Oregon, Eugene, Oreg.

Advisory Panel for History and Philosophy of Science

Carl G. Hempel, Department of Philosophy, Princeton University, Princeton, N.J.

Gerald Holton, Jefferson Physical Laboratory, Harvard University, Cambridge, Mass.

Ernan McMullin, Center for Philosophy of Science, University of Minnesota, Minneapolis, Minn.

Richard S. Rudner, Department of Philosophy, Washington University, St. Louis, Mo.

Robert E. Schofield, Department of Humanities, Case Institute of Technology, Cleveland, Ohio.

L. Pearce Williams, Department of History, Cornell University, Ithaca, N.Y.

Advisory Panel for the International Year of the Quiet Sun

Kinsey Anderson, Space Sciences Laboratory, University of California, Berkeley, Calif.

R. Grant Athay, Chairman, Department of Physics, University of Utah, Salt Lake City, Utah

Joseph W. Chamberlain, Space Division, Kitt Peak National Observatory, Tucson, Ariz.

Herbert Friedman (Chairman), Atmosphere and Astrophysics Division, Naval Research Laboratory, Washington, D.C.

Fred T. Haddock, Jr., The Observatory, University of Michigan, Ann Arbor, Mich.

Joseph Kaplan, Department of Geophysics, University of California, Los Angeles, Calif.

William W. Kellogg, The RAND Corp., Santa Monica, Calif.

Peter Meyer, Enrico Fermi Institute for Nuclear Studies, University of Chicago, Chicago, Ill.

Martin A. Pomerantz, Bartol Research Foundation, Swarthmore, Pa.

E. H. Vestine, The RAND Corp., Santa Monica, Calif.

A. H. Waynick, Pennsylvania State University, University Park, Pa.

Advisory Panel for Mathematical Sciences

Maurice Auslander, Department of Mathematics, Brandeis University, Waltham, Mass.

Paul T. Bateman, Department of Mathematics, University of Illinois, Urbana, Ill.

R. H. Bing, Department of Mathematics, University of Wisconsin, Madison, Wis.

Shing S. Chern, Department of Mathematics, University of California, Berkeley, Calif.

Herman Chernoff, Department of Statistics, Stanford University, Stanford, Calif.

Jurgen K. Moser, Courant Institute of Mathematical Sciences, New York University, New York, N.Y.

George D. Mostow, Department of Mathematics, Yale University, New Haven, Conn.

Elias M. Stein, Department of Mathematics, Princeton University, Princeton, N.J.

Alexander D. Wallace, Department of Mathematics, University of Florida, Gainesville, Fla.

Advisory Panel for Metabolic Biology

Samuel P. Bessman, University Hospital, University of Maryland, Baltimore, Md.

Gene M. Brown, Department of Biology, Massachusetts Institute of Technology, Cambridge, Mass.

Ernest Bueding, Department of Pathobiology, Johns Hopkins University, School of Hygiene and Public Health, Baltimore, Md.

Harold J. Evans, Department of Plant Physiology, Oregon State University, Corvallis, Oreg.

Howard Gest, Adolphus Busch III Laboratory of Molecular Biology, Washington University, St. Louis, Mo.

Wayne C. Hall, Dean of Graduate School, Texas A. & M. University, College Station, Tex.

James A. Olson, Department of Biochemistry, University of Florida, College of Medicine, Gainesville, Fla.

Jack L. Strominger, Department of Pharmacology and Toxicology, University of Wisconsin, Madison, Wis.

Howard J. Teas, Head, Division of Biological Sciences, University of Georgia, Athens, Ga.

Advisory Panel for Molecular Biology

Sam Aronoff, Department of Biochemistry and Biophysics, Iowa State University, Ames, Iowa

Howard M. Dintzis, Department of Biophysics, Johns Hopkins University, Baltimore, Md.

J. Woodland Hastings, Department of Chemistry, University of Illinois, Urbana, Ill.

David S. Hogness, Department of Biochemistry, Stanford University, Stanford, Calif.

Shinya Inoue, Professor of Cytology, Dartmouth Medical School, Hanover, N.H.

William P. Jencks, Department of Biochemistry, Brandeis University, Waltham, Mass.

Walter Kauzmann, Department of Chemistry, Princeton University, Princeton, N.J.

Daniel Tosteson, Department of Physiology, Duke University, Durham, N.C.

Advisory Panel for Oceanographic Facilities

William M. Cameron, Director of Mineral Sciences, Department of Mines and Technical Surveys, Ottawa, Ontario, Canada

Eugenie Clark, Cape Haze Marine Laboratory, Sarasota, Fla.

Parke A. Dickey, Department of Geology, University of Tulsa, Tulsa, Okla.

John Lyman, Bureau of Commercial Fisheries, Department of Interior, Washington, D.C.

Arthur E. Maxwell, Head, Office of Naval Research, Geophysics Branch, Washington, D.C.

Warren C. Thompson, Department of Meteorology and Oceanography, U.S. Naval Postgraduate School, Monterey, Calif.

Advisory Panel for Physics

Hans Frauenfelder, Department of Physics, University of Illinois, Urbana, Ill.

David H. Frisch, Department of Physics, Massachusetts Institute of Technology, Cambridge, Mass.

Lawson M. McKenzie, Scientific Laboratory, Ford Motor Company, Dearborn, Mich.

Elliott Montroll (chairman), Institute for Defense Analysis, Washington, D.C.

Robert Novick, Department of Physics, Columbia University, New York, N.Y.

George E. Pake, Washington University, St. Louis, Mo.

Gerald C. Phillips, Department of Physics, Rice University, Houston, Tex.

Stuart A. Rice, Institute for the Study of Metals, University of Chicago, Chicago, Ill.

Michael Tinkham, Department of Physics, University of California, Berkeley, Calif.

John S. Toll, Department of Physics, University of Maryland, College Park, Md.

William D. Walker, Department of Physics, University of Wisconsin, Madison, Wis.

Advisory Panel for Psychobiology

Norman H. Anderson, Department of Psychology, University of California, Los Angeles, Calif.

E. James Archer, Department of Psychology, University of Wisconsin, Madison, Wis.

Donald S. Blough, Department of Psychology, Brown University, Providence, R.I.

William C. Dilger, Laboratory of Ornithology, Cornell University, Ithaca, N.Y.

Donald R. Griffin, Department of Biology, Harvard University, Cambridge, Mass.

Harold W. Hake, Department of Psychology, University of Illinois, Urbana, Ill.

Frederick A. King, Division of Neurosurgery, College of Medicine, University of Florida, Gainesville, Fla.

Herschel W. Leibowitz, Department of Psychology, Pennsylvania State University, University Park, Pa.

Advisory Panel for Radio Telescopes

Ronald N. Bracewell, Radio Science Laboratory, Stanford University, Stanford, Calif.

Bernard F. Burke, Carnegie Institution of Washington, Washington, D.C.

Paul Chenea, Division of Engineering Sciences, Purdue University, Lafayette, Ind.

L. J. Chu, Department of Electrical Engineering, Massachusetts Institute of Technology, Cambridge, Mass.

Richard M. Emberson, Institute of Electrical and Electronic Engineers, Inc., New York, N.Y.

William E. Gordon, Department of Electrical Engineering, Cornell University, Ithaca, N.Y.

David S. Heeschen, National Radio Astronomy Observatory, Green Bank, W. Va.

R. Minkowski, Radio Astronomy Observatory, University of California, Berkeley, Calif.

John R. Pierce (Chairman), Bell Telephone Laboratories, Inc., Murray Hill, N.J.

George W. Swenson, Jr., The Observatory, University of Illinois, Urbana, Ill.

James H. Trexler, Naval Research Laboratory, Washington, D.C.

Advisory Panel for Regulatory Biology

Ira L. Baldwin, University of Wisconsin, Madison, Wis.

David W. Bishop, Department of Embryology, Carnegie Institution of Washington, Baltimore, Md.

Dietrich Bodenstein, Department of Biology, University of Virginia, Charlottesville, Va.

Albert E. Dimond, Connecticut Agricultural Experiment Station, New Haven, Conn.

Gilbert H. Mudge, Dartmouth Medical School, Hanover, N.H.

George Sayers, Department of Physiology, Western Reserve University, School of Medicine, Cleveland, Ohio

Carroll A. Swanson, Department of Botany and Plant Pathology, Ohio State University, Columbus, Ohio

A. Van Harreveld, Division of Biology, California Institute of Technology, Pasadena, Calif.

Advisory Panel for Science Development

Carl W. Borgmann, Director, Program in Science and Engineering, The Ford Foundation, New York, N.Y.

Robert R. Brode, Professor of Physics, University of California, Berkeley, Calif.

Dale R. Corson, Provost, Cornell University, Ithaca, N.Y.

Colgate W. Darden, Jr., Norfolk, Va.

James D. Ebert, Director, Department of Embryology, Carnegie Institution of Washington, Baltimore, Md.

William B. Harrell, Vice President, Special Projects, The University of Chicago, Chicago, Ill.

Lyle H. Lanier, Executive Vice President and Provost, University of Illinois, Urbana, Ill.

John R. Pierce, Executive Director, Research Communications Principles and Communications System Division, Bell Telephone Laboratories, Inc., Murray Hill, N.J.

Advisory Panel for Sociology and Social Psychology

James A. Davis, National Opinion Research Center, University of Chicago, Chicago, Ill.

Albert H. Hastorf, Department of Psychology, Stanford University, Stanford, Calif.

Alan C. Kerckhoff, Department of Sociology and Anthropology, Duke University, Durham, N.C.

Gardner Lindzey, Department of Psychology, University of Texas, Austin, Tex.

William J. McGuire, Department of Social Psychology, Columbia University, New York, N.Y.

James G. March, Dean of Social Sciences, University of California, Irvine, Calif.

Albert J. Reiss, Department of Sociology, University of Michigan, Ann Arbor, Mich.

George J. Suci, Department of Child Development and Family Relationships, Cornell University, Ithaca, N.Y.

Advisory Panel for Specialized Facilities

George Anastos, Department of Zoology, University of Maryland, College Park, Md.

Sanford S. Atwood, President, Emory University, Atlanta, Ga.

S. F. Carson, Biology Division, Oak Ridge National Laboratory, Oak Ridge, Tenn.

Leslie A. Chambers, Director, Hancock Foundation, University of Southern California, Los Angeles, Calif.

Vernon I. Cheadle, Chancellor, University of California, Santa Barbara, Calif.

Eugene F. Corcoran, The Marine Laboratory, Institute of Marine Science, University of Miami, Miami, Fla.

Jerome Cox, Jr., Central Institute for the Deaf, St. Louis, Mo.

Robert K. Enders, Department of Biology, Swarthmore College, Swarthmore, Pa.

George A. Feigen, School of Medicine, Stanford University, Stanford, Calif.

Robert L. Fernald, Department of Zoology, University of Washington, Seattle, Wash.

Jeffery D. Frautschy, Scripps Institution of Oceanography, University of California, La Jolla, Calif.

Herbert Friedmann, Los Angeles County Museum, Los Angeles, Calif.

Shelby Gerking, Department of Zoology, Indiana University, Bloomington, Ind.

Cadet Hand, Director, Bodega Marine Laboratory, Berkeley, Calif.

Earl S. Herald, California Academy of Science, Golden Gate Park, San Francisco, Calif.

Theodore H. Hubbell, Museum of Zoology, University of Michigan, Ann Arbor, Mich.

F. F. Koczy, The Marine Laboratory, University of Miami, Miami, Fla.

Harlan Lewis, Dean of Life Sciences, University of California, Los Angeles, Calif.

Emil M. Mrak, Chancellor, University of California, Davis, Calif.

William Duwayne Neff, Department of Psychology, Indiana University, Bloomington, Ind.

Geoffrey Norman, Vice President for Research, University of Michigan, Ann Arbor, Mich.

John L. Patterson, Department of Medicine, Medical College of Virginia, Richmond, Va.

Daniel C. Pease, Department of Anatomy, University of California, School of Medicine, Los Angeles, Calif.

Luigi Provasoli, Haskins Laboratories, New York, N.Y.

Edward C. Raney, Department of Conservation, Cornell University, Ithaca, N.Y.

Carl D. Riggs, Department of Zoology, University of Oklahoma, Norman, Okla.

J. David Robertson, Research Laboratory, McLean Hospital, Belmont, Mass.

Murray D. Rosenberg, The Rockefeller Institute, New York, N.Y.

John H. Ryther, Woods Hole Oceanographic Institution, Woods Hole, Mass.

Thomas T. Sandel, Massachusetts Institute of Technology, Center Development Office, Cambridge, Mass.

Seymour Shapiro, Head, Botany Department, University of Massachusetts, Amherst, Mass.

Albert C. Smith, Director of Research, University of Hawaii, Honolulu, Hawaii

Athelstan F. Spilhaus, Institute of Technology, University of Minnesota, Minneapolis, Minn.

Albert Tyler, Department of Embryology, California Institute of Technology, Pasadena, Calif.

Stanley Watson, Woods Hole Oceanographic Institution, Woods Hole, Mass.

Karl M. Wilbur, Department of Zoology, Duke University, Durham, N.C.

Advisory Panel for Systematic Biology

Constantine J. Alexopoulos, Department of Botany, University of Texas, Austin, Tex.

Frederick M. Bayer, Institute of Marine Science, Miami, Fla.

Kenton L. Chambers, Department of Botany and Plant Pathology, Oregon State University, Corvallis, Oreg.

Arthur J. Cronquist, New York Botanical Garden, Bronx Park, New York, N.Y.

Joel W. Hedgpeth, Pacific Marine Station, Dillon Beach, Marin County, Calif.

Terry W. Johnson, Department of Botany, Duke University, Durham, N.C.

Charles D. Michener, Department of Entomology, University of Kansas, Lawrence, Kans.

George S. Myers, Division of Systematic Biology, Stanford University, Stanford, Calif.

Everett C. Olson, Department of Geology, University of Chicago, Chicago, Ill.

Charles G. Sibley, Department of Conservation, Cornell University, Ithaca, N.Y.

James A. Slater, Department of Zoology and Entomology, University of Connecticut, Storrs, Conn.

Franklin Sogandares, Department of Zoology, Tulane University, New Orleans, La.

Wilson N. Stewart, Department of Botany, University of Illinois, Urbana, Ill.

W. H. Wagner, Department of Botany, University of Michigan, Ann Arbor, Mich.

Advisory Panel for University Computing Facilities

William F. Atchison, Head, Rich Electronic Computer Center, Georgia Institute of Technology, Atlanta, Ga.

Mary A. B. Brazier, Brain Research Institute, University of California, Los Angeles, Calif.

Sidney Fernbach, Lawrence Radiation Laboratory, Livermore, Calif.

Joseph O. Hirschfelder, Department of Chemistry, University of Wisconsin, Madison, Wis.

Nathan M. Newmark (Chairman), Department of Civil Engineering, University of Illinois, Urbana, Ill.

Arthur H. Rosenfeld, Massachusetts Institute of Technology, Cambridge, Mass.

William R. Sears, Director, Center for Applied Mathematics, Cornell University, Ithaca, N.Y.

Leonard M. Uhr, Mental Health Research Institute, University of Michigan, Ann Arbor, Mich.

Willis H. Ware, Rand Corporation, Santa Monica, Calif.

Victor H. Yngve, Department of Electrical Engineering, Massachusetts Institute of Technology, Cambridge, Mass.

Advisory Panel for Weather Modification

Louis J. Battan, Institute of Atmospheric Physics, University of Arizona, Tucson, Ariz.

Victor K. LaMer, Department of Chemistry, Columbia University, New York, N.Y.

Gordon J. F. MacDonald, Institute of Geophysics and Planetary Physics, University of California, Los Angeles, Calif.

Dean F. Peterson, Jr. (Chairman), Utah State University, Logan, Utah

Yale Mintz, Department of Meteorology, University of California, Los Angeles, Calif.

Bernard Vonnegut, Arthur D. Little, Inc., Acorn Park, Cambridge, Mass.

APPENDIX B

FINANCIAL REPORT FOR FISCAL YEAR 1965

Salaries and Expenses Appropriation

Receipts

Appropriated for fiscal year 1965	$420,400,000	
Unobligated balance from fiscal year 1964	3,966,915	
Recovery of prior year funds	124,117	
Total availability		$424,491,032

Obligations

Basic Research and Supporting Facilities:		
Basic research project grants:		
Biological and medical sciences		$41,648,842
Mathematical and physical sciences		54,141,560
Engineering		13,714,853
Social Sciences		9,965,661
Subtotal		119,470,916
National Research Programs:		
Antarctic research programs		7,608,211
Indian Ocean expedition		3,667,290
Weather modification		1,997,553
International year of the quiet sun		3,499,600
Deep crustal studies of the earth (Project Mohole)		24,699,280
United States-Japan cooperative science program		722,332
Subtotal		42,194,266
Specialized Research Facilities Support:		
Biological science research facilities:		
Specialized biological facilities	$3,499,508	
Oceanographic research facilities	998,520	
Subtotal		4,498,028
Physical Sciences Facilities:		
Chemistry research instruments	1,432,500	
Oceanographic research facilities	1,996,664	
University astronomy research facilities	1,821,000	
University atmospheric research facilities	599,678	
University physics research facilities	11,429,586	
Subtotal		17,249,428

Basic Research and Supporting Facilities—Con.		
Specialized social sciences research facilities	$210,000	
Engineering research facilities	1,271,995	
University computing facilities	4,512,503	
Subtotal	27,741,954	
National Research Centers:		
National Radio Astronomy Observatory	3,380,000	
Kitt Peak National Observatory	6,915,000	
Cerro Tololo Inter-American Observatory	1,385,000	
National Center for Atmospheric Research	7,800,000	
Subtotal	19,480,000	
Subtotal, basic research and supporting facilities		$208,887,136
Science Education Programs:		
Fellowships and traineeships	40,224,075	
Institutes	43,196,261	
Research participation and science activities for teachers	4,003,610	
Science education for undergraduate students	5,478,698	
Science education for secondary school students	3,402,592	
Spec. advanced science education projects	1,352,990	
Course content improvement	14,551,867	
Instructional equipment for undergraduate education	8,204,584	
Subtotal, science education programs		120,414,677
Institutional Science Programs:		
Institutional grants for science	11,417,659	
Graduate science facilities	21,425,320	
Science development program	27,394,000	
Subtotal, institutional science programs		60,236,979
Science Information Services:		
Studies and support	5,552,612	
Science information coordination	4,886,562	
International scientific information exchanges	683,815	
Subtotal, science information services		11,122,989
Studies of National Resources for Science and Technology:		
Statistical surveys	533,530	
National register of scientific and technical personnel	825,395	
Analytical studies	661,000	
Subtotal, studies of national resources for science and technology		2,019,925
Program Development and Management		13,118,462
Total, NSF		415,800,168

Allocation to other Government agencies		$166,521
Total obligations, fiscal year 1965		415,966,689
Unobligated balance carried forward to fiscal year 1966		8,524,343
Total		424,491,032

TRUST FUND

Receipts

Unobligated balance from fiscal year 1964	$7,285	
Donation from private sources	690	
Total availability		7,975

Obligations

Total obligations fiscal year 1965	457	
Unobligated balance carried forward into fiscal year 1966	7,518	
Total		7,975

APPENDIX C

Patent Resulting From Activities Supported by the National Science Foundation

The Foundation since its last annual report has received notification of the issuance of a patent by the U.S. Patent Office covering an invention arising out of Foundation-supported activities.

Patent Number 3,182,353 entitled, "Guide Means for High Pressure Press," was issued on May 11, 1965, on an invention made by Howard Tracy Hall during the course of research supported by a grant to Brigham Young University. The invention relates to guide and alignment means for a multiple press-member, high-pressure presses and in particular, to guide and alignment means for high-pressure presses which include a plurality of press members which are moved rectilinearly toward a common point to form a closed polyhedral press cell.

APPENDIX D

National Science Foundation-Supported Scientific Conferences, Symposia, and Advanced Science Seminars Held During Fiscal Year 1965

SCIENTIFIC CONFERENCES AND SYMPOSIA IN THE BIOLOGICAL AND MEDICAL SCIENCES

GORDON RESEARCH CONFERENCE ON BIOLOGICAL REGULATORY MECHANISMS—Andover, N.H.; July 20–24, 1964; Chairman: W. George Parks, University of Rhode Island; Sponsor: Gordon Research Conferences, Inc.

CONFERENCE ON MAGNETIC RESONANCE IN BIOLOGICAL SYSTEMS—Boston, Mass.; July 20–22, 1964; Chairman: Oleg Jardetzky, Harvard University; Sponsor: Harvard University.

PSEUDOMONAS WORKSHOPS: MECHANISM AND CONTROL OF VARIABILITY—Cold Spring Harbor, N.Y.; July 20–22, 1964; Chairman: I. C. Gunsalus, University of Illinois; Sponsor: Cold Spring Harbor Laboratory of Quantitative Biology.

FIRST INTERNATIONAL COLLOQUIUM ON RAPID MIXING AND SAMPLING TECHNIQUES APPLICABLE TO THE STUDY OF BIOCHEMICAL REACTIONS—Philadelphia, Pa.; July 23–24, 1964; Chairman: Rudolf H. Eisenhardt, University of Pennsylvania; Sponsor: University of Pennsylvania.

INTERNATIONAL SYMPOSIUM ON THE PHYSIOLOGY OF DIGESTION IN THE RUMINANT—Ames, Iowa; August 19–21, 1964; Chairman: R. W. Dougherty, National Animal Disease Laboratory, Ames, Iowa; Sponsors: Iowa State University and National Animal Disease Laboratory.

SYMPOSIUM ON THE ROLE OF MACROMOLECULAR ORGANIZATION—Chicago, Ill.; August 30, 1964; Chairman: Earl Stadtman, National Heart Institute, Bethesda, Md.; Sponsor: American Chemical Society.

CONFERENCE ON MICROBIAL CLASSIFICATION—Quebec, Canada; August 30–September 5, 1964; Chairman: P. H. A. Sneath, University of Leicester, England; Sponsors: International Association of Microbiological Societies, American Society for Microbiology, and Laval University (Quebec).

FIRST GORDON RESEARCH CONFERENCE ON IONIC MOVEMENTS AND INTERACTIONS IN BIOLOGICAL, CHEMICAL, AND PHYSICAL PHENOMENA—Tilton, N.H.; August 31–September 4, 1964; Chairman: George Eisenman, University of Utah; Sponsor: Gordon Research Conferences, Inc.

SYMPOSIUM ON EVOLVING GENES AND PROTEINS—New Brunswick, N.J., September 17–18, 1964; Chairmen: Vernon Bryson and Henry J. Vogel, Rutgers, The State University; Sponsor: Rutgers, The State University.

NINTH INTER-AMERICAN CONGRESS OF PSYCHOLOGY—Miami Beach, Fla.; December 17–22, 1964; Chairman: George A. Kelly, Ohio State University; Sponsor: Ohio State University.

INTERNATIONAL CONFERENCE AND SYMPOSIUM ON COMMUNICATION AND SOCIAL INTERACTIONS IN PRIMATES—Montreal, Canada; December 29–31, 1964; Chairman: Stuart A. Altmann, University of Alberta, Canada; Sponsor: American Association for the Advancement of Science.

CONFERENCE ON THE MECHANISM OF ACTION OF NAD-DEPENDENT DEHYDROGENASES—Lexington, Ky.; March 17–19, 1965; Chairman: Alfred Winer, University of Kentucky Medical Center; Sponsor: University of Kentucky.

SYMPOSIUM ON THE POLYSACCHARIDES AND PEPTIDOGLYCANS OF BACTERIAL CELL WALLS—Detroit, Mich.; April 6, 1965; Chairman: Roger Jeanloz, Harvard Medical School; Sponsor: American Chemical Society.

ROCKY MOUNTAIN BIOENGINEERING SYMPOSIUM—Denver, Colo.; May 3–4, 1965; Chairman: Joseph C. Daniel, Jr., University of Colorado; Sponsor: University of Colorado.

PLANNING CONFERENCE ON PROBLEMS OF EUTROPHICATION—Washington, D.C.; May 8–9, 1965; Chairman: G. A. Rohlich, University of Wisconsin; Sponsor: National Academy of Sciences-National Research Council.

CONFERENCE ON INTERSEXUALITY IN FISHES—Sarasota, Fla.; May 20–25, 1965; Chairman: Eugenie Clark, Cape Haze Marine Laboratory, Inc.; Sponsor: Cape Haze Laboratory.

THIRTIETH COLD SPRING HARBOR SYMPOSIUM—Cold Spring Harbor, N.Y.; June 4–11, 1965; Chairman: John Cairns, Cold Spring Harbor Laboratory for Quantitative Biology; Sponsor: Cold Spring Harbor Laboratory for Quantitative Biology.

INTERNATIONAL CONGRESS ON ORGANOGENESIS—Baltimore, Md.; June 6–12, 1965; Chairman: James D. Ebert, Carnegie Institution of Washington; Sponsors: International Institute of Embryology, Carnegie Institution of Washington, and Johns Hopkins University.

SECOND CONFERENCE ON LEARNED AND NON-LEARNED BEHAVIOR IN IMMATURE ORGANISMS—Stillwater, Minn.; June 13–17, 1965; Chairman: Harold W. Stevenson, University of Minnesota; Sponsor: Social Science Research Council.

TWENTY-FOURTH ANNUAL SYMPOSIUM OF THE SOCIETY FOR THE STUDY OF DEVELOPMENT AND GROWTH—Northfield, Minn.; June 21–23, 1965; Chairman: Herbert Stern, University of Illinois; Sponsors: Growth Society and Carleton College.

GORDON RESEARCH CONFERENCE ON NUCLEIC ACIDS—New Hampton, N.H.; June 21–25, 1965; Chairman: Gobind Khorana, University of Wisconsin; Sponsor: Gordon Research Conferences, Inc.

Gordon Research Conference on Cell Structure and Function—New Hampton, N.H.; June 28–July 2, 1965; Chairman: James Bonner, California Institute of Technology, and David Luck, The Rockefeller Institute; Sponsor: Gordon Research Conferences, Inc.

Gordon Research Conference on Proteins—New Hampton, N.H.; June 28–July 2, 1965; Chairman: W. J. Harrington, Johns Hopkins University; Sponsor: Gordon Research Conferences, Inc.

SCIENTIFIC CONFERENCES AND SYMPOSIA IN THE ENGINEERING SCIENCES

Symposium on Concentrated Vortex Motions in Fluids—Ann Arbor, Mich.; July 6–10, 1964; Chairmen: G. K. Batchelor, University of Cambridge, England and Wilbur C. Nelson, University of Michigan; Sponsor: International Union of Theoretical and Applied Mechanics.

1964 International Cryogenic Engineering Conference—Philadelphia, Pa.; August 17–21, 1964; Chairman: K. D. Timmerhaus, University of Colorado; Sponsor: University of Colorado.

Third Conference on Fundamental Research in Plain Concrete—Allerton Park, Ill.; September 8–11, 1964; Chairman: Clyde E. Kesler, University of Illinois; Sponsors: American Concrete Institute, American Society of Civil Engineers, American Society of Testing and Materials, Portland Cement Association, and Reinforced Concrete Research Council.

Diffusion in Body-Centered-Cubic Materials—Oak Ridge, Tenn.; September 9–11, 1964; Chairman: John A. Wheeler, Jr., Oak Ridge National Laboratory; Sponsor: American Society for Metals.

1964 ASME–ASLE International Lubrication Conference—Washington, D.C.; October 13–16, 1964; Chairman: C. M. Allen, Battelle Memorial Institute; Sponsors: American Society of Lubrication Engineers, Lubrication Division of the American Society of Mechanical Engineers, U.S. Air Force, National Aeronautics and Space Administration, and Army Research Office (Durham).

International Symposium on the Non-Linear Flexural Mechanics of Reinforced Concrete—Miami, Fla.; November 1964; Chairman: Herbert A. Sawyer, Jr., University of Florida; Sponsors: American Concrete Institute, American Society of Civil Engineers, and the University of Florida.

Shock and Vibration Research—New York, N.Y.; December 1, 1964; Chairman: O. B. Shier, II, American Society of Mechanical Engineers; Sponsors: University of Illinois, Illinois Institute of Technology, University of Michigan, Michigan State University, University of Minnesota, Purdue University, University of Wisconsin, and the American Society of Mechanical Engineers.

Third Symposium on Thermophysical Properties—Lafayette, Ind.; March 22–25, 1965; Chairman: Serge Gratch, Ford Motor Company, Dearborn, Mich.; Sponsors: American Society of Mechanical Engineers and Purdue University.

1965 INTERNATIONAL CONFERENCE ON MODERN TRENDS IN ACTIVATION ANALYSIS—College Station, Tex.; April 19–22, 1965; Chairmen: Richard Elliott Wainerdi, Texas A. & M. University and D. Gibbons, United Kingdom Atomic Energy Authority, England; Sponsors: International Atomic Energy Agency, Eurisotop Office of the European Atomic Energy Community, U.S. Atomic Energy Commission, Activation Analysis Research Laboratory, and Texas A. & M. University.

CONFERENCE ON NONDESTRUCTIVE TESTING OF WOOD—Pullman, Wash.; April 22–24, 1965; Chairmen: George G. Marra and William L. Galligan, Wood Technology Section, Washington State University; Sponsor: Washington State University.

NATIONAL SPRING MEETING OF THE SOCIETY FOR EXPERIMENTAL STRESS ANALYSIS—Denver, Colo.; May 5–7, 1965; Chairman: Arthur Ezra, Rocky Mountain Section of the Society for Experimental Stress Analysis; Sponsor: Society for Experimental Stress Analysis.

SYMPOSIUM ON THE APPLICATION OF CRYSTALLIZATION TECHNIQUES—San Francisco, Calif.; May 16–19, 1965; Chairman: J. E. Powers, University of Michigan; Sponsor: American Institute of Chemical Engineers.

COLLOQUIUM ON NATURE OF INELASTIC BEHAVIOR OF CONCRETE AND ITS STRUCTURAL EFFECTS—Ithaca, N.Y.; June 1965; Chairman: George Winter, Cornell University; Sponsors: Portland Cement Association and Cornell University.

RHEOLOGY SYMPOSIUM—Washington, D.C.; June 7–9, 1965; Chairman: A. W. Marris, Georgia Institute of Technology; Sponsor: American Society of Mechanical Engineers.

SECOND INTERNATIONAL POWDER METALLURGY CONFERENCE—New York, N.Y.; June 14–17, 1965; Chairman: Kempton H. Roll, Metal Powder Industries Federation; Sponsor: Metallurgical Society of American Institute of Mechanical Engineers.

SYMPOSIUM ON PERSPECTIVES IN OCEAN ENGINEERING—Washington, D.C.; June 14–17, 1965; Chairmen: John D. Isaacs, Scripps Institution of Oceanography, and David S. Potter, GM Defense Research Laboratories, Goleta, Calif.; Sponsors: Marine Technology Society and the American Society for Limnology and Oceanography.

SCIENTIFIC CONFERENCES AND SYMPOSIA IN THE MATHEMATICAL AND PHYSICAL SCIENCES

CONFERENCE ON THE PHYSICS OF TYPE II SUPERCONDUCTIVITY—Cleveland, Ohio; August 28–29, 1964; Chairman: B. S. Chandrasekhar, Western Reserve University; Sponsor: Western Reserve University.

NINTH INTERNATIONAL CONFERENCE ON LOW TEMPERATURE PHYSICS—Columbus, Ohio; August 31–September 4, 1964; Chairman: John G. Daunt, Ohio State University; Sponsor: Ohio State University.

CONFERENCE ON THE CHEMISTRY OF ORE-FORMING FLUIDS—Princeton, N.J.; August 30–September 4, 1964; Chairman: E. N. Cameron, University of Wisconsin; Sponsor: Society of Economic Geologists, Inc. and Princeton University.

GORDON RESEARCH CONFERENCE ON NUCLEAR STRUCTURE PHYSICS—New London, N.H.; August 31–September 4, 1964; Chairmen: Bernard L. Cohen and Norman Austern, University of Pittsburgh; Sponsor: Gordon Research Conferences, Inc.

CONFERENCE ON COSMIC RAYS AND HIGH ENERGY PHYSICS—Cleveland, Ohio; September 25–26, 1964; Chairman: Frederick Reines, Case Institute of Technology; Sponsor: Case Institute of Technology.

1964 NATIONAL CLAY MINERALS CONFERENCE—Madison, Wis.; October 5–8, 1964; Chairman: Sturges W. Bailey, University of Wisconsin; Sponsors: University of Wisconsin and the Institute of Paper Chemistry.

THIRD EASTERN UNITED STATES THEORETICAL PHYSICS CONFERENCE—College Park, Md.; October 30–31, 1964; Chairman: John S. Toll, University of Maryland; Sponsor: University of Maryland.

IAGA SYMPOSIUM ON MAGNETISM OF THE EARTH'S INTERIOR—Pittsburgh, Pa.; November 16–25, 1964; Chairman: Takesi Nagata, University of Tokyo; Sponsor: University of Pittsburgh.

INTERNATIONAL SYMPOSIUM ON HIGH ENERGY ASTRONOMY—Austin, Tex.; December 15–18, 1964; Chairman: E. L. Schucking and Alfred Schild, University of Texas, and Ivor Robinson, Southwest Center for Advanced Studies; Sponsors: University of Texas, Southwest Center for Advanced Studies, National Aeronautics and Space Administration, Air Force Office of Scientific Research (AFOSR) and the Office of Naval Research.

SECOND ANNUAL CONFERENCE ON SYMMETRY PRINCIPLES AT HIGH ENERGY—Coral Gables, Fla.; January 20–22, 1965; Chairman: Behram Kursunoglu, University of Miami; Sponsors: University of Miami, Air Force Office of Scientific Research, Atomic Energy Commission, National Aeronautics and Space Administration (NASA) and the Office of Naval Research.

MEETING ON PLEISTOCENE STRATIGRAPHY IN DEEP-SEA SEDIMENTS—Palisades, N.Y.; January 23, 1965; Chairman: R. F. Flint, Yale University; Sponsor: Columbia University.

SERIES OF SCIENTIFIC CONFERENCES ON THE STATISTICAL ASPECTS OF WEATHER MODIFICATION—Chicago, Ill.; January 1, 1965–December 31, 1965 (First conference January 9, 1965 at the University of Chicago); Chairman: Byron W. Brown, Jr., University of Minnesota; Sponsor: University of Minnesota.

Conference on Problems of Stellar Evoluton—La Jolla, Calif.; February 17–19, 1965; Chairman: Ivan R. King, University of California; Sponsor: University of California, Berkeley.

Sixth Experimental Nuclear Magnetic Resonance Conference—Pittsburgh, Pa.; February 25–27, 1965; Chairman: Charles A. Reilly, Shell Development Company, Emeryville, California; Sponsor: Mellon Institute.

Conference on Phenomena in the Neighborhood of the Critical Point—Washington, D.C.; April 5–8, 1965; Chairman: Melville S. Green, National Bureau of Standards; Sponsor: National Bureau of Standards.

Symposium on Function Algebras—New Orleans, La.; April 19–24, 1965; Chairman: Fred B. Wright, Tulane University; Sponsors: Office of Naval Research and Tulane University.

Symposium on the Construction of Large Telescopes—Tucson, Ariz., and Pasadena, Calif.; April 1965; Chairman: I. S. Bowen, Mount Wilson and Palomar Observatories, Pasadena, Calif.; Sponsors: International Astronomical Union and California Institute of Technology.

International Symposium on Nucleation Phenomena—Cleveland, Ohio; April 7–9, 1965; Chairman: Alan G. Walton, Case Institute of Technology; Sponsor: Case Institute of Technology.

Conference on the Internal Conversion Process—Nashville, Tenn.; May 3–5, 1965; Chairman: Joseph H. Hamilton, Vanderbilt University; Sponsors: Atomic Energy Commission and Vanderbilt University.

Midwest Conference on Theoretical Physics—Columbus, Ohio; May 14–15, 1965; Chairman: Robert L. Mills, Ohio State University; Sponsor: Ohio State University.

Conference on Carbon 14 and Tritium Dating—Pullman, Wash.; June 8–11, 1965; Chairman: Roy M. Chatters, Washington State University; Sponsors: Atomic Energy Commission and Washington State University.

Fifth Berkeley Symposium on Mathematical Statistics and Probability—Berkeley, Calif.; June 21–July 18, 1965; Chairmen: Lucien LeCam and Jerzy Neyman, University of California, Berkeley; Sponsors: Office of Naval Research, Air Force Office of Scientific Research, and the University of California, Berkeley.

International Conference on the Physics of X-Ray Spectra—Ithaca, N.Y.; June 22–24, 1965; Chairmen: Lyman G. Parratt, Cornell University, Joyce A. Bearden, Johns Hopkins University, and E. Leonard Jossem, Ohio State University; Sponsors: Atomic Energy Commission and Cornell University.

SCIENTIFIC CONFERENCES AND SYMPOSIA IN THE SOCIAL SCIENCES

BIOLOGY OF HUMAN VARIATION—New York, N.Y.; February 11–13, 1965; Chairman: Josef Brozek, Lehigh University; Sponsor: New York Academy of Sciences.

CONFERENCE ON THE TEHUACAN PROJECT—Andover, Mass.; May 1965; Chairman: Douglas S. Byers, Robert S. Peabody Foundation for Archeology; Sponsor: Robert S. Peabody Foundation for Archeology.

CONFERENCE ON MODELS OF COMMUNITY POWER STRUCTURE—Ann Arbor, Mich.; June 28–July 9, 1965; Chairman: Warren E. Miller, University of Michigan; Sponsor: Interuniversity Consortium for Political Research.

ADVANCED SCIENCE SEMINARS

INTERNATIONAL FIELD INSTITUTE IN GEOLOGY, PARIS BASIN—American Geological Institute, Washington, D.C.; June 5–August 5, 1965; Director: B. J. Siegel.

1965 BRANDEIS UNIVERSITY SUMMER INSTITUTE IN THEORETICAL PHYSICS—Brandeis University, Waltham, Mass.; June 21–July 30, 1965; Director: S. Deser.

SUMMER FIELD PROGRAM IN ANTHROPOLOGY—Brandeis University, Waltham, Mass.; June 15–September 15, 1965; Director: R. A. Manners.

JOINT SUMMER INSTITUTE IN HOMOLOGICAL ALGEBRA FOR GRADUATE AND POST-DOCTORAL STUDENTS OF MATHEMATICS—Bowdoin College, Brunswick, Maine; June 22–August 12, 1965; Director: D. E. Christie.

SUMMER SEMINAR IN MATHEMATICS AT THE UNIVERSITY OF MONTREAL—Canadian Mathematical Congress, Montreal; June 28–August 6, 1965; Director: L. F. S. Ritcey.

ADVANCED SCIENCE SEMINAR ON PLANETARY ATMOSPHERES—Florida State University, Tallahassee; June 21–August 6, 1965; Director: S. L. Hess.

SUMMER SESSION ON INTER-ACTIONS BETWEEN TOXICANTS AND PROTOPLASMS—North Carolina State of the University of North Carolina at Raleigh; June 14–July 23, 1965; Director: F. E. Guthrie.

TWENTIETH SYMPOSIUM ON MOLECULAR STRUCTURE AND SPECTROSCOPY—Ohio State University Research Foundation, Columbus; June 14–July 18, 1965; Director: H. H. Nielsen.

FIELD TRAINING FOR ANTHROPOLOGISTS—Stanford University, Calif.; June 20–August 27, 1965; Director: B. J. Siegel.

SUMMER PROGRAM IN GEOPHYSICAL FLUID DYNAMICS—Woods Hole Oceanographic Institution, Mass.; May 21–July 27, 1965; Director: W. V. R. Malkus.

ADVANCED FIELD TRAINING IN ARCHAEOLOGY—University of Arizona, Tucson; June 11–August 6, 1965; Director: R. H. Thompson.

INSTITUTE FOR THEORETICAL PHYSICS—University of Colorado, Boulder; June 14–August 20, 1965; Director: W. E. Brittin.

ADVANCED SCIENCE SEMINAR IN ENERGETICS IN METALLURGICAL PHENOMENA—University of Denver, Colo.; June 21–August 13, 1965; Director: W. M. Mueller.

WINTER SEMINAR ON ADVANCED CONTROL—University of Florida, Gainesville; February 22–27, 1965; Director: O. I. Elgerd.

FIELD TRAINING IN SYSTEMATIC VERTEBRATE ZOOLOGY AND PALEONTOLOGY—University of Kansas, Lawrence; June 15–July 25, 1965; Director: E. R. Hall.

ADVANCED SCIENCE SEMINAR IN LINGUISTICS—University of Michigan, Ann Arbor; June 28–August 18, 1965; Director: H. H. Paper.

TWO ADVANCED SCIENCE SEMINARS ON QUANTITATIVE POLITICAL SCIENCE RESEARCH—University of Michigan, Ann Arbor; June 1–August 31, 1965; Director: W. E. Miller.

FIELD TRAINING FOR ANTHROPOLOGISTS—University of Nevada, Reno; June 20–August 27, 1965; Director: W. L. d'Azevedo.

FIELD SCHOOL IN ETHNOLOGY AND LINGUISTICS—University of Oklahoma, Norman; June 1–July 31, 1965; Director: W. E. Bittle.

FIELD TRAINING IN ANTHROPOLOGY, PUEBLO, MEXICO—University of Pittsburgh, Pa.; June 20–August 27, 1965; Director: D. Landy.

ADVANCED SCIENCE SEMINAR IN CROSS-CULTURAL RESEARCH—University of Pittsburgh, Pa.; February 22–27, 1965; Director: G. P. Murdock.

FIFTH SUMMER INSTITUTE FOR THEORETICAL PHYSICS—University of Wisconsin, Madison; June 14–August 14, 1965; Director: K. McVoy.

APPENDIX E

Publications of the National Science Foundation

This listing includes publications issued by the National Science Foundation during fiscal year 1965. A complete listing of available Foundation publications may be obtained upon request from the Foundation.

The publications marked with a price may be obtained from the Superintendent of Documents, Government Printing Office, Washington, D.C., 20402. Other publications are available from the Foundation.

ANNUAL REPORTS

1. Fourteenth Annual NSF Report, for fiscal year ending June 30, 1964: NSF 65–1, $.45.
2. National Science Foundation Grants and Awards, fiscal year 1964: NSF 65–2, $1.
3. Sixth Annual Weather Modification Report, for fiscal year ending June 30, 1964: NSF 65–9, $.30.

DESCRIPTIVE BROCHURES

1. Science Course Improvement Projects: I. Courses, Written Materials, Films, Studies: NSF 64–8.
2. International Years of the Quiet Sun: NSF 64–18, $.20.
3. Improving the Dissemination of Scientific Information: NSF 64–22.
4. Financing a College Science Education: NSF 65–6, $.20.

SCIENCE RESOURCE BULLETINS

1. Reviews of Data on Science Resources:

   Vol. I, No. 1: Research and Development in American Industry, 1963: NSF 64–26, $.10.

   Vol. I, No. 2: Salaries and Professional Characteristics of U.S. Scientists, 1964: NSF 64–27, $.05.

   Vol. I, No. 3: Research and Development in the Electrical Equipment and Communication Industry, 1956–62: NSF: 65–3, $.10.

MANPOWER AND EDUCATION STUDIES

1. American Science Manpower, 1962 (A biennial report of the National Register of Scientific and Technical Personnel): NSF 64–16, $1.
2. Scientific and Technical Personnel in the Federal Government, 1961 and 1962: NSF 65–4, $.40.

RESEARCH AND DEVELOPMENT ECONOMIC STUDIES

1. Current Projects on Economic and Social Implications of Science and Technology, 1963: NSF 64–10, $.50.
2. Federal Funds for Research, Development, and Other Scientific Activities, fiscal years 1962, 1963, and 1964, Volume XII: NSF 64–11, $1.
3. Research and Other Activities of Private Foundations, 1960: NSF 64–14, $.35.
4. Industrial R. & D. Funds in Relation to Other Economic Variables, NSF 64–25, $.65.

SCIENCE INFORMATION REPORTS

1. Scientific Information Notes (Bimonthly periodical reporting national and international developments in scientific and technical information dissemination): Single copy, $.25; subscription, $1.25 per year.
2. Scientific information Activities of Federal Agencies (A series of pamphlets describing the policies and practices of Federal agencies relative to their scientific and technical information activities):

   No. 27. Department of Defense—Part II, Defense Documentation Center: NSF 64–13, $.10.

   No. 28. U.S. Department of Health, Education, and Welfare—Part IV, National Library of Medicine: NSF 64–23, $.10.

   No. 29. National Aeronautics and Space Administration: NSF 64–29, $.10.

   No. 30. Department of Agriculture—Part II, National Agricultural Library: NSF 65–5, $.10.
3. Current Research and Development in Scientific Documentation, No. 13: NSF 64–17, $1.75.
4. Characteristics of Scientific Journals, 1949–59: NSF 64–20, $.30.

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