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LETTER OF TRANSMITTAL

WASHINGTON, D.C.
January 15, 1965.

MY DEAR MR. PRESIDENT:

I have the honor to transmit herewith the Annual Report for Fiscal Year 1964 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.

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A listing of grants, contracts, and fellowships awarded in fiscal year 1964 appears in a separate publication entitled National Science Foundation Grants and Awards, Fiscal Year 1964, NSF 65–2. It is available from the Superintendent of Documents, U.S. Government Printing Office, Washington, D.C., at a cost of $1.00.

THE DIRECTOR'S STATEMENT

This annual report covers my first year as Director of the National Science Foundation. It may be appropriate, therefore, to begin by introducing some of my own views concerning the role of science and technology in the life and progress of our country, the responsibilities of the Federal Government for promoting science, technology, and education in the public interest, and, in particular, the role that should be played by the National Science Foundation.

In the span of less than a single lifetime, virtually every aspect of our society and our personal lives has been vitally affected by the tremendous new impact of science and technology. The posture and composition of our military defense forces are determined by this partnership of scientific knowledge. The space program, with implications stretching far beyond the limits of imagination, is wholly a product of this generation. Our position among the nations of the world depends on our scientific and technological accomplishments—as well as on our cultural attainments, which, in turn, are nourished by science and technology.

We have witnessed radical improvements in medical care, nutrition, and in our standard of living generally. Even our entertainments—the arts and recreation—have benefited from this transformation of our society, an event that is difficult to compare with anything heretofore witnessed in human history.

My comments will elaborate on some of the things that I believe are of importance to the scientific community and the Nation at this time in our history. They stem from the following basic convictions:

- Science and its applications have become such an important part of our culture that they deserve more attention (critical as well as supportive) from the American public and its leadership.
- The interrelationships between science and education and between both of these and government (at all levels) must be healthy if our scientific advance is to be continued.
- A central government is quite properly the creature and servant of the people; hence it can and should do those things for which the people see—or are brought by leadership to perceive—a significant need.
- Support of the scientific enterprise can and should be provided from many sources, including—but *not* especially—the Federal Government.
- All those professionally concerned with scientific and technological activity bear a responsibility for making clear these facts: that *re-*

search and *development* are separable and separate entities, and that they interact one with the other in ways which are mutually helpful; that science is closer to research, and engineering is closer to development, but that there is much overlap on all sides.

- Expenditures for development can and should be justified on grounds which relate to end purpose, goal, or mission—and should not be made competitive with expenditures for basic or broadly based applied research.
- Broad progress, in science and science administration as elsewhere, usually results from the establishment and gradual expansion of particular salients rather than through inch-by-inch advance across a wide front; "imbalances" are therefore inevitable, and even have a certain value as goads to further action.
- As one increasingly important contributor to the Federal effort directed toward keeping U.S. science strong and progressive, the National Science Foundation must continue to provide support for academic science; the Foundation must, therefore, remain throughly informed concerning the problems of colleges and universities, as well as the problems of the science faculty members at these institutions, and should try to invent mechanisms which will as nearly as possible solve the problems both of investigators and of institutions.

The complexity of modern technology in our society—to which Government programs in space, defense, and elsewhere are contributors—places a heavy burden on the country's educational facilities. In order to keep pace with developments, our schools must conduct elaborate and costly efforts to update their capabilities as they prepare scientists to cope with the technology of the 1970's and later. At the same time, the quantitative workload of our universities has mushroomed as they educate increasing numbers of scientists and engineers to meet current needs of industry and Government. Now we have reached the point where Government must be prepared to shoulder an even greater share of responsibility for education in the sciences, first on the basis of traditional concern for national welfare and progress, and secondly because Government requirements themselves constitute one of the factors that are taxing the educational structure to capacity.

To summarize, continuing progress in science and technology is essential to the public welfare and, hence, is a matter of concern to all the people. To assure this progress is clearly a concern of the Federal Government.

The Federal Government's Responsibility

American science was developing along sound and promising lines when the Great Depression struck. For a while, along with many other areas of intellectual activity, it faltered. It had already begun its own recovery when the urgencies of World War II quickly pushed it forward at an ever-faster pace. Progress during those years, and in the span of time to the present, has brought us face to face with challenges and opportunities even greater than those posed for our forebears by the Industrial Revolution. The traditional role of the Federal Government has changed as the scope of its responsibilities has been raised to new heights. Our national destiny quite literally depends on how well we meet these responsibilities.

A primary objective of the Federal Government should be and is to make sure that our capabilities in the areas of science and technology are the very best the social structure can produce. This means that leadership must see to it that we have a vigorous and healthy scientific and technological base which will lead to continued social and economic advance. Scientific and technological progress must be viewed as dependent, in the long run, on two factors:

1. The need to maintain and constantly augment a fund of scientific knowledge derived through research, particularly basic research.
2. The need to strengthen science education, especially higher education, to be sure that we produce adequate numbers of young scientists and engineers qualified to do the things our national goals require.

A second Government objective is to develop—or have developed—the hardware, materials, and processes required for national programs conducted by the Government itself, such as those in military defense and space.

A third Federal objective is to foster and encourage developments that will react to the direct benefit of the people. Here, the distinction lies in the fact that the public rather than the Government is the "customer." Improvements in public health; better practices in agriculture; improved transportation; development of energy, water and other resources; and conservation: these and many other applications of the sciences are properly the concern of the Federal Government since private elements of our society cannot be expected to assume sole or even primary responsibility.

Both the Congress and the public have recently focused interest on the rapid increase in expenditures for research and development by the Federal Government. The concern is understandable since the increase over recent years is substantial. Federal expenditures for research and development have increased from $74 million in 1940 to about $12 billion in 1963. The amount cited for 1940 was only one percent of total Federal expenditures; the 1963 figure accounted for 13 percent.

It is possible for misunderstanding to arise if these totals are scrutinized without considering what they represent. This is one of the problems noted by the Select Committee on Government Research of the House of Representatives, which said in its first report: ". . . the most significant thing that can be said about these figures is that, isolated, they are misleading."

What, then, are the facts? How can the figures be presented in their proper perspective?

To begin with, the familiar term "research and development" does not refer to a single entity. On the contrary, it covers a very broad range of scientific and technological activities. These activities range from the most fundamental basic research to the development of highly complex devices. The convenient abbreviation R&D can be dangerous in that it can lead to confusion and misunderstanding.

The obvious questions arise occasionally: "How much can we afford for research and development? What percentage of the Federal budget or of the Gross National Product should be allotted to research and development?" In my judgment, this approach to the problem is fallacious. To reach the perspective we are seeking, research and development should be considered in terms of the component parts.

All development and much of applied research are directed toward specific national goals. These may be in defense, space, agriculture, public health, or elsewhere. A more meaningful question would be: "How necessary is this particular undertaking to achievement of a national goal?" Developments for military defense should be thought of in the context of military defense. The cost of developing a particular defense item should not be considered in competition with research for public health or basic research in general, but in the overall context of defense expenditure. The same reasoning should apply to developmental projects in space exploration, atomic energy applications, and other national programs. In this approach, only expenditures for basic research—and certain components of applied research—should be regarded as the national investment in science.

Scientific and technological activities included in gross expenditures for research and development are usually divided into three categories: basic research, applied research, and development. The boundaries between them are not sharply defined. They cannot be compartmented neatly, however convenient such a procedure might be for the administrator or the budget officer. For example, what the university scientist may regard as "applied" research may seem very basic to the engineer looking for immediately applicable results.

All research is, of course, the quest for knowledge, and knowledge implies understanding as well as information. Basic research seeks an understanding of the laws of nature without regard for specific utilitarian value. The real objective of basic research is not merely to discover a collection of separate facts by weighing this and measuring that—but to develop an understanding of nature by seeking out the *why* and *how* of nature's behavior.

The fact of understanding is singularly important in science and its applications. It is not sufficient for a scientist to have an inventory of isolated facts; he needs to understand them well enough to be able to move on from them to new areas.

Applied research is carried out with practical and usually, but not necessarily, specific objectives in mind. Such research may involve special measurements to yield data needed for some engineering purposes. It could be a broad study of high-temperature materials for application to many purposes. Much applied research seeks detailed information regarding a specific situation for which the general laws are known from basic research. Obviously applied research pursues courses of action deemed most promising in terms of practical results. Increasing our understanding of natural laws, although important, is not the primary objective.

Now let us look at development, the offspring of research. Development is the systematic use of knowledge directed toward the design and production of useful prototypes, materials, devices, systems, methods, or processes. This includes the construction and testing of "hardware," including military weapons systems, space vehicles, nuclear reactors, and many other items great and small. This is the costliest aspect of the research and development spectrum, both in Government and in private industry. It is distinct and separate from research in that it applies the results of research to the production of end products. Much and often most of what we call development is not "science" in the real sense; rather, it is akin to fabrication, construction, and testing, and it often involves large and expensive programs.

All three areas of activity are important. Applied research builds on the results of basic research. Development builds on both. The more complete our basic knowledge, the easier the task of applied research and of development. The debt owed by technology to science is paid back, however, for many fields of basic and applied research are made possible or more fruitful through new technological developments. For example, much of modern research is made possible by electronic devices originally developed for radio, television, and radar. Special materials, such as metallic alloys, plastics, and ceramics, as well as countless industrial devices and other things of practical importance serve as important tools for research. The range of possible research is broadened and the cost is often greatly lessened by these contributions.

Perhaps scientists have been remiss in not explaining the nature of basic research more clearly. We have also made the mistake of trying to illustrate the ultimate utilitarian value of basic research by examples in which we try to show that a single fundamental experiment has had important practical impact. Nuclear fission has been used as such an example for years. Even in this case, a whole series of experiments preceded and followed the discovery of fission. Without them the fission experiment could not have accomplished what it did, even though it was a rare and outstanding scientific-technological breakthrough.

In the broad sense, basic research is the foundation upon which rests all technological development. The technological fruits of research are harvested from a mosaic of knowledge made up of a great many experiments and the understanding derived from them—just as a tree springs from no single root but from many rootlets reaching deep down to the source of nourishment. Thus it is not appropriate to ask: "How can this particular piece of basic research ever possibly have practical application?" The proper question is: "How much might this contribute to total understanding?"

Transistors provide a good example of the process by which basic research eventually reaches practical application. How did this important advance in electronic technology—the basis of a multibillion dollar industry—come about? It was not by a single invention, not by the results of one experiment or even one program. The applied research and development that brought the transistor into being rested on a great store of basic knowledge—especially in solid state physics and in the field of very pure chemical materials—accumulated through the work of many individuals in many academic and other institutions, including the Bell Telephone Laboratories where the initial development took place. Without this basic knowledge, the development—and indeed the idea itself—would not have been possible.

Apart from the ultimate practical importance of basic research, we must not overlook its intellectual and cultural value—a quality it shares with all forms of knowledge, literature, and the arts. Scientists as well as others make the mistake of referring to "the sciences" as being clearly separate from "the humanities." This is unfortunate, for science is not inhumane, and it is easily demonstrated that the life of the human race has been enriched by the ideas of science, as well as by the material benefits which science has made possible. In a deeply meaningful sense, science is one of the humanities.

Because of the dramatic and spectacular associations surrounding space vehicles and sophisticated items of military hardware, the public is sometimes prone to lose sight of the broader spectrum of Government interest in science and science education. The national effort to foster scientific progress has been likened to "pushing back the darkness" and it goes forward on a wide front. Research and training programs in oceanography, the biological and medical sciences, the atmospheric sciences, the social sciences—to name just a few of the areas of interest to the National Science Foundation—are all properly included in programs of Government support of one kind or another. Nearly all Government agencies provide some kind of support to science, but necessarily, in the general case, along lines that are oriented to their mission responsibilities. The involvement of the Department of Defense, the Atomic Energy Commission, the National Aeronautics and Space Administration, and several other departments and agencies is well known and the reasons for their interest in science are clear. But it is not widely recognized that significant sums are obligated for research and development by the Treasury Department (through the U.S. Coast Guard, mainly), the Post Office Department, the Veterans' Administration, and 10 units under the Department of the Interior. Altogether, depending on how one counts Bureaus and other units of major governmental entities, several dozen Federal components can be identified as substantial contributors to the scientific and technological enterprise in the United States.

How did we reach the present stage of involvement of the Federal Government in support of science? What historical events and points of view can we call on to give us understanding of where we now find ourselves?

The Historical Perspective

In science, perhaps more than in most other areas, "what is past is prologue." The history of scientific progress in the United States is important, both in its own right and as a necessary part of our background if we are to understand what is now feasible and desirable. Because science and education are inextricably intertwined, we must also bear in mind what has happened in education over the years.

It has become obvious to most Americans that continued progress in science and technology is essential to further development in pursuit of the American dream, or the "Great Society" as it has recently been described. It has also become inescapably clear that the Federal Government must continue to shoulder a substantial share of responsibility to insure that the pace of progress does not falter. The principle of government responsibility is accepted, and we are faced with the task of making the wisest possible decisions concerning the direction and intensity of support for science and education.

Government interest in promoting scientific progress and education is historically an integral feature of the American tradition. From the very outset, our forefathers expressed eagerness to assume a role as patrons of science in the light of its usefulness to the development of the nation. It was no accident that the Declaration of Independence appealed to "natural law." Jefferson and his colleagues were wholly conscious of the potential benefits of science and its implications for the infant nation.

It is notable that the Constitution empowered the Congress to "promote the Progress of Science and the useful Arts" at a time when the very word "science" had not yet become a part of the popular vocabulary. There were numerous suggestions submitted, by James Madison and Charles Pinckney in particular, which would have included in the Constitution specific provision for the establishment of a national university devoted in large measure to education in the sciences. Both Washington and Jefferson favored such an institution. There was widespread discussion of Government charters for scientific societies, and special incentives or subsidies for creative effort in science and technology.

Some of the suggestions submitted by the architects of our society were surprisingly imaginative. Many emphasized the need for a national system of education, and urged study of the sciences and utilitarian subjects rather than a continuing overemphasis on the study of the classics. Among the foremost advocates of educational innovation was Jefferson, who believed that merit rather than wealth should determine the educational opportunities of youth. Public education, commencing with the primary school and closing with the university, should be open to anyone whose abilities warranted these opportunities.

The educational ideas of Jefferson and his contemporaries are important, not so much for what they accomplished immediately—the country was still too poor to support a full-scale revolution in education—but in that they provided guideposts for the future.

The educational foundations upon which our forefathers so courageously set out to build a great society were singularly unimpressive by the existing standards of European countries. The president, three professors, and four tutors comprised the entire instructing staff at Harvard in 1800. The Harvard medical school had three professors and graduated only two or three students each year. When Franklin died in 1790, America lost its only scientist of international repute.

But if Federal funds were scarce, the Congress nevertheless did much for education as the United States moved through the years of the 19th century. When the Northwest was opened, not only was one section in each township granted for schools, but a donation of two townships was made to the Ohio Compay to found a university, thus establishing the original endowment of Ohio University at Athens. When Ohio became a State in 1803, Congress likewise granted a township to establish Miami University for the settlers around Cincinnati. As each new State was added to the Union, similar grants were made, with the result that 17 State universities were in existence by 1860.

The Morrill Act of 1862 was a great step forward in Federal aid to education. Under this legislation the Government granted public land to each State—30,000 acres for each senator and representative—for the establishment of mechanical and agricultural schools. These land-grant colleges include some of the most productive and progressive educational institutions of the present day. It has been estimated that the Federal Government in one way or another has donated altogether some 118,000,000 acres to education.

In addition to these farsighted efforts in support of education, the Federal Government, very early in its history, assumed positive responsiblities in a number of other areas associated with science and technology. The Patent Office, one of the oldest Government agencies, was established in 1790—indeed, its function was provided for in the Constitution. Its purpose then, as now, was to encourage and protect inventors so that they might receive just reward for their contributions to national progress.

In the early years of the 19th century, the Congress approved funds for an ambitious coastal survey to promote shipping, and authorized construction of a national turnpike leading into the new country opening up in the West. The Army surveyed the Great Lakes and lent technical assistance in construction of canals and railroads. Beginning a little later, the Army Medical Corps started contributing an invaluable service to the Nation with its work in the control of epidemic disease and in other areas of health.

Thus it is clear that the Government has been in partnership with its citizens in the fields of education, science, and technology from the beginning of our history. Moreover, the climate of burgeoning America was highly favorable for scientific and technological development, a condition stemming from the philosophical and political convictions that constitute the basis of true Americanism.

Against this background, Americans built a model of modern society, and emerged from the wilderness to assume full stature in the community of nations. From a small trickle in the beginning, technological advances soon reached torrential proportions, with problem and solution following each other in dramatic succession.

Beginning with the textile mills of New England, the wave of technological development swept the Nation. The shipping industry flourished as Yankee clippers took to the seven seas. Introduction of agricultural machinery, new processes for smelting iron, the cotton gin, steam engines, electric motors, and a score of other innovations contributed to the building of industrial America. On the western prairies, the telegraph replaced the pony express.

A new profession came into being—the mechanical engineer—as one discovery followed fast on the heels of the last. The sewing machine, invented by Elias Howe in 1846, revolutionized the textile and shoe industries. The electric light and the telephone appeared on the scene as the century of progress reached a climax. When the Patent Office opened its doors in 1790, the clerks waited three months for the first applicant to present himself. In the hundred years that followed, nearly two million patents were granted, remarkable evidence of "Progress of Science and the useful Arts."

The first hundred years of existence as a free nation were truly eventful for the United States. The material wealth of the country multiplied several hundred times over—but a nation's advance should not be measured in material goods alone. Similarly, it would be difficult to estimate the fiscal investment of the Federal Government in its efforts to promote education, technology, and science. Speculation on the "might have been" is fruitless, and there is no way to measure the debt we owe to Jefferson and the other pioneer giants who charted a course for the ship of state.

The great majority of scientific work in the United States during the 19th century was devoted to the solution of practical problems, the invention of "things" and processes that would immediately become useful and profitable. Science lived in close proximity with trade and industry and material development. In satisfying the insatiable hunger for technological advances, there was even ample room for the talented and lucky amateur. Emerson, with his lofty disdain for society as a "joint-stock company" and for the "education at a college of fools" was representative of the element which hung a sign on the door of American intellectualism reading, "Scientist Kindly Use Rear Entrance." It was an attitude, unfortunately, that spilled too far over into the 20th century.

It is quite true that the pursuit of intellectual excellence for its own sake in 19th century America was directed mainly along the avenues of philosophy and the arts. Science gave little time to basic research—the quest of new knowledge for its own sake and without thought of practical application. All of the inventions and technological advances that went into building industrial America were based on an inherited body of scientific knowledge—the sum of scientific discoveries which had originated largely in Europe. The fund of mathematical knowledge which enabled the Army Engineers to build canals and survey the Great Lakes in the 1840's was substantially unchanged 50 years later. Science as an intellectual process was, if not ignored, at least neglected. Expansion of the intellect in the simple pursuit of excellence was overshadowed by the dramatic demands of technology.

But with continuing heavy emphasis on the technological applications—and little effort in pure research as was the case in the 19th century—one might be moved to ask if the bank of scientific knowledge may not eventually be exhausted. If science becomes bankrupt, can material progress continue? We know that past civilizations have withered and died from stagnation.

To the great good fortune of science and of the Nation, American universities began in the latter part of the 19th century to engage in scientific research. Leading scientists on their faculties, many of whom had studied in the great universities of Western Europe, clearly perceived the scholarly virtues of research, both in its impact on the faculties themselves and in the role that it could play in the education of budding scientists. Beginning in a few of the leading institutions, recognition of the importance of academic research gradually spread, often under great handicaps with respect to time and money, until by the end of World War I it had become traditional in all the major universities and many others. This trend grew throughout the 1920's and the 1930's, in spite of financial setbacks during the Great Depression. During this whole period great and vital financial assistance was rendered through the generosity of many of the privately endowed foundations. So firmly did the importance of research become recognized by the well-informed that increasing numbers of forward-looking industries engaged in it themselves and in some instances supported it in the universities. A few private nonprofit research institutions, usually supported by a private foundation, also came into existence. Thus, by the advent of World War II, research had become a widespread enterprise, though its value had not yet been recognized by the public as a whole.

The unprecedented accomplishments of scientists during World War II led to a new and general awareness of the importance of science, especially research. It was, therefore, not surprising that President Roosevelt a short while before his death requested Vannevar Bush to prepare for him recommendations detailing how:

> The information, the techniques, and the research experience developed by the Office of Scientific Research and Development and by the thousands of scientists in the universities and in private industry [can] be used in the days of peace ahead for the improvement of the national health, the creation of new enterprises bringing new jobs, and the betterment of the national standard of living.

Bush responded in less than 8 months with his well-known report, *Science—The Endless Frontier.* The central point of view that the report emphasizes has come to be an unquestioned principle over the intervening two decades. In the summary of his report Bush said:

> The Government should accept new responsibilities for promoting the flow of new scientific knowledge and the development of scientific talent in our youth. These responsibilities are the proper concern of the Government, for they vitally affect our health, our jobs, and our national security. It is in keping also with basic United States policy that the Government should foster the opening of new frontiers and this is the modern way to do it. For many years the Government has wisely supported research in the land grant colleges and the benefits have been great. The time has come when such support should be extended to other fields.

Bush's wise advice was heeded in many quarters, eventually in its broadest sense. In the initial postwar years, however, support for science and its applications was largely motivated by the goals of national security, better health, and other practical needs. The Office of Naval Research, the Atomic Energy Commission, and later, the National Institutes of Health instituted vigorous programs backed by increasing financial support. Although justified by practical ends, these programs served as salients from which grew support for basic science. Wise men directing the programs of these and other agencies saw that progress in the applications of science could flourish only when resting on a base of fundamental knowledge and understanding. As this realization grew within the public and the Congress, basic research began to be accepted as a proper objective for Federal support without regard to foreseeable applications for each component part. This realization reached maturity in the Congress in 1950 with the act establishing the National Science Foundation as an independent agency devoted to the support of science and science education without regard to specific practical missions. No limitations were placed upon the activities to be covered so long as they were scientific.

In addition to bringing about a greatly increased realization of the important role of science in society, World War II resulted in adoption of a remarkable invention in the methodology by which the Federal Government conducts its scientific work. During the war, the Government turned in large measure to private institutions to carry out military research and development. The success of this method led to its continuation into the peacetime era. A growing majority of the work was conducted under grants or contracts with universities or industry or other institutions, depending on the nature of the work. Even many federally owned laboratories, some so large as to be national in character, were operated under contract by such private institutions. So complete was the adoption of this method that the Atomic Energy Commission and, later, the National Science Foundation were barred by statute from the direct conduct of scientific work themselves. This trend continues. As contrasted with the prewar years when a large majority of Federal research and development activities were in intramural laboratories, less than one-fifth is found there now. Notably, almost half of the expenditure for basic research support is in the colleges and universities where it has a strong impact on higher education. Indeed some programs, notably one supported by the National Institutes of Health, explicitly combine the objectives of research and graduate student training. It is worth noting that approximately one-third of the almost $1 billion in support of research in the universities' own laboratories comes from the Defense Department. A like amount comes from the National Institutes of Health—most of it going to the medical schools. NSF supplies about 15 percent; AEC, eight percent; and the rest is scattered.

Nearly all of the work in the educational institutions and much of that conducted elsewhere is supported through so-called "project" grants or contracts. Under this system individual scientists or groups of scientists apply through their institutions for funds to support fairly well-defined research. These proposals are scrutinized by the particular agency, which selects the most meritorious ones for support within the limitations of its funds. Many of the agencies, notably the National Science Foundation and the National Institutes of Health, base their judgments largely on the recommendations of experienced scientists from outside the Government who work in the same or closely related fields. This system of "judgment by the peers" brings into the evaluation the most highly qualified scientists in the country and is furthermore a protection against the possibility of errors in judgment that might result were programs determined by a relative few within the Govenment who were not in immediate and constant touch with the progress of the various fields.

In addition to support of the conduct of research, the various agencies have supplied specialized facilities for research in such fields as nuclear physics, oceanography, astronomy, and many others, in addition to computers for use in virtually all fields. Some of the agencies have provided funds, often on a matching basis, to construct general laboratories for graduate research.

Forming an important component in the total research effort are the so-called "national centers" operated for the Government by individual educational institutions, by corporations sponsored by such institutions, or by industry. In many instances they serve as centers where equipment so large, complicated, and expensive as not to be feasible for individual universities can be located to serve the needs of the scientific community as a whole.

The magnitude and complexity of the Federal Government's research and development programs are so great as to make it increasingly necessary to have continuous coordination. In the first place, one is always confronted by limitations of manpower, of facilities, and of fiscal resources. Secondly, it is necessary to guard against fragmented research efforts where pooled resources would accomplish much more than merely the sum of individual items. Thirdly, many scientific activities transcend the responsibility or interests of a single agency. Then too, one must safeguard against any unwarranted duplications or important omissions resulting from peculiarities of Government organization or of agency jurisdiction. Finally, the increasing knowledge of science and technology leads to the recognition that many problems are never completely resolved, but must be looked at continuously from new vantage points.

The key individual in the coordination of the research and development programs of the Federal Government is the Special Assistant to the President for Science and Technology. He is also Chairman of the President's Science Advisory Committee and of the Federal Council for Science and Technology, as well as head of the Office of Science and Technology.

The President's Science Advisory Committee is comprised of leading scientists and engineers from outside the Government who review the status of important fields of science, utilizing, as appropriate, special panels whose total membership includes several hundred scientists from all over the country. This arrangement not only brings to bear on Government problems the wisdom and experience of all these individuals, but also is an effective mechanism for communication among scientists in the universities and industries actively engaged in research and development and between them and the Government, thus providing an important clearinghouse for information and ideas.

The Federal Council for Science and Technology consists of the chief scientific officers of the nine Federal agencies most heavily involved in scientific activities. It is concerned primarily with resolving problems of a multiagency nature and with coordinating the work among the agencies. It leans heavily on the scientific advice of the President's Science Advisory Committee and the National Academy of Sciences. Through various committees and the staffs of the agencies and of the Office of Science and Technology, it examines areas of primary national interest where a concentrated effort and Governmentwide approach is deemed essential, either because of the magnitude of the activity or because of the multiplicity of agencies involved. Whole scientific fields are reviewed with respect to scientific expectation and national goals as well as to possible gaps and overlaps. Noteworthy success has been achieved in oceanography and in the atmospheric sciences. In these cases reports from the National Academy of Sciences have been particularly helpful.

The Office of Science and Technology is concerned primarily with national policies of science and technology, both the role of science in policy and the complementary role of policy with respect to science. It also provides staff assistance to the President's Science Advisory Committee, the Federal Council for Science and Technology, and the Science Advisor, and it is the official channel from the Executive Branch to Congress.

These various mechanisms combine effectively to provide the Executive Branch with the best scientific wisdom both inside and outside the Government and to bring about effective coordination in all the multitudinous scientific and technical activities while leaving the intimate direction and decisionmaking to the agencies wherein lies the detailed knowledge of requirements for the various missions.

The Role of the National Science Foundation

The National Science Foundation, an independent agency of unique characteristics, was established by Act of Congress in 1950 to support science in the broadest sense. Thus, it may be said that the Congress laid out the Foundation's mission in strategic terms, leaving to the agency wide discretion in choosing its mechanisms or tactical approaches to the problem of helping science move forward.

The Foundation has chosen, wisely I believe, to stress investment in people as a broad element of the strategic approach. Science advances through the creative efforts of well-educated, gifted people. Identification of such people and appropriate support for their endeavors constitute a logical approach to assuring that progress will indeed take place.

NSF grants in support of research mainly have supported established investigators, or new people with outstanding promise. Fellowships for graduate study—and beyond—have been awarded to young people of great intellectual merit solely on the basis of ability.

In the past, the Foundation has relied heavily on project grants in making funds available for support of research. This has proven to be an effective mechanism, and is still considered basically sound. With the passage of time, however, certain inadequacies have come to light; as will be pointed out later, we are finding it desirable to supplement the research project grant system with other devices.

In the area of science education, heavy emphasis was originally placed on graduate education—particularly on support of graduate fellowships for predoctoral study. However, early in the Foundation's history, the staff became aware of the need for additional activities at collegiate and even precollegiate levels. There were many problems uncovered at these levels, leading to initiation of a number of programs.

Because of the very broad mandate contained in its authorizing legislation, the National Science Foundation has been able to play a unique role with respect to education in the sciences. The authority for such activities resides in the portion of the act which authorizes and directs the Foundation to "initiate and support . . . programs to strengthen scientific research potential in the mathematical, physical, medical, biological, engineering, and other sciences. . . ." Thus, while the Foundation properly supports science education programs at many levels, the goal is to strengthen the potentialities for national research capability.

When an individual assumes new responsibilities, he naturally brings to the new task certain attitudes and points of view which derive from his own experiences and concerns. In taking over from Dr. Alan T. Waterman as Director of the National Science Foundation, I found a number of questions and problems which seemed to me in need of resolution. Many of these problems had been recognized by others—including my predecessor. All pose substantial difficulties, and it is clear to me that many of them will require a great deal of attention before they are satisfactorily resolved.

There are a few of these problem areas that I consider to be of particular moment, and it seems to me appropriate and even desirable that I make use of this opportunity to present my point of view as to how the Foundation can move toward acceptable solutions of such issues as these:

- Should the Foundation attempt to devise new or modified support programs rather than continuing to rely mainly on the project grant method?
- How can one be sure that the relative amounts of support being provided by NSF to the various fields of science are approximately correct?
- What changes, if any, should NSF make in its policies and procedures in response to the increasing concern over geographical concentration of Federal funds for research and development activities?

Clearly these problems are not uniquely relevant to the National Science Foundation; the other agencies of Government concerned with scientific and technological matters must also address themselves to essentially the same questions. Nonetheless, there are two senses in which these problems and others of comparable importance are particularly relevant to the Foundation's assigned responsibilities. In the first place, NSF was created in order to provide a governmental unit which could look at problems of science and technology in the broadest possible sense. Hence its task has been and still is to consider the health of science now and in the future, without regard to specific short-range goals associated with a limited mission. Thus, the nature and scope of its programs can be adjusted in flexible ways, over relatively short periods of time, to make them responsive to new or changed needs.

The second sense in which such questions can be viewed as particularly relevant to the Foundation's role derives from the charge given NSF by the Congress to develop and encourage the pursuit of a National policy for the promotion of basic research and education in the sciences. In carrying out this assigned responsibility (which, by virtue of Reorganization Plan No. 2 of 1962, it shares with the Office of Science and Technology), the Foundation must of necessity take into account the activities and procedures of other Federal agencies and all other public and private groups that are concerned with improving the nation's scientific potential. This means that NSF must inform itself and others concerning the actualities of Federal and other support of science and technology. This is accomplished by means of comprehensive and thoroughly detailed surveys of research and development expenditures, scientific and technical manpower, and other related matters that lend themselves to statistical treatment. Moreover, NSF has a central responsibility for presenting special analyses which will help all those concerned with policymaking in this domain to base their decisions on the most accurate and significant information available. Therefore, while it is obvious that the search for solutions of these problems is important in terms of the Foundation's own programs and procedures, it is necessary to remember also that these efforts must take into account our statutory responsibilities as they relate to policy formulation.

There is overwhelming evidence that the project grant system—as used by NSF and other agencies—is desirable no matter what other steps are taken to strengthen the relationship between the Government and the colleges and universities. Even those advocating the need for new or different kinds of support have, in the majority of cases, conceded that new types of support should be used only as a supplement to the project grant mechanism. But inherent in the system are some defects. For example:

- Decisions are made outside the institution on the nature and amount of support to be provided the various components of a given institution; the institutional leadership has either limited or no opportunity to make decisions relative to assuring balanced growth in the various departments and other units.
- Scientists or administrators may alter the preferred balance of research in order to favor those efforts they judge most likely to receive Federal support.
- Younger, unknown investigators have difficulty obtaining support.
- It is difficult for an institution to establish new activities, such as interdisciplinary units or programs.
- Funds are often not available for flexible use; in particular it is difficult to support activities of common benefit to several projects—for example, libraries, shops, and electronic computers.
- Experienced, proven research workers are sometimes required to resubmit applications for continued support every year or two, when the nature of their work makes it evident that the completion of their projects would require much longer.

There is no simple way to overcome these defects. If it were possible to support much more research, several of these difficulties would immediately become less worrisome or disappear. Given continued hard choices, however, it appears desirable to work toward at least partial solutions to some of these problems.

NSF is looking for solutions along several different paths. For one thing, presidents and deans are being reminded that they must concur in the submission to the Foundation of research proposals; they can therefore, if they feel sufficiently strongly about a given case, refuse to forward to NSF a proposal which they do not think would fit into the long-range plans of the institution.

Project grants are also being broadened so that in many cases fairly large areas can be encompassed within a single grant, thus assuring consideration for and coordination between relevant groups if a grant is eventually made.

NSF is actively seeking new administrative devices which will make it possible to give assurance of longer-term support, even in cases where it is not possible actually to obligate funds for the support to completion of lengthy projects.

Because all of these changes in point of view and approach still leave something to be desired, the Foundation continues to seek out new and better ways of allocating its funds so as to optimize their usefulness in advancing science. Since project grant funds are of necessity limited in their use to certain purposes associated with a specific research activity, even those departments which receive fairly generous project support from NSF and other agencies frequently call attention to their need for relatively small amounts of flexible money. There are many ways in which so-called "free" money can be used to improve the research capability of a department or other institutional unit. The Foundation has, since 1961, made available "Institutional Grants" to help meet this need. The grant amount in each of these cases is determined by formula from the total of research and research training grants awarded an institution during a specified 12-month period. The funds thus made available can be used by the institution for any purpose which, in the judgment of the institution's president, will advance scientific research or education in the sciences on his campus. During fiscal year 1964, Institutional Grants totaling $11.4 million were made to 370 colleges and universities in all 50 States, the District of Columbia, and Puerto Rico.

Although all of these steps are useful, more must still be done to help build up institutions in those parts of the country which at present are not particularly strong in science. To accomplish this, programs different in kind from the traditional project grants will be needed; substantial funds will be required in order to have any significant impact on the national situation. The Foundation should focus attention primarily on the problem of institutional development rather than on regional development *per se*, but it is obvious that strengthening a number of institutions would provide opportunities for achieving a considerable degree of geographic dispersion of "science development" funds. It is my conviction that NSF— and other agencies to the maximum extent possible—should take advantage of any opportunities they can to improve scientific capabilities in all parts of the country.

During fiscal year 1964, the Foundation initiated a new Science Development Program which is designed to help a small number of institutions move forward rapidly to a new level of quality both in research and in education; under this program, relatively large sums—up to about $5 million—will be granted to a few institutions which can make the most convincing cases that they are prepared to move ahead on a fairly broad front toward significantly higher quality in both research and education. The funds are to be used over a 3- to 5-year period, and the institution must provide assurance that it will be able to carry on at the newly achieved level of excellence when the NSF grant expires. The first grants under the NSF Science Development Program will be made during fiscal year 1965. It is my hope that we can proceed quickly to a point where at least some science development grants in a second category can be made. Under this newer scheme (not yet approved), smaller renewable grants would be made to a somewhat larger number of institutions to enable departments or groups constituting "pockets of strength" to accelerate their qualitative growth to a point where they can become significant centers of research and education. It would be premature to predict a specific time when NSF will find it possible to make grants of this kind.

A related though separate matter has to do with the Foundation's initiation, also in fiscal year 1964, of a new Graduate Traineeship Program. This activity, limited during its first year to engineering, resulted in the award of grants to 109 institutions; each grant provided for a specified number of Graduate Trainee stipends, totaling 1,220 altogether, plus special allowances to help defray the institution's costs incurred in providing a year of training for each graduate student receiving an award. Akin in several respects to the Foundation's fellowship programs, the Graduate Traineeship program differs substantially in that it passes on to the grantee institution the responsibility for selecting the students to be supported as Trainees. Because of the intimate connections between graduate education and research, it is clear that departments that are moving rapidly toward educational and research excellence need to be in a position where they can build up their population of graduate students by offering support to carefully selected individuals. Since the Graduate Traineeship program makes this possible in many cases, it can also—though to a limited degree—be considered a program devoted to developing science potential throughout the Nation. In fiscal year 1965 this new activity is scheduled to grow markedly and to be extended to the mathematical and physical sciences. Still later it will be extended to the biological and social sciences. As it increases in size and scope, we believe the program will become an important factor in assisting both well-established and newer departments throughout the Nation.

The second problem or issue mentioned in the above listing involves the question of priority. How can we best determine when a "proper balance" of support has been achieved among the various fields of science?

It may turn out in the long run that the correct answer to this question is "We cannot." But additional efforts to arrive at more nearly optimal levels of support—given limited resources—seem desirable. The Foundation, in its operational activities as well as in its various studies on behalf of the Government as a whole, plans to give additional emphasis to the compilation and analysis of data which bear specifically on the question of relative total levels of support and measures of apparent needs. The techniques for obtaining reliable data in this area are still relatively primitive, but we believe that they can be improved and that substantial progress can be made in a few years toward a system which will be somewhat more clearly rational than that which we now are forced to use. Thus, we hope eventually to be able to cite fairly precise figures relative to the average amount of total research support available to academic scientists, by field of science, and to augment such data with judgments from competent people in the various fields on the question of reasonable ranges of support levels for each discipline.

In some relatively small fields, such as astronomy, we can even now come close to developing a national picture of the capabilities of the existing group of research workers, their facilities requirements, and the potentialities relative to training of additional specialists in the field. Such detailed analysis is beyond our present capabilities for most of the larger fields of science, but we are currently supporting and conducting studies designed to shed light on these problems within specific disciplines. The problem of making interfield priority judgments should become more manageable if somewhat more complete information on a field-by-field basis can be made available.

The Foundation is also attempting to formulate an approach to interfield priority assessment which would take into account the probable contributions of NSF-supported basic research to the solution of a variety of national problems. Thus, for example, it is possible that a whole cluster of basic research activities might justifiably be supported in several fields of the behavioral and environmental sciences, all of which would in one way or another shed light on what is now called the "transportation-urbanization" problem. The complex of scientific and technological issues surrounding the increasing needs for water will continue to focus attention on such interacting areas as hydrology, weather modification, and desalinization. Research and training activities specifically oriented toward the solution of some of the identifiable problems in this complex may prove to be particularly important. Obviously, such an approach would not supplant other efforts to determine relative priorities but further investigation may demonstrate that this approach is a useful way of supplementing other mechanisms.

It is clear that determination of appropriate levels of support by fields of science is a problem that will continue to require judgments which take into account policies, attitudes, and political realities—none of which can be treated quantitatively. These may, in a good many cases, turn out to be the most important elements in setting priorities. For the immediate future, therefore, the Foundation has no alternative but to continue basing its decisions relative to support levels on judgments which take into account both quantitative elements and more subjective considerations, all the while pressing its search for facts and analytical techniques which, hopefully, will assure an increasing degree of validity in such decisionmaking.

The issue of increasing the geographical spread of federally supported research and development (the third of the problem areas outlined above) began to reach significant levels of concern in fiscal year 1964. Various groups in Congress have taken an interest in this matter. In particular, the Subcommittee on Science, Research and Development of the House Committee on Science and Astronautics carried out an extented series of hearings which focused on this issue late in the fiscal year. This group asked NSF and other agencies to comment on the following question:

> Is it possible to achieve greater uniformity in the geographical distribution of Federal contracts and grants without affecting the quality or cost of research and development?

In testimony before that subcommittee on May 6, 1964, I responded to this question in the following terms:

> If I correctly interpret the meaning of its various terms, I have to say that the answer to this question is unequivocally "no". Briefly put, to achieve high quality results requires going where the best capability exists. That capability is now quite concentrated geographically. Hence the maintenance of high quality results will result in concentration unless and until we build up a broader geographic base of capability. And this will require additional expenditures.
>
> This does not mean that we are helpless in the effort to assure a more widespread distribution of support for research and development. What it does mean is that we cannot hope to obtain maximum output of research and development results unless we support and use the facilities and the scientists and engineers in our great centers of scientific and technological activity. Hence if we are interested in research of high quality, done with minimum delay, we must not go to those institutions which would first have to build up a capability and then begin to accomplish the job that we want done.

I might have added that it is from the presently strong institutions that the men must come who will lead the way in the improvement of the others. Hence, merely to divert support from the stronger to the weaker would defeat the very goal of broadening our base of excellence.

With respect to the Foundation's future attitude and probable actions in connection with this issue, I noted in the same statement that:

> In keeping with my conviction that we must try to find new and more effective ways of helping build increased strength in science throughout all parts of the country, I have instructed various staff elements at the Foundation to give increasing attention to this issue. As a result, it now seems clear that we will wish to seek funds for fiscal year 1966 which can be specifically devoted to helping departments of science which show real promise as future centers of strength to accelerate the rate of growth in their scientific capabilities. I have discussed this matter with the National Science Board and the Board is in agreement with my position that such a move is both desirable and timely. Although the precise mechanisms for accomplishing this goal are still being developed—and therefore have not yet been approved by our Board—I am reasonably certain that next year we will be launching one or more new programs designed to develop the nation's research and science education potential.
>
> In the meantime, we intend to continue our efforts to assure a wide and yet effective distribution of the funds entrusted to us by the Congress. We believe we have obeyed the Congressional injunction to "avoid undue concentration" of our support, and we shall make sure that we continue to do so.

Obviously, this is an issue that we must not ignore. But it is not so critical that we should allow our justifiable concern to stampede us into hasty actions which might prove harmful.

We have heard the phrase "centers of excellence" used many times over the last few years. NSF, along with various other agencies, has been trying to find ways of giving this concept meaning and of helping create new scientific capabilities of high quality where only the potential exists at present.

NSF believes the phrase "centers of excellence" should be interpreted broadly. It should not be reserved for use only in connection with an entire institution. It is conceivable that a really first-class department of oceanography might be created in an institution which, overall, is not among the leaders, and which has only marginal strengths in, for example, psychology or astronomy. Thus, we would want the term to be thought of as usable in reference to: a coherent unit within a department, a department, a small group of related departments, a "school" (of engineering, for example), or an entire institution. So conceived, an effort to build up the scientific potential of the Nation by the creation of new centers of excellence becomes mainly a problem of bringing to bear one or more of NSF's present programs on the present "pockets of strength" in many institutions. The Foundation's newly developed Science Development Program can have a significant impact in this area, and I am convinced it will. But it should not be thought of as the sole or even the primary way now available to obtain either training funds or research support from NSF. Depending on the specific status and needs of a given institutional component, any one of several Foundation programs might be helpful. The range of programs now available can help with: the purchase of undergraduate instructional equipment, the construction or renovation of graduate research facilities, the provision of research equipment through project grant funds, and the further training of faculty members—to cite a few of the most pertinent program activities now being carried out by NSF.

No matter what steps we may find it possible to take in helping to increase the number of outstanding departments or institutions, we must preserve our programs of support in which present excellence is the prevailing criterion in order that the institutions that have already achieved high standards in science will also continue to improve. As we intensify our efforts to broaden the regional distribution of high quality research and education in the sciences, we must avoid policies that would weaken those institutions that have made U.S. science strong, and that are also our major sources of the highly capable teaching and research personnel needed for the development of new centers. Substantial and arbitrary changes in the distribution of Federal support for scientific research and education at the expense of support for the already strong institutions would not, in the long run, benefit any geographic region and would almost surely damage the national interest.

The Foundation is sometimes subjected to criticism for having too many programs. This is indeed a problem, both for the colleges, universities, and other groups with which we do business as well as for the Foundation itself. There are, on the whole, good reasons for having a wide variety of programs, and it is clear that every program we now have can claim ardent supporters. Even so, we must avoid unduly increasing the complexity of our activities, and it is my intention to do all I can to keep this from happening. To this end, we will be making careful studies of our current activities to see where it may be possible to introduce simplifications.

In this statement I have tried to convey the challenges and changes, the problems and responsibilities which have confronted the Foundation during my first year as Director. I do not anticipate that the future will bring any magical solutions for our many problems, nor will we find any miraculous process by which we can do without effort what must be done. But our goal is a worthy one, and I find the pursuit of it eminently gratifying.

ORGANIZATION

During fiscal year 1964 a number of organizational changes were effected in the staff of the Foundation both to reflect my ideas regarding administration, and to fill vacancies.

The post of Deputy Director (vacant for some time) was occupied during the fiscal year by Dr. John T. Wilson; I count myself fortunate in having been able to persuade Dr. Wilson that he should relinquish a responsible administrative post at the University of Chicago to return to NSF (where he had held several responsible positions for almost a decade).

My assessment of the administrative task facing the Foundation in July 1963 convinced me that the steadily increasing managerial load demanded a somewhat more decentralized organizational structure. As a consequence of this decision, a modified pattern of organization was established a few weeks after I became Director. The most significant change effected at that time was the redefinition of the functions of the Foundation's Associate Directors and some regrouping of the functions assigned to them. Each Associate Director now has full "line" responsibility for the Divisions and Offices which report to him. An important step in a specific case was the creation of a new post (at the Associate Director level, though not so called) to manage the highly complex Project Mohole, involving very deep drilling in the ocean bottoms.

As a result of the expiration of the terms of several members of the National Science Board, the statutory governing body of the Foundation, new members were appointed by the President, and a new chairman—Dr. Eric A. Walker, President of the Pennsylvania State University—was elected. Dr. Philip Handler, of Duke University, was elected Vice Chairman.

The new members of the Board, whose terms expire May 10, 1970 are: Dr. H. E. Carter, Head, Department of Chemistry and Chemical Engineering, University of Illinois; Dr. Julian R. Goldsmith, Associate Dean, Division of the Physical Sciences, University of Chicago; Dr. William W. Hagerty, President, Drexel Institute of Technology; Dr. Mina S. Rees, Dean of Graduate Studies, the City University of New York; Mr. John I. Snyder, Jr., President and Chairman of U.S. Industries, Inc.; Dr. Julius A. Stratton, President, Massachusetts Institute of Technology; and Dr. Frederick P. Thieme, Vice President, University of Washington.

In reporting on my first year as Director of the National Science Foundation, I wish to acknowledge with respect and admiration the work of my predecessor, Dr. Alan T. Waterman. Under his leadership, the Foundation moved forward steadily and purposefully during more than 12 years of continuously expanding responsibility. The precedents he set during this period, and the counsel he provided in the months immediately before and after I assumed direction of Foundation activities have been of great importance to me.

It is generally recognized that no two individuals approach an administrative responsibility in precisely the same way. When a position changes hands, it is to be expected that new courses of action and new organizational patterns are likely to result. Furthermore, the rapid growth of the Foundation in recent years, itself gave rise to new requirements. Thus, I have felt no constraint in making certain changes in organization and procedures which seemed to me appropriate. These changes which I deemed desirable are, however, collectively secondary in comparison with those elements of the Foundation which remain much the same today as they were when Dr. Waterman retired.

It is a pleasure for me to acknowledge, for myself and on behalf of science in general, the impressive and lasting contributions made by Dr. Alan T. Waterman as first Director of the National Science Foundation.

LELAND J. HAWORTH.

PROGRAM ACTIVITIES
of the
NATIONAL SCIENCE FOUNDATION

INSTITUTIONAL PROGRAMS

Both the Federal Government and the Nation's colleges and universities have been aware of the need for Federal support of science and science education in ways other than those of the usual individual project grants. That these ways should encourage autonomy in institutional planning and protect the scientist's freedom in conducting research of his choice is considered of vital importance in keeping healthy the Government's relationships with institutions of higher education.

The National Science Foundation as one of the key agencies in supporting science on the Nation's campuses has, therefore, in recent years inaugurated a number of institutional programs. These programs recognize that the responsibility of planning for strong science activities must be assumed more and more by the institutions themselves. The programs described in the following pages are based on this premise.

SCIENCE DEVELOPMENT PROGRAM

In March 1964, the Foundation began a program designed to assist selected academic institutions in strengthening significantly their activities in science and engineering. The major objective of the Science Development Program is to increase the number of institutions of recognized excellence in research and education in the sciences. It is not intended to replace existing programs or to consolidate grants for administrative convenience. Rather, this program's primary purpose is to accelerate improvement in science by providing funds to be expended in accordance with carefully developed plans. Such plans must be designed to produce significant upgrading in the quality of the institution's science activities. Grants will be made to colleges and universities judged to have the greatest potential for moving upward to a higher level of scientific quality and for maintaining this quality.

For more than 2 years prior to launching the Science Development Program, the Foundation considered the concepts and problems of institutional development. As a base, there was the stimulus of the President's Science Advisory Committee statement of November 15, 1960 (the Seaborg Report), that defined the need for an increase in the number of high-quality graduate centers. However, during the Foundation's study of the strengths and weaknesses of colleges and universities, it became evident that in initiating new broad approaches for the support of science, NSF should not limit eligibility to graduate programs only. Thus, the announcement of the new Science Development Program states that:

> Institutions of higher education in the United States, its territories and possessions, may apply, if they grant baccalaureate or higher degrees in science or engineering . . . Since the goal is to increase the number of strong academic centers in science, institutions already recognized as being outstanding in science should continue to depend on existing programs for assistance. On the other hand, important criteria in the selection of grantees will be: (a) the presence of sufficient scientific strength at the institution to serve as a base for the proposed development plan, and (b) the availability of adequate financial resources to give reasonable assurances that the institution's goals . . . can be achieved and maintained.

Although outstanding institutions are not singled out specifically and excluded from participation, the announcement makes it clear that this program was not initiated primarily to overcome any weaknesses they may have. A variety of existing programs provide for the continued development of such institutions. No institution is excluded from applying provided that it meets all requirements, including present scientific strength, the availability of adequate financial resources for reaching the objective, and availability of resources to maintain the objective once achieved.

Although no limit has been set on the amount of a Science Development grant, the maximum will probably be $5 or $6 million, and no more than 10 to 15 grants can be expected each year. The grants are designed to emphasize significant major improvement in scientific strength during a 5-year period, as opposed to long-term subsidy. In general, support from the Foundation will be for the first 3 years of a 5-year plan with a possibility of a supplementary grant not to exceed 2 years. 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.

In the 3 months interval between the announcement of the program in March 1964 and the end of the fiscal year, representatives of about 165 colleges and universities held conferences with Foundation staff concerning Science Development plans.

Interviews with institutional representatives have made it clear that priorities of needs differ. There are some common needs. Funds for faculty development appear to be of highest priority. Probably every proposal will emphasize this as being essential. Funds to attract high-quality students are nearly always mentioned as a high priority need. Generally, these are discussed in terms of fellowship-type stipends as opposed to "working your way through college" type stipends. General-purpose equipment is always mentioned as an item to be included in a

Science Development proposal, but, as these are preliminary discussions, the requirements are not very specific and representatives express needs ranging from expensive specialized equipment to hand tools. It appears that requests for funds for new construction will be included in the proposals from many institutions.

This program is a most important departure from existing programs; it will set a pattern and plot a direction for additional ways of strengthening science. The Science Development Program will help to build scientific strength in additional geographic regions and to some extent will have the effect of providing a wider distribution of funds. However, this program, with $28 million available in fiscal year 1965, cannot possibly satisfy the demands for significant increases in funds in all geographic areas.

INSTITUTIONAL GRANTS FOR SCIENCE

One way that the Foundation helps American colleges and universities meet their most pressing requirements is through Institutional Grants for Science. This program, which began experimentally on a small scale in 1961, is now well known. Designed to strengthen science in institutions of higher learning and to respect their autonomy and integrity, it provides funds that can be used at the discretion of the institution to meet special needs in science and to stimulate efforts to reach self-determined goals of well balanced and effective science programs.

All over the country, colleges and universities face similar problems in their scientific endeavors. There are universal needs, such as finding staff and funds for supporting research, providing spacious and well-equipped laboratories, keeping courses of instruction abreast of rapidly expanding knowledge, and increasing the numbers and quality of baccalaureates and doctorates in science and engineering to meet national requirements for trained manpower. However, local circumstances always give these general needs a particular shape on the individual campus. Institutions avail themselves of NSF's many special-purpose programs—research grants, fellowships, undergraduate research equipment, etc.—but they still must have funds to use flexibly to blend and balance their many activities, to strengthen their weak spots, and to fit their particular requirements and aspirations. Institutional Grants for Science provide funds that can be adapted easily to the science programs of any campus.

To insure maximum elasticity in the use of Institutional Grant funds, the Foundation has kept the administrative requirements of the program simple. To qualify for an Institutional Grant, a college or university must have received from the Foundation, during the 12 months ending March 31, a grant for basic research or for selected programs in science education. In applying for a grant the president of an institution need only submit a brief letter in which he pledges that the funds will be used solely for science. Once a year the institution submits a report indicating the purposes for which grant funds have been spent; appraising the results of their use; and accounting for the grant funds on hand at the beginning of the year, the funds expended during the year, and the funds to be carried over to the next year and merged with a later Institutional Grant.

The amount of each Institutional Grant is determined by applying a formula to the amount of the applicable grants an institution has received from the Foundation during the period April 1 to March 31. The formula used for computing the 1964 grants was: 100 percent of the first $10,000 of applicable grants, 10 percent of the amount from $10,001 to $1,200,000, 1 percent of the amount from $1,200,001 to $3,000,000 and 0.5 percent of the amount above $3,000,000, to a maximum Institutional Grant of $150,000.

In fiscal year 1964, Institutional Grants totaling $11,355,395 were made to 370 colleges and universities in all 50 States, the District of Columbia, and Puerto Rico. The grants ranged in amount from $1,400 to the allowable maximum of $150,000. Table 1 shows the distribution of Institutional Grants and recipients, by size of grant.

Reports received from colleges and universities, summarized in table 2, show a variety of uses of Institutional Grant funds: purchase of research and instructional equipment; improvement and expansion of laboratories and other scientific facilities; filling of gaps of science library shelves; provision of essential travel funds; investigation of

Table 1.—*Distribution of Institutional Grants for Science, 1964*

[Thousands of dollars]

Size of grants	Funds		Institutions	
	Amount	Percent	Number	Percent
Less than 2.5	$11	(1)	6	2
2.5 to 4.9	96	1	25	7
5.0 to 9.9	349	3	49	13
10.0 to 19.9	2,132	19	165	45
20.0 to 29.9	631	6	26	7
30.0 to 49.9	1,251	11	32	9
50.0 to 74.9	993	9	17	4
75.0 to 99.9	1,502	13	17	4
100.0 to 149.9	3,790	33	29	8
150.0	600	5	4	1
Total	11,355	100	370	100

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

Table 2.—Distribution of Institutional Grant Expenditures by Use, Fiscal Year 1963[1]

Use	Amount	Percent
Equipment	$1, 264, 730	40. 0
Facilities	338, 573	10. 6
Library resources	294, 283	9. 2
Project research	669, 023	21. 0
Salaries and stipends	346, 353	[2] 10. 8
Travel	94, 951	3. 0
Printing and publications	25, 902	. 8
Special projects	54, 568	1. 7
Reserve funds	97, 661	3. 1
Total	3, 186, 044	100. 0

[1] Latest year for which breakdown is available.

[2] Salaries are also included in certain other categories.

promising research ideas; payment of stipends of graduate laboratory and research assistants; support of publication of completed research papers; and initiation of special and interdisciplinary activities in scientific research and education.

The chief use of Institutional Grant funds was the purchase of scientific equiment. By far the largest part of the equipment expenditures was for nonexpendable items, none of which cost more than $10,000. Expenditures for facilities resulted in many improvements, among them new animal rooms, new and renovated greenhouses, a geophysical laboratory, semiprivate cubicles for graduate students in biology, and computation centers. The purchase of books and periodicals and the improvement of science library services was another important—and growing—use of the funds. Still another widespread need that was met by Institutional Grant funds was the support of research projects in their beginning stages.

Research funds provided by Institutional Grants frequently went to areas of science that campus scientists and administrators considered important but that did not gain much outside support. The strengthening of research in the social sciences was said to be the most important result of the Institutional Grant at one university. Often, too, the support of graduate students' research projects speeded up the completion of their doctoral degrees, and undergraduate student research assistants were encouraged to enter graduate work in science.

Research projects were occasionally designed to improve science teaching. Many institutions found Institutional Grant funds useful for the payment of travel expenses of their faculty to attend scientific meetings or to do research. Also, the funds frequently paid the travel expenses of distinguished scientists invited to lecture on the campuses.

GRADUATE SCIENCE FACILITIES

The dramatic expansion of science in this country has led to an acute shortage of laboratory facilities necessary for conducting basic research and for training future scientists. Both of these vital activities are carried out very largely in the graduate laboratories of our colleges and universities. These laboratories are used by faculty members, research associates, and graduate and postdoctoral students working on theses or other independent projects. While in the long run men are more important than facilities, the immediate limiting factor today in many fields of science and in many universities is in buildings and equipment. Moreover, an adequate and well equipped science facility contributes to economy of operation by minimizing waste of scientific time and talent.

Unfortunately, many graduate-level research facilities in the United States consist of old equipment, obsolete buildings, and critically overcrowded laboratories. The vast increase in research activity, the rapid pace of scientific progress, and the rising numbers of graduate students have caused available facilities to be stretched far beyond a reasonable capacity. The shortage of laboratories not only restricts the number of people who can do research and who can be educated in the sciences, but also restricts the kind of research that can be done.

An expansion of science facilities requires large financial resources that are not generally available to the great majority of educational institutions. The resources of our colleges and universities are already taxed to the utmost in keeping up with the expansion of the overall educational program. Consequently, few institutions can undertake, through non-Federal resources, the required expansion or upgrading of their graduate-level facilities.

After 2 years of consideration, the Foundation, in fiscal year 1960, initiated an experimental program offering financial support for the renovation or construction of graduate-level science facilities. The overwhelming institutional response attested to the urgent need for a program of this type. The Graduate Science Facilities Program was then established on a permanent basis by the Foundation in fiscal year 1961, the budget being increased from $2.1 million in 1960 to $8.5 million in 1961. Grants were made on a matching basis requiring the institutions to match each dollar of Federal funds with at least $1 of funds from non-Federal sources.

The need to expand the Graduate Science Facilities Program was further made evident by the President's Science Advisory Committee when it reported in December 1962 that, to meet national needs, it would be necessary to double the number of graduate students in engineering, mathematics, and physical sciences by 1970. To carry out an educational program of this magnitude, and to conduct the increased amount of research required for the Nation's scientific well-being, requires a marked expansion of science facilities. A study shows that all present funding sources exclusive of the Federal Government only provide educational institutions with 30 to 50 percent of their financial requirements for graduate science facilities.

The results of the study concerning science facilities requirements for the decade 1963–72 indicate the magnitude of the problem. Institutions of higher learning are considering facility needs totaling $10.7 billion. Of this amount, $6.8 billion will be required for research and graduate training facilities and $3.9 billion for undergraduate teaching facilities.

The Foundation has responded to the need for graduate science facilities by expanding its support program from $2.1 million in 1960 to $30.5 million in the 1964 fiscal year, a total of $96.2 million for the 5-year period.

Since its inception, the Graduate Science Facilities Program has received 1197 proposals representing requests totaling $291 million. Within the first year after the announcement of the program, a large number of relatively small requests (293) averaging $75,000 were received. These presented, by and large, requests for renovation and modest construction projects. Funds of $2.1 million were available to satisfy the $22 million total requested the first year. In subsequent years there has been a steady increase in both the annual total sums requested and the average amount requested, reaching during fiscal year 1964 an annual total of $109 million, with only $30.5 million available (28 percent of the demand). For the 5 years of the program, only one-third of the total requests for $291 million could be satisfied by Foundation expenditure of $96.2 million.

Requests are now averaging very nearly one-half million dollars. Currently 26 percent of the requests and 15 percent of the grants are for amounts greater than $500,000. The increasing size of proposals in recent years reflects a change in the proposed projects from renovation and small unidisciplinary buildings to new, larger, multidisciplinary structures. Requests for high-rise buildings are becoming more frequent as institutions coordinate their sciences and as they tend to conserve their land. This trend will no doubt continue.

The distribution of program funds among the various fields of science has closely paralleled the distribution of the requests. Within the broad divisions of physical sciences and life sciences, physical sciences facilities have received 60 percent, or $57.9 million of the $96.2 million total grant funds; life sciences facilities have received 40 percent, or $38.3 million. A more detailed distribution of facilities funds among the individual fields of science is depicted in figure 1. Here it will be seen that the fields of chemistry, physics, and engineering are the major recipients of program funds.

This past fiscal year has seen an increased interest in distributing all grants on a wider geographical basis. Since students generally attend

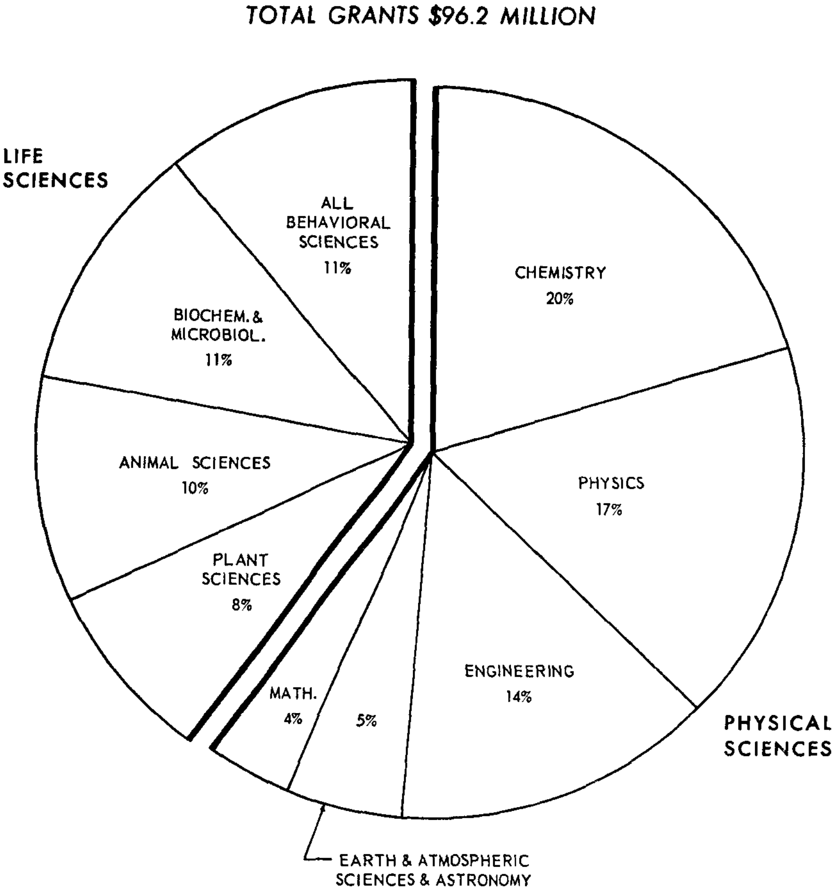


Figure 1.—*Percent Distribution of Total Graduate Science Facilities Grants by Field of Science, Fiscal Years 1960–64.*

universities located within a short radius of their home areas, it is necessary that educational institutions throughout the Nation be upgraded.

Although operating within carefully drawn limits of eligibility and merit, the program has resulted in wide geographical coverage. During the first 5 years of operation, the Science Facilities Program has placed grants in 152 institutions in 49 States and the District of Columbia. A list of the number of total dollars requested and total funds granted to each State through Fiscal Year 1964 is presented in table 3.

A few examples of recent grants will provide an idea of the diversity of projects to which the Graduate Science Facilities Program contributes support. Syracuse University was awarded a grant of $1,588,300 to help support the construction of a new physics building. The entire structure will cost more than $4.1 million, and the grant represents half of the cost of the portion devoted to graduate-level research and train-

Table 3.—*Cumulative Graduate Science Facilities Requests and Grants by State, Fiscal Years 1960–64*

State	Amount requested	Amount granted
Alabama	$1,253,100	$55,300
Alaska	891,000	765,325
Arizona	2,426,073	668,300
Arkansas	1,312,400	224,500
California	26,011,881	12,143,300
Colorado	8,850,500	2,111,550
Connecticut	9,791,620	1,358,737
Delaware	787,300	487,400
District of Columbia	1,873,739	659,550
Florida	8,919,150	2,535,425
Georgia	2,293,049	476,000
Hawaii	83,800	83,800
Idaho	299,100	6,700
Illinois	29,767,366	7,989,250
Indiana	6,678,658	2,007,950
Iowa	7,878,043	4,862,000
Kansas	2,475,392	726,925
Kentucky	1,196,584	43,800
Louisiana	765,188	141,800
Maine	179,800	8,750
Maryland	4,035,925	2,226,500
Massachusetts	18,705,615	8,061,890
Michigan	13,128,031	3,306,135
Minnesota	4,473,747	1,268,400
Mississippi	2,724,230	128,350
Missouri	10,158,090	2,301,350
Montana	75,100	29,800
Nebraska	2,288,100	613,650
Nevada	1,175,000	....
New Hampshire	1,628,150	1,257,450
New Jersey	6,347,733	2,481,500
New Mexico	2,171,230	645,350
New York	26,524,759	10,621,590
North Carolina	7,311,975	2,177,025
North Dakota	928,225	253,150
Ohio	5,273,605	1,870,200
Oklahoma	3,276,344	1,419,730
Oregon	2,034,390	1,053,925
Pennsylvania	17,251,929	4,070,795
Rhode Island	3,699,000	1,354,850
South Carolina	1,568,397	36,200
South Dakota	341,400	89,600
Tennessee	2,900,395	1,563,700
Texas	11,690,761	3,539,350
Utah	2,654,502	849,200
Vermont	259,700	45,000
Virginia	2,913,955	875,600

Table 3.—Cumulative Graduate Science Facilities Requests and Grants by State, Fiscal Years 1960–64—Continued

State	Amount requested	Amount granted
Washington	$5,470,117	$2,112,225
West Virginia	1,254,900	130,000
Wisconsin	13,550,387	4,464,500
Wyoming	1,114,350	3,100
Puerto Rico	13,600	....
Total	290,677,385	96,206,477

ing. The areas of basic research which will benefit from the new facility include high energy physics, solid state physics, and surface physics.

An example of support for a small renovation project is provided by a grant made to Montana State University. The old Law School Building had been assigned to the Department of Psychology, which proposed to convert a former mock courtroom into a laboratory for the study of processes involved in human creativity. A grant of $2,350 covered 50 percent of the total renovation costs of $4,700.

A large proportion of facilities grants are for less than half of the eligible costs, in which case the university "overmatches" the grant. For example, the University of Colorado has planned a complete new engineering center complex to cost $8.5 million. Of this amount, $4.7 million is the cost of the space devoted to graduate research and training. A grant was made in the amount of $1,325,000 representing a Federal contribution of 28 percent of the cost of the eligible portion, or 16 percent of the total cost. This facility will benefit mechanical, electrical, civil, chemical, and aerospace engineering, and exemplifies the trend toward large and expensive "complexes" housing a variety of sciences.

As can be seen from the foregoing, the Foundation's Graduate Science Facilities Program endeavors to support, selectively but with a minimum of Federal direction, proposals from institutions that on their own initiative are developing plans to solve their own particular problems. The process of selectivity in apportioning the Federal funds available is felt to be the strength of this program and a strong factor in encouraging excellence.

SUPPORT OF SCIENTIFIC RESEARCH

The National Science Foundation supports basic scientific research because of the importance of new scientific knowledge to our national welfare and security. The future strength of the United States depends, in substantial measure, on the effectiveness of today's basic research efforts. From its inception, a primary goal of the National Science Foundation has been to expand the scientific base on which our welfare and security depends. We are now witnessing the fruition of efforts begun in 1951 and intensified after Sputnik in 1958. Science in the United States is moving forward rapidly and this progress must be maintained. The needs are great, but so are the opportunities. Only Federal funds can adequately nurture this growth which is so essential to our future greatness.

Although the National Science Foundation is only one of a number of Federal agencies supporting basic research, it is the sole one responsible for considering whether the overall effort is adequate in magnitude, balanced as to subject matter, and of high quality. The goal of Federal support for basic research should be to provide U.S. scientists who are capable of doing creative work with the opportunity to do so.

Basic research activities are given direct support by the Foundation in a number of different ways. The best known and largest of these is the program of project research grants to institutions for the support of individual scientists or small groups of scientists. Most funds for this type of support are given for research at academic institutions, where research is closely allied with education, especially at the graduate level.

A closely related program provides specialized research facilities and equipment for groups engaged in significant basic research. Where the Foundation is responsible for a special national or international program backed by the Federal Government, basic research may be supported from funds especially appropriated for that purpose. In a few cases, the Foundation has established national research centers to provide major facilities or carry out large-scale research operations which cannot be undertaken by an individual university. The graduate science facilities program provides matching funds for construction or renovation of laboratory space and for general-purpose laboratory equipment. Most fellowship and traineeship awards are to individuals planning to carry out research at the graduate or postdoctoral level. Several other NSF science education activities also have major research components. These include funds granted for research participation by college and high school teachers and by undergraduate students. Basic research is not complete until the information obtained is disseminated and made permanently available through the scientific literature. Hence, most of our science information activities must be considered to be an integral part of the basic research process. Finally, it is estimated that about half of the funds provided for institutional grants for science is spent on the direct costs of doing research.

To summarize, basic research activities received over $250 million in fiscal year 1964 distributed as follows:

	Million
Project Grants and Contracts	$115. 0
Specialized Research Facilities	19. 7
National Research Programs	26. 2
National Research Centers	19. 3
Graduate Science Facilities	30. 3
Institutional Grants for Science (50 percent)	5. 7
Science Information Services	11. 1
Fellowships and Traineeships	30. 7
Research Participation	
College Teachers	1. 5
High School Teachers	. 8
Undergraduate Students	6. 1
Total	266. 4

It is clear from the tabulation given above that a much larger sum is spent on the broad task of obtaining new scientific knowledge than the amount actually awarded in the form of basic research project grants. Conversely, of course, much of the Foundation's direct expenditure on basic research is equally essential for education in science, especially at the graduate level.

BASIC RESEARCH PROJECTS

During fiscal year 1964, the Foundation took final action on 6,020 basic research proposals requesting $448 million, and made 3,105 grants in the amount of $115 million in response to these proposals. Thus, while some support was available for 49 percent of the proposals acted upon, only 26 percent of the total funds requested could be granted. In the 3,105 grants made, the $115 million actually provided was $149 million less than the amount requested. In other words, the average successful proposal was reduced by 56 percent when the grant was made. Some of this reduction was effected by cutting the duration of the request, typically from 3 years to 2 years, but substantial cuts were also made in the actual programs proposed.

Most of the project research support provided by the Foundation is in the form of grants to institutions for the support of individual scientists or small groups of scientists. Normally, a single grant provides support for only one phase of a continuing program which may extend over many years or indeed represent a lifetime of creative endeavor by the scientist. Continuity of support is exceedingly important to the scientists, especially if he is supervising the research of a series of graduate students who have entrusted their careers to him.

Foundation funds appropriated for the support of basic research projects are "no-year" funds. This means that the money provided in grants may be used for an indefinite period beyond the current fiscal year. In practice, the maximum grant duration provided by the Foundation has been 5 years. In order to provide continuity of support, we have endeavored to maintain an average grant duration of at least 2 years. The following table shows how the average duration of basic research grants has changed over the past 5 years.

Fiscal Year	*Average duration (years)*
1960	2.2
1961	2.0
1962	1.9
1963	2.2
1964	1.9

The decrease from 1963 to 1964 combined with a levelling-off in available funds has made it very difficult to maintain the degree of program longevity achieved in the past. This is especially true in the light of continued increases in demands for support of worthwhile research programs.

Of the 2,915 proposals declined or withdrawn during the year, at least half were for worthwhile projects which would have been supported if more funds had been available. It is very difficult to analyze the effect of a proposal being declined, but we know that in many cases the work proposed simply could not be started. Assuming that half the declined proposals should have been supported and that the average cut-back would have been 56 percent, about $40 million in additional funds would have been required to support the worthwhile projects which had to be declined. The average approved proposal was for $90,000 as against $60,000 requested in the average declined proposal. This means that many of the proposals declined were from smaller schools where an award would have given valuable impetus to the scientific program at the institution and where a declination almost surely had a most discouraging impact.

As shown in table 4, most of our basic research grant funds went to 288 academic institutions located in 50 States and the District of Colum-

Table 4.—*NSF Grants for Basic Research, Amount and Number of Institutions, by State, Fiscal Year 1964*

(Thousands of dollars)

State	Amount		Institutions supported	
	Total	College and university	Total	College and university
Alabama	$129	$75	4	3
Alaska	543	543	2	2
Arizona	1,335	1,268	4	2
Arkansas	276	276	1	1
California	17,640	16,494	48	30
Colorado	1,410	1,386	8	5
Connecticut	3,043	2,943	5	4
Delaware	333	333	1	1
District of Columbia	1,886	514	14	6
Florida	2,681	2,670	7	5
Georgia	751	733	5	4
Hawaii	952	813	2	1
Idaho	83	83	4	4
Illinois	9,051	8,950	19	16
Indiana	2,473	2,473	5	5
Iowa	1,545	1,540	5	4
Kansas	990	990	4	4
Kentucky	301	301	5	5
Louisiana	966	966	7	7
Maine	165	138	4	3
Maryland	2,349	2,324	6	3
Massachusetts	11,446	9,960	27	14
Michigan	3,783	3,687	12	8
Minnesota	1,841	1,782	3	2
Mississippi	97	86	3	2
Missouri	1,632	1,566	9	7
Montana	289	289	2	2
Nebraska	144	144	2	2
Nevada	177	177	1	1
New Hampshire	247	847	2	2
New Jersey	3,386	2,924	9	6
New Mexico	502	475	5	4
New York	12,392	11,303	50	27
North Carolina	2,590	2,492	7	5
North Dakota	81	81	2	2
Ohio	2,288	2,226	18	15
Oklahoma	475	468	4	3
Oregon	2,377	2,276	7	5
Pennsylvania	6,674	5,803	27	16
Rhode Island	1,212	1,174	4	2
South Carolina	174	174	3	3
South Dakota	102	102	3	3
Tennessee	812	796	8	7
Texas	2,701	2,533	14	12

Table 4.—*NSF Grants for Basic Research, Amount and Number of Institutions, by State, Fiscal Year 1964*—Continued

(Thousands of dollars)

State	Amount		Institutions supported	
	Total	College and university	Total	College and university
Utah	739	739	3	3
Vermont	118	118	1	1
Virginia	438	438	7	7
Washington	2,748	2,748	7	7
West Virginia	104	104	1	1
Wisconsin	4,062	4,045	5	3
Wyoming	40	40	1	1
Grand total	113,173	105,410	409	288

bia. Table 5 lists the 32 institutions which received basic research grants totaling one million dollars or more. Perhaps the most significant feature of this analysis is the increasing stature of the State universities as sources of fundamental scientific knowledge and trained scientists. Excellence in science is no longer a prerogative of a few privately endowed institutions, but has become a goal which more and more State institutions are achieving. In all such cases initiative at the State level has preceded and catalyzed the granting of Federal support. Of the academic institutions receiving over a million dollars, 15 were State institutions and 16 private. In the latter group are included a number of private institutions receiving substantial State support.

Outside of the academic community, about 120 nonprofit research institutions received research project support during fiscal year 1964. These included a wide variety of institutions ranging from the Woods Hole Oceanographic Institution to local museums of natural history. Practically all such institutions supported have close ties with the academic world, and in many cases provide specialized collections, as in the case of museums, or unique research opportunities which are essential to the progress of science. Most of the projects in these institutions are supported under programs in the biological sciences.

Table 6 summarizes the research projects program by subject categories. 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 1964, NSF 65–2.

The administrative burden within the Foundation of handling this number of research proposals is very large, and heavy demands are also made on the outside scientific community in the review process. Typically, each proposal is reviewed by about four outside reviewers. A reasonable estimate is that each review takes a minimum of one hour's time on the part of the reviewer. Thus about 24,000 man-hours of effort were invested by the scientific community in this process during fiscal year 1964, equivalent to over 10 man-years of full-time effort. In addition, a full-time staff of about 70 scientists in our research divisions has the final responsibility for evaluating proposals and recommending grant action.

Table 5.—*Institutions Receiving NSF Basic Research Grants Totaling at Least $1 Million, Fiscal Year 1964*

[Thousands of dollars]

University of California (Berkeley)	$4, 238
University of Illinois	4, 216
Harvard University	4, 141
University of Wisconsin	3, 830
Massachusetts Institute of Technology	3, 437
University of California (Los Angeles)	3, 408
University of Chicago	2, 901
Columbia University	2, 517
Stanford University	2, 464
Cornell University	2, 372
Yale University	2, 369
University of Washington	2, 296
University of Michigan	2, 266
Princeton University	1, 912
University of Pennsylvania	1, 880
Duke University	1, 801
University of Minnesota	1, 773
University of California (San Diego)	1, 617
Johns Hopkins University	1, 574
California Institute of Technology	1, 462
Pennsylvania State University	1, 418
Purdue University	1, 380
University of Texas	1, 282
University of Arizona	1, 232
University of Oregon	1, 176
University of Miami	1, 175
University of Rochester	1, 153
Northwestern University	1, 103
University of Colorado	1, 050
University of Pittsburgh	1, 033
Oregon State University	1, 012
Woods Hole Oceanographic Institution	1, 003

Mathematical, Physical, and Engineering Sciences

The scope of subject matter encompassed under this category is extremely broad ranging from basic research projects in the areas of man's physical environment (astronomy, atmospheric sciences, and earth sciences), to disciplines fundamental to these and to other sciences (chem-

Table 6.—*National Science Foundation Research Project Awards, by Field of Science, Fiscal Year 1964*

Field	Number	Amount
Biological and medical sciences:		
Developmental biology	106	$4, 110, 750
Environmental biology	140	3, 813, 900
Genetic biology	105	4, 433, 500
Metabolic biology	135	4, 555, 286
Molecular biology	210	9, 450, 569
Psychobiology	131	3, 588, 635
Regulatory biology	166	4, 581, 850
Systematic biology	287	5, 170, 000
General biology	21	1, 602, 475
Subtotal	1, 301	41, 306, 965
Mathematical, physical, and engineering sciences:		
Astronomy	76	4, 527, 884
Atmospheric sciences	59	4, 029, 125
Chemistry	305	10, 530, 550
Earth sciences	239	9, 384, 366
Engineering	386	12, 716, 441
Mathematical sciences	281	10, 042, 900
Physics	199	13, 071, 350
Subtotal	1, 545	64, 302, 616
Social sciences:		
Anthropological sciences	107	2, 699, 305
Economic sciences	48	2, 207, 164
Sociological sciences	60	2, 620, 307
History and philosophy of science	35	572, 800
Special projects and resources	9	1, 278, 600
Subtotal	259	9, 378, 176
Total	3, 105	114, 987, 757

istry, mathematics, and physics), and to the extension of these for man's utilization (engineering). The rapidly increasing numbers of scientists working in these areas have been stimulated to some extent in most recent years by the Nation's space program. Accordingly, while scientific merit is the principal criterion for support of research projects by the Foundation, it has been keenly aware of the assistance which many of the projects have afforded to the completion of the training of new scientists in these disciplines.

With hundreds of projects in widely differing sciences currently under support, it is difficult to provide even general descriptions in all areas.

Representative, and significant because of recent accomplishments, are the following:

Stars Near the Sun. Dr. Willem J. Luyten, University of Minnesota astronomer, has for many years been exploring the relatively near, relatively small stars. His method is based on the fact that all stars move with respect to one another, and those which are closest to earth appear to travel most rapidly. In order to pick out the apparently fast-moving (and therefore nearby) stars, Dr. Luyten first compared pairs of photographs of regions of the sky taken by the Harvard Observatory at times 30 years or more apart. In this manner Luyten has discovered 400 of the 500 known white dwarf stars, and finds that the fainter the star, the more of them there are in a given volume of space in the solar neighborhood. Only in the region of the sky near the sun can there be a check on the really faint stars, those with candlepowers ranging down to less than a thousandth that of our sun. (The stars making up the familiar constellations of the night sky are mostly giants in candlepower and, because they can be seen at great distances, appear fairly numerous.)

The current excitement in this research area derives from full utilization of the Palomar Sky Survey plates, a sky mapping job done about 10 years ago with the 48-inch Schmidt telescope on Palomar Mountain in California. The great light grasp and wide angle coverage of this famous astronomical camera, combined with the sharpness of the stellar images it produces, made the sky map an essential tool for observatories all over the world. Because of the excellent images and large scale of these Schmidt plates, Luyten recently estimated that if new photographs were made with this instrument, which reaches stars many times fainter than his previous work, it should be possible to find whether stars exist in the range of size down to that of the planets of our solar system. After a pilot program confirmed the power of the method, Luyten took on with NSF support the full task of repeating the more than 900 Palomar Survey plates.

The results have exceeded expectations. Examination of the first 30 plate pairs has revealed more than 12,000 nearby stars in apparent rapid motion, essentially all in a brightness range unreachable before. It now appears there may be as many as 350,000 stars in this category.

As in the earlier work, objects of unusual interest are already appearing. One star in the constellation Cetus may be considerably smaller than the moon if Luyten's distance estimate of 48 light-years is correct for this abnormally small white dwarf. It appears to be 100,000 times less luminous and 160 times smaller than a normal dwarf of the same color. Its diameter, roughly 1/1000 the sun's, makes it the first star found with a size under 1,000 miles—less than that of the planets and many of the satellites of the planets, yet hot enough on its surface to reveal its presence as a star. The density for this star would be 300 tons per cubic inch, more than 100 million times that of water.

Luyten has also found several moving red nebulae, small gas clouds with diameters between 100 and 500 times the distance of the earth from the sun, equal to 2 to 10 times the diameter of our planetary system. He suggests, "This is the same order of magnitude as the presumed diameter of the primeval nebula which developed into the solar system, even though the luminosities must average only $1/10000$ of that of the sun. Perhaps these nebulae are either still developing into solar systems or were "spoilt in-the-making."

The National Academy of Sciences at its spring 1964 meeting named Luyten as its Watson Medalist for his work over many years on the near frontier, crowned by the exciting results in his latest and largest project.

Cool Red Giant Stars. Infrared observations of cool red giant stars marked the second successful flight of Stratoscope II, a 36-inch balloon-borne telescope project of Dr. Martin Schwarzschild, Princeton University. Following an earlier flight of limited success (reported in the NSF 13th Annual Report), the outstanding achievement of this flight, November 26–27, 1963, indicated good progress toward the greater photographic capability planned for later flights.

Data gathered on the second flight showed that the atmosphere of cool, red, giant stars has a very large water vapor absorption effect in the infrared. The water vapor absorbs large sections of the radiation emitted by the stars, while permitting the remainder of the infrared radiation to pass through from the surface of the star to outer space.

This, in turn, means that the amount of water vapor present in the atmospheres of these stars must henceforth be taken into account by astronomers attempting to compute the atmospheric temperatures and the amounts of energy radiated from the stars.

Heretofore, prediction of physical conditions existing on these stars have been inferred from ground-based observations. Attempts to extend these ground-based observations from the visual wavelengths into the infrared have been severely limited because the absorbing effects of the earth's atmosphere at infrared wavelengths conceal the much smaller effects from the stars. Stratoscope II, floating at 80,000 feet, obtained data free from the effects of the earth's atmosphere.

Mira, a well known long-period variable star, was revealed to have especially large amounts of water vapor in its atmosphere—about the same amount in a unit cross-section of the star's atmosphere as in a similar column of the earth's atmosphere. Water vapor estimates resulting from the Stratoscope II flight ranged from the high revealed on Mira to a low of much less than one-tenth as much recorded on Betelgeuse. Excellent information was also obtained on the atmospheres of four other red giant stars—Mu Cephei, R Leonis, Rho Persei, and Mu Geminorum—showing their water vapor contents to lie between the maximum observed on Mira and the minimum detected on

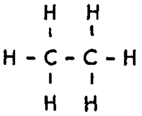
Betelgeuse. The increase in water vapor absorption was shown to follow the progression to later spectral types having cooler atmospheres.

From other observations made during the flight, the moon proved to be brighter in the infrared than in the visible region of the spectrum; excellent spectra of Jupiter confirmed the presence of absorption bands of methane and ammonia, the major constituents of the Jovian atmosphere. The amount of absorption due to interstellar ice grains was found to be below that predicted by theory, over the 2,000 light-year path to the star Mu Cephei.

Synthesis of Cubane. In organic chemistry there are certain types of basic chemical structures, or molecules, which are characteristic units of important classes of chemical compounds. Occupying a central position in these structures are carbon atoms, which can be attached to one another by mutually attractive forces, or bonds. On the periphery of the central carbon atoms, hydrogen atoms may be attached to the carbon atoms, to form "hydrocarbon" molecules.

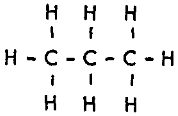
Two simple molecules of this kind are pictured below, where each carbon atom is designated by a C, each hydrogen atom by an H and each attractive force (or bond) by a dash (–).

Ethane



$$\begin{array}{ccccccc} & & H & & H & & \\ & & | & & | & & \\ H & - & C & - & C & - & H \\ & & | & & | & & \\ & & H & & H & & \end{array}$$

Propane

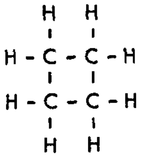


$$\begin{array}{ccccccccc} & & H & & H & & H & & \\ & & | & & | & & | & & \\ H & - & C & - & C & - & C & - & H \\ & & | & & | & & | & & \\ & & H & & H & & H & & \end{array}$$

Since the carbon atoms are arranged linearly, these molecules are called "open-chain" compounds, and fall into the general class of compounds designated by the term "aliphatic hydrocarbons."

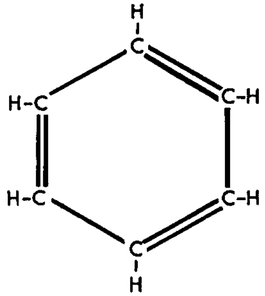
In another type of molecule the central carbon atoms are arranged in a ring. These are called alicyclic hydrocarbons, one of which is pictured below.

Cyclobutane



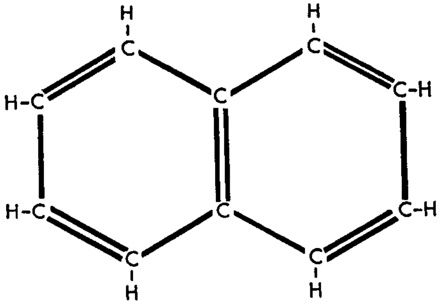
If the carbon ring contains six members, and each carbon atom has a single hydrogen atom bonded to it, it then attaches itself doubly to one of its carbon neighbors. An example is shown in the following diagram:

Benzene



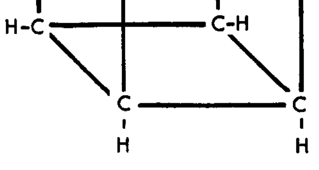
More complex arrangements are possible, such as the following:

Naphthalene



All of the compounds just mentioned are of great commercial and industrial importance. More complicated compounds which are of the same general type comprise a major portion of all the chemicals now used by our civilization. It is natural that chemists should be on the alert to discover, if possible, new types of molecules—that is, ones in which the carbon core is differently arranged—since these might then become the basis of a new system of compounds of academic and practical importance. A radically different type of carbon core is found in the following compound in which the carbon core atoms form a cube. This box-like or cage structure is unique in that it has a hole or cavity in the center.

Cubane



Organic chemists have made many attempts over the years to synthesize cubane. In 1961 H. H. Freedman, of the Dow Chemical Co., succeeded in preparing a compound that has a cubical core of carbon atoms, but in place of each single hydrogen atom shown in the diagram, there appeared a complicated subsystem containing six additional carbon and five additional hydrogen atoms. Because of its complexity it was not possible at that time to be sure of the exact structure of the new compound.

In June 1964, Philip E. Eaton, a 28-year-old chemist at the University of Chicago, completed the first successful synthesis of cubane, itself, in his research program supported by a Foundation grant. This work was described in the August 5, 1964, number of the Journal of the American Chemical Society and has attracted worldwide attention.

Eaton's discovery paves the way to an extensive study of the chemistry of box-like molecular structures. A number of chemists from U.S. universities have requested samples of cubane from Dr. Eaton, and an intensive study of its properties is underway.

It appears that potential practical applications may be found for compounds derived from cubane, particularly those in which each hydrogen atom (H) is replaced by a group consisting of one nitrogen atom and two hydrogens (the so-called amine group, NH_2). Two chemical companies have approached Dr. Eaton to discuss the possibility of obtaining compounds derived from cubane for testing as drugs to combat virus infections.

There is also a very good possibility that cubane compounds in which the hydrogen atoms have been replaced by atoms of bromine, chlorine, or iodine will have uses as agricultural chemicals. Derivatives of cubane-containing chlorine and oxygen may exhibit properties that will make them useful as pesticides, fungicides, and herbicides.

It is interesting to note that in his original proposal, on the basis of which the Foundation supported his work, Dr. Eaton did not discuss the synethesis of cubane. In conducting basic research it is usually not possible to predict at the start what significant achievements will be made or to know what practical applications may result.

Elementary Particle Physics. High-energy nuclear physics made startling progress during the fiscal year, with a major revision of the concept of elementary particles. The proton and neutron have long been known to be constituents of atomic nuclei, and could thus be considered as fundamental or elementary entities in nature. But with the ever-increasing multiplicity of particles resulting from high energy interactions, there seemed to be little order to the entire system of these particles. The only real information that physicists were able to obtain was that there existed a set of quantities that were conserved during interactions, and that some of the particles—the majority—interacted strongly with each other while others interacted only weakly. The strong interaction seemed to be the key to the forces which bind the atomic nucleus, and so this problem was of crucial interest. It is essential that any physical explanation of elementary particles be able to predict the general order governing the realtionships between these particles.

Two theories had been proposed to explain strongly interacting particles. One was the "Regge Pole" theory; the other consisted of a "group theory" approach which related the particles according to the symmetry of their properties. In both theories it was assumed that none of the particles now know might be truly elementary but that these particles were in reality energy states similar to the ground and excited electronic states of an atom. One important test of which of the two theories was superior lay in the prediction by the group theory approach of the existence of an undiscovered particle. This particle, called the "omega minus," was needed to complete a group of 10 of the particles related to each other by the theory.

The postulated omega minus particle was finally discovered in the spring of 1964 by a group of scientists at Brookhaven National Laboratory. Two of these scientists were NSF grantees from Syracuse University. The existence of the omega minus indicates great promise that the group theory approach may point the way to a complete physical understanding of the interactions between many types of nuclear particles.

Since the strongly interacting particles would now seem to be energy states of some underlying physical system, it is important to know the nature of their internal structure. Last year, J. Orear and G. Cocconi, under an NSF grant to Cornell University, reported continued successes with their experiment using the Brookhaven 30 BeV accelerator, in which highly accelerated protons were used to bombard stationary protons. The main purpose of the experiment was to probe deeply inside the proton in the hope of determining whether it is truly an elementary particle, or whether it has a structure in the sense that the hydrogen atom has a structure (with its nucleus and orbiting electon.) Some current theories speculated that the proton has a small, hard core surrounded by clouds of particles called mesons. The data resulting from their work is consistent with this interpretation.

Sharing Time on Computers. An exciting new development in computer science is the concept of computer "time-sharing." The usefulness of the computer for research purposes is often limited by the substantial time lag is not the result of slow operations of the computer itself, but because of the time required for one man to prepare for computer use after the previous user has finished. This delay particularly limits research that requires a large number of very short computer runs interspersed with human decisions.

One aim of research in time-sharing is to design hardware and programming systems that permit a large number of independent users, each with his own remote console, to communicate directly with a large central computer in such a way that to all external appearances each has at his complete immediate disposal a computer of sufficient speed, capacity, and flexibility to carry out his computations. There is general agreement that such a concept will lead to new areas of applicability of computers to scientific research.

The minimum equipment requirements for effective time-sharing have been recognized for some time, and computers are now becoming available with many of the desired features. Although important research aimed at developing improved "hardware" remains, at the moment the major effort is concentrated on the development of effective operating systems. These are extremely complex master-control programs for the computers, whose purpose is to supervise the scheduling of working programs in such a way that each of a large number of programs has control of the computer for a brief interval of time every few seconds or so. Thus, for example, if 20 users are simultaneously requesting the machine, the master control program might allot each one in turn 1/10 of a second during which time the computer might execute 10,000 to 100,000 elementary operations. In this way each user might have access to the results of that much computation every 2 seconds.

Two of the leading centers for time-sharing research are Massachusetts Institute of Technology and Stanford University, where investigators, with partial support from the Foundation, have developed workable operating systems. These systems were demonstrated at the annual meeting of the Association for Computing Machinery in August 1964. Further outstanding work is being done at Dartmouth University and Carnegie Institute of Technology on machines that were partially supported by the Foundation's computer facilities program.

New Tool for Chemical Engineering Research. A major contribution to scientific progress in the last half century has been the realization that chemical reactions occur as a series of very definite steps. Even relatively simple reactions (e.g., the formation of water from hydrogen and oxygen), are made up of several steps, each of which involves very short-lived elementary reactions of highly reactive intermediates. One important class of such intermediates is termed free radicals. By using the techniques of electron spin resonance (ESR) spectroscopy (an instrumental technique developed since World War II) for the study of free radicals, the scientist is able to obtain information concerning the structure and properties of these reactive intermediates.

Robert C. Reid and Charles G. Hill, of the Massachusetts Institute of Technology, used an ESR spectrometer to study the reaction at a temperature of 77° K (−320° F) of gas-phase hydrogen atoms with a solid film of propylene. The propylene was deposited as a thin film in the resonance cavity of the ESR spectrometer. Hydrogen atoms produced by microwave electrical discharge were allowed to contact the propylene in both flow and diffusion systems. The concentration of hydrogen atoms in the resonance cavity was measured during the course of the reaction with the ESR spectrometer. From this information it was possible to construct a model of the intermediate reactions leading to formation of propanes and other end-product compounds.

This study marks the first time that ESR spectroscopy has been applied to a determination of the kinetics of the reaction between a gas-phase free radical and a solid substate. In fact the use of ESR spectroscopy to study the kinetics of gas-phase, free-radical reactions is still in its infancy. This research demonstrates the feasibility of using ESR techniques to study an entirely new class of reactions, i.e., gas-solid reactions involving free radicals.

Biological and Medical Sciences

The ultimate aim of fundamental research in the biological and medical sciences is the understanding of life in all its forms. All living organisms—plant and animal, microscopic and macroscopic—are studied by the life scientist. Life processes take place on many levels of complexity, from molecules, which form the basic building units of living systems, through the cell, and on to whole populations of organisms interacting with each other and with their external environment. Biological research encompasses a wide range of approaches from laboratory experimentation to field studies of organisms in their natural habitats.

The Foundation supports research in all areas of biology. A comprehensive review of the projects supported during the past year would reflect the multiplicity of approaches to a number of fundamental questions posed by scientists in their quest for a more complete understanding of the living world. To highlight some of these problems, selected studies are described below.

Research has shown that the fundamental processes of all cells are essentially the same, whether the processes take place in plants, animals, bacteria, or viruses. The biologist can therefore select from the myriad of life forms those organisms that give most promise of providing solutions to the problems that interest him.

Some biologists whose work is described below use viruses and bacteria to determine the chemical structure and mode of operation of the nucleic acids in the transmission of hereditary information; others use sea urchin eggs to study the phenomenon of fertilization and development; still others use the embryonic chick to investigate the differentiation of cells into their specialized groups, fish to study the aging process, the bat for research on sensory systems, birds for behavioral studies, and all types of organisms for classification and discovery of evolutionary relationships.

A BASIC PROBLEM OF BIOLOGY is how hereditary information is transmitted from generation to generation and how this information is translated into the numerous cellular activities which characterize the living organism. Much of the knowledge which is leading to the solution of this problem has been gained through the study of the nature and behavior of two classes of compounds found in all living organisms—nucleic acids and proteins. The nucleic acids are the carriers of 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. The character of the individual cells in turn is responsible for the nature of the whole organism.

Deoxyribonucleic acid (DNA), one kind of nucleic acid, is found in the nucleus of every cell. It has a flexible ladder-like structure twisted in the form of a double coil composed of segments called nucleotides which consist of a sugar, a phosphate, and nitrogen-containing bases. The uprights are made up of sugar and phosphate, and the rungs, of the base pairs. It is the sequence of the nucleotides which provides the code for storing and transmitting the genetic information. Another kind of nucleic acid, ribonucleic acid (RNA) found in the cytoplasm outside the nucleus, controls the manufacture of proteins. The DNA, acting through RNA, determines the structure of the proteins being made. The specific structure of each type of protein is fixed by the particular sequence of 20 amino acids which are the building blocks of which all proteins are composed.

During the past year NSF-supported projects have contributed substantially to the impressive progress that has been made in molecular genetics. For example, a study by Charles Yanofsky, of Stanford, has resulted in experimental confirmation of the widely accepted concept that the sequence of amino acids which define a specific protein is determined by the sequence of nucleotides in the DNA molecule. He was able to determine the sequence of amino acids in a long segment of a bacterial enzyme and to make a detailed genetic map of the gene that determines the specificity of this protein. By comparing the chemical analysis of the protein with the genetic analysis of the gene, specific genetic alterations (mutations) have been correlated with particular amino acid substitutions in the protein.

Gobind Khorana and his group, at the University of Wisconsin, have developed chemical techniques which permit the assembly of specific DNA bases in known sequences. From these DNA fragments, synthetic RNA's can then be made whose base sequences are also known. Using these RNA's, proteins can then be synthesized whose amino acid sequences can be determined. In this manner the specific amino acid sequence can be related to the original base sequence in the DNA, thus determining the genetic code. This new approach promises to overcome most, if not all, of the decoding problems.

Recent experiments indicate that the genetic code is probably the same in all organisms. This has been demonstrated by mixing components from different sources in test-tube experiments and observing that the coding is not altered. For example, the protein-making machinery can be isolated from rabbit cells and mixed with the genetic information isolated from bacterial cells. The result is that bacterial proteins are made just as if the protein-making machinery of bacteria were used.

ANOTHER FUNDAMENTAL PROBLEM OF BIOLOGY relating molecular genetics to embryology is the means by which the fertilized egg develops into a mature organism composed of billions of cells of many different kinds. Recent advances in genetics have made it possible to obtain a better understanding of the manner in which the different cell types originate and of the underlying molecular mechanisms responsible for these differences.

As previously noted, cell types are differentiated from one another not only by their structure, but also by the specific proteins they manufacture. Skin cells manufacture keratin; stomach cells, pepsin, etc. Cellular differentiation may therefore be defined as the acquisition of the ability to manufacture a specific protein which determines, in part, the structure and function of a cell.

Clifford Grobstein and his associates, at Stanford University, have been studying the differentiation process in the mammalian pancreas and have discovered that the formation of pancreatic tissue depends on an interaction between two different tissues, an epithelium and a mesenchyme. The epithelium will not begin to differentiate into pancreatic tissue until it receives a chemical signal from the mesenchyme. Even before the pancreas could be recognized from its structure, it was possible to demonstrate the appearance of the pancreatic enzyme amylase, a protein characteristic of pancreas tissue. More recent experiments have shown that the control of this process is at the level of the gene. This supports the hypothesis of cell differentiation relating the synthesis of cell-specific proteins to the "turning on" of a gene.

Eugene Bell and his colleagues, at the Massachusetts Institute of Technology, are studying feather production in chick embryonic skin. The characteristic protein of the feather is keratin. Because the cells that differentiate into feathers fill up quickly with keratin at a very late stage in the development of the feather, these scientists reasoned that the genes controlling the making of keratin must somehow be regulated to make a lot of keratin in a short time. They discovered that the genes involved are formed early in the feather's development and established the protein-synthesizing machinery (RNA). Much later the genes activate the machinery resulting in the rapid build-up of keratin. Related studies by Aaron Moscona, of the University of Chicago, involve the retina of the chick eye characterized by a specific enzyme which reaches high levels of activity during development. The conclusion was the same, that cell differentiation reflects the activation of a specific complex of genes in different tissues.

When during development of an egg are the controlling genes "turned on"? Several NSF grantees are studying this problem in the sea urchin—Albert Tyler of California Institute of Technology, Paul Gross of Brown University, Fred Wilt of the University of California (Berkeley), and Ray Iverson of the University of Miami, among others. Immediately after fertilization, many eggs exhibit a rapid increase in their ability to synthesize proteins. Does this increase indicate the "turning on" of the genes of development? Current research, coupled with evidence already available, suggests a remarkable phenomenon—the mature, unfertilized egg contains the stored information for synthesizing the essential proteins of early development. This information presumably was introduced into the cytoplasm of the egg during its maturation in the ovary. At that time some few genes were active and the necessary machinery for synthesizing the proteins needed for cell growth and replication was stored in the egg. Early development, leading to the production of a large number of undifferentiated cells, does not require the immediate intervention of genes. However, before the cells produced undergo their respective differentiation, the genes responsible for the characteristic protein-specific patterns must be "turned on."

NOT ONLY IN THEIR DEVELOPMENT, but in all functional activities, living organisms characteristically exhibit a high degree of order. Underlying these ordered processes are regulatory mechanisms operating at all levels from the complex decision-making processes in the central nervous system, through the reflex responses, down to the functions of the individual cells. This includes the manner in which the organism obtains and utilizes the energy essential to carry on its vital processes, as well as the biochemical reactions involved in the building up or breaking down of the substances of cells and organisms. Much of the orderliness in living systems may be attributed to the behavior of proteins.

Practically all chemical reactions taking place in the living organism require enzymes. Enzymes are proteins that regulate the rate at which these reactions take place. Each enzyme controls one and only one specific reaction. For example, the food we eat—the fats and carbohydrates which provide energy and the proteins which provide the amino-acid building blocks which the body needs to reassemble in the form of its own proteins—is digested by means of enzymes.

Research is now underway to determine what gives an enzyme its catalytic power and to understand the relationship between the small part of the surface of a large enzyme molecule that is the active site and the remainder of the molecule. Studies on three different enzymes seem to answer these questions. Kenneth Walsh of the University of Washington found that two digestive enzymes produced by the pancreas, chymotrypsin and trypsin, have completely different sequences of amino acids in their structure, but contain the same amino acids at their active sites. The problem now is to determine why these two enzymes which are so alike in their active sites have different specificities. Edward Fisher and his colleagues, also of Washington, are working with another enzyme, phosphorylase, which triggers the first step in the conversion of glycogen (the form in which the body stores sugar) to glucose (the form in which the body uses it). They have identified the active site which consists of 14 amino acids. This site is unique in that it can perform opposite reactions; it can either take on or give up a phosphate. This behavior of the enzyme is related to its structure which can evidently assume two characteristic forms. Klaus Hofmann, of the University of Pittsburgh, also working with enzymes has partially synthesized ribonuclease and has determined the active site on the molecule.

Control of biological phenomena does not always require the direct mediation of proteins. Illustrative of research being performed on regulatory processes at the nonmolecular level are studies on the role of the endocrine system in the aging process. O. H. Robertson, of Stanford University, is studying Pacific salmon, a species which always dies shortly after spawning, an almost unique phenomenon among vertebrates. He observed that, by the time of spawning, the pituitary gland exhibits greatly increased activity and has increased in size. Such activity causes degenerative changes in many of the organs of the salmon. To determine if these degenerative changes which lead ultimately to death could be inhibited, spawning was prevented by castration. The noncastrated salmon all matured and died in their fourth year, while the castrated salmon continued to live and keep their juvenile appearance until the seventh year when they began to show evidence of senility. These results indicate that it is the maturation of the gonads (sex glands) rather than the loss of gonadal substances at spawning which initiates the process leading to ultimate deterioration and death, and that the degenerative alterations characteristic of spawning salmon represent an acceleration of the aging process.

The means by which man perceives colors is also a biological process of great interest. Only in the last year has it become possible to identify the basic molecular components involved in color perception—the red, green, and blue pigments. George Wald and his colleagues at Harvard University after years of extensive study have been able to demonstrate the presence of each of the pigments. Using a new microspectrophotometer developed in their laboratory, these investigators were able to measure precisely the minute responses of the light-sensitive pigments contained in the cones—very tiny receptors found in the retina of the eye. Identification of these three pigments makes possible an explanation of color blindness. It could be caused by the lack of one of the pigments or by a mixup in signals in the brain where two differently pigmented colors blend their responses (as does a painter to obtain secondary colors) to produce the entire natural range of color. It is interesting to note that E. F. MacNichol, Jr., and W. B. Marks, of Johns Hopkins, have been working independently on the same problem and have obtained results which agree with Wald's.

FINE CONTROL OF BIOLOGICAL SYSTEMS and an expression of vastly complex order and sensitivity to minute changes in environment surrounding them is illustrated in the structure and function of the nervous system. Behavior of biological systems is an area of major importance receiving the attention of life scientists, ranging from the geneticist to the psychologist.

Behavioral studies deal with the organism as a whole—how it receives information from the surrounding environment, how it assimilates this information, and how it initiates a response. Studies deal with sensory functions, learning and memory, problem solving and thinking, motivation and emotion.

Research on the capacity of the central nervous system to receive, process, and use sensory information from the environment is underway in the laboratory of Donald A. Griffin of Harvard University. He regards the abilities of bats to navigate and catch insects by echo-location as indirect evidence that their relatively small brains are capable of resolving many details about their environment through auditory analysis of echoes. The bat produces short pulses of very-high-frequency sound. Any object in the field of this sound reflects the sound, producing an echo that the bat uses to locate the object in space. The analysis of echoes is a very rapid process, in fact so rapid that an insect is often detected and captured in less than 1 second. Recent experiments have shown that certain fine discriminations are possible. One type of bat can distinguish by echo-location between insects tossed into the air and small discs that return very similar echoes. Experiments with a fish-catching bat have revealed ability to distinguish between small objects at the surface of water.

Research during the past 25 years has illustrated the importance of a continuing study of the behavioral capabilities of such animals as well as the underlying neural mechanisms. In 1939 it seemed almost incredible that echo-location existed at all. In 1949 it appeared reasonable that bats could locate and avoid stationary objects, but not that they might use their natural sonar systems to catch small flying insects. By 1959 it had become clear that they do just that, with great speed and precision. The recent evidence that they also make fine discriminations among objects points to the need for systematic exploration of performance capabilities.

The relative roles of inheritance and learning in animal behavior is also of great interest. Peter Marler and Mikawo Tamura, of the University of California, Berkeley, have recently examined the developmental basis of vocal behavior in a group of sparrows, finding clear evidence for the role of cultural transmission in the maintenance of normal patterns of singing behavior. They report that dialects are very clearly marked in the song of the male in a particular group of sparrows, so that separate populations can be characterized by certain properties of the pattern as revealed in sound spectrograms. Full song develops at about 7 or 8 months of age. If young birds are captured at an age of 1 to 3 months in the area where they were born and are then brought into acoustical isolation in the laboratory, they develop normal song dialect. If, however, they are taken from the nest at an earlier age of 3 days to 2 weeks—raised by hand and kept in acoustical isolation—they come into full song at the appropriate time, but the songs are abnormal in several respects, and characteristics of the local dialect are lacking. When hand-raised birds are placed alone in acoustically insulated chambers and allowed to hear the normal song characteristic of their group through a loud speaker at ages up to 2 months, they will subsequently produce a fair copy of it.

Several other lines of evidence support the interpretation that the dialect characteristics of this species are transmitted by tradition from the adults of one generation to young of the next.

ORGANISMS GENERALLY EXIST as members of separate populations. These populations exhibit fluctuations in their structure and composition and through many millions of years exhibit profound changes. Such evolving populations lead to the establishment of a wide diversity of populations of organisms. The naming and classifying of life forms in a logical, systematic fashion is basic to all other biological activity. Biological research is incomplete unless the identity of the organism is known with certainty. Each organism, whether it be a single-celled amoeba, a giant centuries-old redwood, or a human being, is a reasonably distinct entity and is related to all other organisms—living or fossil. To achieve these classifications many research studies are carried out ranging from description and cataloging to highly complex testing and interpretation of evolutionary processes using the latest techniques of molecular biology and computer technology. The following examples give an idea of the diversity of the subject matter being investigated.

Of special interest are the relationships that exist between organisms. Every visitor to the zoo wonders, as he watches the antics of the caged monkeys and apes, whether the relationships between the observer and the observed is really so close after all. Study of external features and behavior alone fails to provide really convincing evidence of the true interrelationship between monkeys and apes, and apes and man. Morris Goodman, of Wayne State University, has asked himself this age-old question, but in a new way. He reasons that because of the intricate composition and distinctive nature of protein molecules, there is no likelihood that unrelated organisms could possess similar proteins solely by chance. Therefore, any similarity indicates a relationship. He showed that blood proteins from gibbons, orangutans, chimpanzees, gorillas, man and other members of the family Hominidae, show varying degrees of similarity. The proteins, when subjected to appropriate treatment and then exposed to a series of electrical fields, tend to migrate differentially to form distinctive two-dimensional patterns. The results reveal, that as far as blood proteins go, the apes that evolved in Africa—the chimpanzee and gorilla—are far more closely related to man than are the orangutan and gibbon of Asian origin.

The commonplace white potato (*Solanum tuberosum*), a New World plant, is daily food for millions of people, yet its exact origin, identity, and evolutionary relationships are still to be exactly determined. It is the problem of the systematist to decipher its genealogy. The problem has been a complex one—first to learn what wild tuber-producing species exist and which of these have most likely been involved in the ancestry of the numerous cultivated forms of the modern white potato. A botanical survey of wild potatoes in the mountains of Middle and South America involving field studies, collection of material, and the ultimate detailed description of all potato species found throughout the natural range of these plants is the first order of business in such taxonomic research. Through NSF support a major monograph on the potato based mainly on morphological data has now been published by Donovan S. Correll of the Texas Research Foundation. Using Correll's taxonomic treatment as a very necessary platform, another scientist, Hugh H. Iltis of the University of Wisconsin, is now conducting more refined biosystematic research involving modern population concepts in which the study of genetic and ecological behavior are emphasized. The need for such continuing research is due to the complex natural hybridization which was found to exist among species of potato. His investigation will permit analyses of natural and artificial hybrids, and may make it possible to determine exactly how the races of modern cultivated potatoes have come into being through evolutionary processes.

ALL ORGANISMS LIVE IN AN ENVIRONMENT whose fluctuations disturb the well-balanced mechanisms responsible for their ordered activities. Further understanding of the whole organism involves studies of the effect of these environmental influences on the organism. Such studies are concerned not only with the relationship of various physical and chemical factors to organisms, but also with the relationships of one organism to another or a population of organisms to other populations.

A study of the factors which control productivity of a lake is a typical example. The supply of nutrients received from regional drainage and the geological age of the lakes and their depth is of great importance in this control. The history of certain large lakes which have received mass fertilization in the form of effluent from sewage treatment has shown that their character changed more rapidly than would be expected on the basis of natural aging. W. Thomas Edmondson, University of Washington, has been examining the striking changes in the character of Lake Washington, which has been receiving nutrients in the form of treated sewage. The increase in organic material has resulted in greater plankton blooms. Suspension of sewage dumping into Lake Washington will remove a major source of nutrients and should reverse the present rapid developments in the lake's character. This presents an unusual opportunity to learn more about the relation between changing nutrient supply and productivity in lakes.

Other studies are concerned with similar processes in the ocean. Although the existence of the nitrification process in coastal waters has been demonstrated, there has been no proof until recently that nitrifying bacteria live in the open sea beyond the continental shelf. Nevertheless, nitrate must be regenerated because it is constantly being used as a source of nitrogen by plants in the ocean. Bostwick Ketchum and Stanley W. Watson, of the Woods Hole Oceanographic Institution, have isolated the first nitrifying bacterium from the ocean, and have characterized this bacterium, both morphologically and physiologically. The biochemical pathway by which this organism oxidizes ammonia to nitrite has also been determined. Our knowledge of the complexities of the food chain in the sea from organic material to small organisms to fish has, therefore, been further extended.

Social Sciences

An important corollary to basic research in the physical and life sciences is precise scientific work in the social sciences. Understanding of man in relation to other men as individuals, groups, and nations—the domain of the social sciences—has not kept pace with man's knowledge and mastery of the physical universe, and is urgently needed in a world of increasing populations, emerging nations, and growing tensions. Valid knowledge of human behavior, a subject about which there are many unscientific opinions, prejudices, and misconceptions, can only be obtained through objective research methods. It is to such basic research investigations that the Foundation lends support.

Basic research in the social sciences is interpreted as meaning research on problems that can be studied by methods that will yield independently verifiable results and that will produce results with general implications, rather than findings relevant principally to a particular time, place, or event. The Foundation supports research designed to elicit the scientific understanding of social processes and behavioral phenomena, but not studies designed to endorse particular social policies or to promulgate solutions of specific social problems.

The primary areas of social science support are cultural and physical anthropology, archaeology, demography, economics, geography, linguistics, political science, psychology, sociology, and the history and philosophy of science.

However, the disciplinary identification of the proposer does not enter into the judgment of a research proposal. In all instances proposals are judged primarily in terms of one criterion: the potential contribution of the research to basic science. The investigator is left free to concentrate on questions that require new data, the development or improvement of method, or the formation of theoretical models as a guide to empirical inquiry, and is free to choose any methods of investigation, including quantitative, experimental, and other techniques, as long as they are scientific and appropriate to the projected study.

ALTHOUGH EXPERIMENTAL METHODS are used to some extent in the social sciences, frequently such methods are technically or financially infeasible. To compensate, social scientists often can use other devices and opportunities for observing social behavior under "real life" conditions in the hope of being able to identify and measure the varying relationships among the most important factors. A fair proportion of the Foundation's support for the social sciences goes for projects of this nature.

For example, changes in the social environment which are unusually rapid—even catastrophic—sometimes provide productive opportunities for adding to scientific knowledge. The public reaction to the shocking assassination of President Kennedy was studied immediately after the event, and the data that are now being analyzed are expected to contribute to our knowledge of both individual and group behavior.

A more pleasant, but nevertheless rather sharp environmental change was the tax cut enacted by Congress in the spring of 1964—one of the largest reductions of this kind in history. Whatever its effects on the Nation may prove to be, the change provides an excellent laboratory-like opportunity to study the reactions of the public to substantial changes in available income. How consumption and saving-investing patterns respond to the tax cut may allow insight into behavior relevant not only to fiscal processes but also of broader social and economic significance.

Another group of research projects which were initiated in response to a sudden event was that created by the Aswan Dam project. Here it is important to seize the last opportunities for archaeological exploration of the reservoir area before it is inundated. Work is underway in salvaging the prehistoric and protohistoric archaeology of this area located in Egyptian and Sudanese Nubia. Although only partial and preliminary results are available at this time, it is clear that a detailed outline will emerge of the entire span of man's occupation of Nubia from the hunting-gathering culture of the Lower Paleolithic through successive periods of increasingly more complex culture to the agricultural societies of the Neolithic and historic periods. Already discovered is the extraordinary fact that until the Upper Paleolithic the drainage pattern of Nubia was quite unlike the present, the Nile as we know it having come into existence only about 35,000 years ago. Simultaneously, the biological characteristics of the human population of Nubia are being investigated over the last 10,000 years. A major discovery in this context is that the Nile valley supported a hitherto unknown and highly aberrant population during the early Neolithic: one with low foreheads, heavy supraorbitals, massive jaws, and other traits uncommon in present-day man.

AMONG THE MOST IMPORTANT FEATURES of our contemporary world are the rapid alterations being brought about by the impact of Western culture on primitive peoples and the industrialization of underdeveloped countries. Economic, political, and social changes abound as movements toward nationalism intensify over the world. Old tribal structures give way to more modern political units. Traditional social and economic organizations are adapted or abandoned. New patterns of behavior and social organization appear, often differing as much from the Western ways which induce them as from indigenous customs. Social scientists find in these changes an opportunity to create and test generalizations about human social behavior. Typical of studies in this are those dealing with: adaptation of native New Guinea societies to administrative control, the impact of the modern national economy on the traditional market system of Mexico, a test of some theoretical propositions about the social forces which may account for the persistence of more than one language in certain countries, and an investigation of the relation of selected social and economic variables to political organization in countries throughout the world. Such contemporary culture changes as the urbanization of Yugoslav peasant communities and the commercialization of an isolated Tyrolean mountain village are also being studied.

AMONG ARCHAEOLOGICAL PROJECTS supported by the Foundation, that of the Tehuacan Valley is of special interest as an example of Middle American civilization. Since 1961 intensive study has been carried on in the Tehuacan Valley, 150 miles southwest of Mexico City, by the R. S. Peabody Foundation for Archaeology. The study is providing a record of the cultural history and growth of the region covering a continuous period of 12,000 years, virtually unmatched in any other area of the world. Archaeological reconnaissance resulted in the discovery of 392 sites, ranging from small temporary camps to large city ruins. A total of 750,000 specimens were uncovered and cataloged. At 12 sites, major excavations were undertaken. In the caves, owing to the extreme aridity of the floors, foodstuffs, feces, and other normally perishable human remains were preserved. Together with the artifact record, these have made possible an unusually complete reconstruction of the way of life of the ancient Tehuacanos. The findings have also yielded a large body of information about subsistence practices, food habits, climatic change, the size of the basic social groupings, and even the annual migration cycle of the prehistoric valley population. The information from these caves, the archaeological findings from open camp, village, and town sites, and the large series of radiocarbon dates, although not yet fully analyzed, have produced as complete and detailed a chronology of cultural development as any in the world.

AN NSF-SUPPORTED RESEARCH PROJECT in social psychology now underway has published initial results which are of considerable popular interest. The project conducted by the National Opinion Research Center of the University of Chicago in 1963 was a nationwide study into the prestige attached to occupations. The same ground was covered as in a 1947 survey so that changes in attitude over the post-World War II period could be measured.

Results indicate that the scientific occupations have risen sharply in public esteem, while political occupations in general have lost prestige. The sharpest drop was experienced by bankers who fell from 10th in 1947 to 24th in 1963. A listing of top-ranked occupations in 1963 and 1947 follows. The same number indicates a tie in rating.

Occupation	1963	1947
U.S. Supreme Court Justice	1	1
Physician	2	2
Nuclear physicist	3	18
Scientist	3	7
State Governor	5	2
Government scientist	5	10
Cabinet member	7	4
U.S. Congressman	7	7
College professor	7	7
Chemist	10	18
Lawyer	10	18
Diplomat	10	4
Dentist	13	18
Architect	13	18
County judge	13	13
Psychologist	16	28
Director, large corporation	16	18
Mayor, large city	16	6
Minister	16	13
Department head, State government	20	13
Airline pilot	20	24
Priest	20	18
Civil engineer	20	23
Banker	24	10
Biologist	24	28

NATIONAL RESEARCH CENTERS

The national research centers maintained by the Foundation are capital research facilities that are deemed essential to the Nation's basic research effort. Each center plays a vital role in the development of a particular area of science by creating urgently needed observational or research facilities for use by qualified scientists from all parts of the country. The facilities are also used by staff scientists engaged in research programs appropriate to each of the centers.

There are now four such research centers—each managed by independent nonprofit corporations composed of confederations of universities. They are: National Radio Astronomy Observatory (Green Bank, W. Va.), managed by Associated Universities Incorporated (AUI); Kitt Peak National Observatory (Tucson, Ariz.) and Cerro Tololo Inter-American Observatory (Chile), both managed by the Association of Universities for Research in Astronomy, Inc. (AURA); and the National Center for Atmospheric Research (Boulder, Colo.), managed by the University Corporation for Atmospheric Research (UCAR).

As is the case for the national research programs, the stimulus for the establishment of a national center comes from the scientific and academic community when its members are in agreement that a new major facility is needed to expedite progress or to remove deficiencies in some specialized field of science. The National Academy of Sciences-National Research Council, the appropriate scientific societies, as well as key Government officials have all, at times, participated in the discussions with the Foundation which led to the initial establishment of these centers. The highly successful national laboratories founded and funded by the Atomic Energy Commission provided NSF with valuable precedents and guidelines.

The Foundation has proceeded with caution in establishing the national research centers. The most obvious reason is that such centers are, by nature, expensive to build and operate. In some educational and research areas the extension of Foundation support is used as a means of stimulating activities whose support and growth, once they are established, would be taken over by other agencies—State or private. However, in the case of the national research centers, it soon became obvious that only the Federal Government was capable of supplying the necessary capital and operating funds. The creation of a center implied, therefore, an indefinitely continuing special commitment to that particular field of science. Hence centers are created only in fields where the need has been strongly established.

A second major reason for caution is the determination on the part of the Foundation that national research centers should supplement and not replace its programs in support of education and basic research in those fields. A corollary consideration is that the creation of a national center usually brings about a substantial increase in the allocation of Foundation resources to the field of science with which the center is identified. Such an action, therefore, must be considered within the always difficult and sometimes controversial context of the allocation of the limited resources of the Foundation among types of activity and among fields of science.

After giving careful consideration to these points, the Foundation adopted a general policy only to support "large-scale basic scientific facilities when the need is clear and it is in the national interest, when the merit is endorsed by a panel of experts, and when funds are not readily available from other sources." This action was a direct consequence of extensive investigation of the need for improved observational facilities for use by the Nation's optical and radio astronomers. It led to the establishment of the national astronomy centers. Soon thereafter, in response to urgent need, the support of national centers was extended to the atmospheric sciences with the creation of the National Center for Atmospheric Research.

Although it has long been recognized that the combination of basic research with the education of graduate students has almost always produced the best climate for both, the centers would, of necessity, be places where the educational part of the process would be strongly subordinated. It was felt that if the majority of the scientists on the governing boards of the centers were also representatives of universities with vigorous programs in the same fields, the scientific programs and facilities would be managed so as to best complement the well-established activities of the universities. Management by groups of scientists and administrators drawn primarily from the universities would help to maintain the informal but efficient intergroup cooperation that is typical of the Nation's best research groups. Also, the use of widely representative and scientifically qualified governing boards would help to force planning for new facilities and programs at any one center to be responsive to the needs of the entire community of scientists in the field rather than to the parochial interests of the scientific staff of the center itself. Thus, each center is operated under contract with an appropriate consortium of university representatives: AUI, AURA, and UCAR.

National Radio Astronomy Observatory

This Observatory, the first national research center established with Foundation support, is a large multi-instrument radio astronomy facility and represents a response to an urgent need for facilities to study the heavens by means of the radio waves emitted from stars and other sources in outer space. Two major radio telescopes have been built and a third is expected to be ready by December 1964.

A 300-foot diameter, parabolic-reflector instrument has been in successful operation for a year and a half. Not fully steerable, the instrument moves only by tilting in a north-south direction. This large, movable, dish-shaped antenna has been exceedingly useful in the detection and measurement of radio sources and in the determination of the amount of neutral hydrogen gas within our galaxy and neighboring galaxies. During the past year, this telescope has been used almost entirely by visiting astronomers at Green Bank, a situation quite in accord with the function of this center as a national observatory in radio astronomy.

Early this year a second unique facility was completed. It is composed of two 85-foot parabolic dishes, one of which is movable on large wheels and, when operated in conjunction with the previously built stationary unit, provides a wide base-line interferometer of greater length than any other system in the United States at the present time. This combination of two average-size radio telescopes, by utilizing wave interference phenomena, provides some, but not all, of the advantages of a single radio telescope, of vastly greater size and cost. The advantage gained is primarily in the resolution (ability to measure very small angles). The new interferometer, now that it has been completed, will make possible the determination of positions and sizes of celestial radio sources with accuracies previously unobtainable.

A third instrument, now rapidly nearing completion, is the 140-foot diameter, fully steerable, high-precision paraboloid which has been under construction for several years. The polar axis and the 17-foot diameter spherical bearing are completed and have been delivered and mounted on the pedestal. The yoke and hub assembly, which will support the main dish, has been moved into place and attached to the spherical bearing. The rest of the dish structure is virtually completed, and it is anticipated that the installation of surface panels will be completed before the end of 1964. This instrument, because of its combination of size and surface accuracy, will provide the National Radio Astronomy Observatory with observational capabilities unequaled elsewhere.

During the 1964 fiscal year, the programs using the 300-foot transit instrument have largely involved detailed observation of neutral hydrogen. One of the most important research projects completed using this facility was that of Bernard Burke, of the Carnegie Institution of Washington, wherein the principal objective was to discover the density distribution and motion of neutral hydrogen in the Andromeda nebula. Of all the neighboring galaxies, this giant spiral nebula most nearly resembles our own, and through study of this system we should be able to derive a better understanding of our own galaxy. By measuring the shift in wavelength of the electromagnetic radiation from the hydrogen of that galaxy, it is possible to determine the velocity of various parts of the nebula relative to our own galaxy. By means of these Doppler-shift measurements, contours of intensities were plotted on a scale of velocity versus distance along the major axis of the nebula. The difference in velocities in the two halves provides direct evidence of the rotation of the spiral structure in the Andromeda nebula. Significant differences in the hydrogen gas distribution in different parts of this galaxy were also observed.

The work of Gart Westerhout, of Maryland University, has involved the acquisition of many plots of the hydrogen distribution within our galaxy. These plots are taken by means of numerous scans across our Milky Way. The data as recorded require a great deal of processing in the form of auto-correlation and computer integration before they can be reduced to a form for useful application on this important astronomical problem.

Green Bank, the site of these unusual instruments, is sheltered quite well among the hills of West Virginia where the disturbances of man-made radio noise are at a minimum. Freedom from such disturbances is an important factor in permitting maximum utilization of these exceptional radio telescopes.

During the 1964 fiscal year, $4.6 million was obligated for the National Radio Astronomy Observatory—$2.2 million for program development and operating, $1.8 million for scientific support equipment, and $0.6 million for site development and facilities. The staff consisted of 32 scientists and engineers, plus 139 support personnel.

Kitt Peak National Observatory

This second national research center established with Foundation support is intended to provide optical astronomers from all over the country with modern telescopes at an excellent site in a good climate. Kitt Peak is a mountain 6,875 feet high, located on the Papago Indian Reservation, 45 miles southwest of Tucson, Ariz. The administrative headquarters of the Observatory are in Tucson.

Research at Kitt Peak is organized in three categories: solar, stellar, and space. The solar group has in full operation the largest solar telescope in the world. This instrument, partly underground, forms an image of the sun which is 34 inches in diameter. The image can either be photographed directly, or the light can be analyzed by powerful spectrographs. Most of the research so far has involved studies of the solar spectrum utilizing photoelectric scanning rather than photography. The primary purpose of these studies is to accurately determine the exact chemical composition of the sun's outer layers.

The light-gathering power of this solar telescope is so great that it has been used at night for studies of objects, such as the moon, the planets, and some of the brighter stars. An unusual feature of the instrument is that it is completely air conditioned in order to increase the steadiness of the image.

During the summer of 1964, the stellar division put into operation its new 84-inch diameter reflector telescope. This instrument, the fourth largest telescope in the United States, is expected to be a very versatile instrument for stellar photography and spectroscopy. It has already been used by staff members for accurate photoelectric brightness determinations of stars. This telescope became available to visiting astronomers during the fall of 1964.

Other equipment operated by the stellar division consists of a 36-inch and two 16-inch telescopes which have been used by visiting astronomers for about 65 percent of the available observing time during the past year. About half of the visiting astronomers are advanced graduate students gathering material for their doctoral dissertations. Their research is mostly concerned with photoelectric studies of the intensity of various celestial objects in the near ultraviolet, visible, and infrared regions of the optical spectrum.

In the space programs, a number of Aerobee rockets equipped with spectrometers were launched at the White Sands Missile Range in New Mexico. Several new features were discovered in the daytime atmospheric glow, due to emission by nitrogen and oxygen, which it is hoped, will help to explain the emission mechanisms and the composition of the earth's upper atmosphere. A new observational program has been started at the Airglow Laboratory on Kitt Peak where the various spectral lines and bands in the twilight atmospheric glow are now regularly observed. A three-man expedition left in May for Chacaltaya, Bolivia, to observe polarization of the zodiacal light at an altitude of 17,000 feet above sea level.

Work on a 50-inch remotely controlled telescope is going forward. This instrument will be mounted on Kitt Peak and will be completely automatic, its program and operation controlled from Tucson by wire or radio link. The key purpose of constructing this type of telescope is to develop techniques for automated operation which will be needed eventually for controlling the operation of orbiting telescopes in space.

A total of $4.4 million was allocated to the Kitt Peak National Observatory—$2 million for program development and operation, $2.3 million for scientific support equipment and $0.1 million for site development and facilities. On the staff were 38 scientists and engineers, plus 142 supporting personnel.

Cerro Tololo Inter-American Observatory

The New York Times, in an interview reported on August 2, 1964, quoted Dr. Lawrence H. Aller, chairman of the astronomy department of the University of California at Los Angeles, as saying:

> "When the Good Lord made the universe, he unfortunately put the astronomers in the Northern Hemisphere and the most interest-

ing stars and galaxies in the Southern Hemisphere. Since we can't move the heavens, the astronomers will have to head south."

This, in brief, explains the creation of an observatory to provide astronomers access to telescopes in the Southern Hemisphere to study those parts of the sky which are invisible in the north. After a 3-year search in Chile, a site was found which offers exceptionally fine observing conditions because of its altitude and extremely dry climate. It is called Cerro Tololo, a mountain 7,400 feet high on the western slope of the Andes in the La Serena-Vicuna area about 300 miles north of Santiago. The headquarters building of this new observatory, located in the coastal city of La Serena, is nearly completed and should be occupied in the fall of 1964. A road to the top of Cerro Tololo was finished in December 1963. Since then, the top of the mountain has been leveled, providing a plateau large enough to accommodate all telescopes planned for this observatory. A 60-inch and a 36-inch telescope, under construction in the United States, are expected to be in operation early in 1966. With these instruments, it will be possible to study objects such as the southern part of the Milky Way and the two nearest external galaxies (the Magellanic Clouds) which are not visible from the United States.

Astronomical research has been conducted at this site for the past 2 years using one of the Kitt Peak 16-inch telescopes. A program of photoelectric photometry designed to measure the intensity of a number of stars in different colors has been carried out with the cooperation of several Chilean astronomers. Plans call for a small permanent staff to operate this observatory. Most of the observing time will be made available to visiting astronomers from both North and South America.

Of the $1 million obligated for the Cerro Tololo Inter-American Observatory in 1964, $250,000 was for program development and operation, $400,000 for scientific support equipment, and $350,000 for site development and facilities. A staff of 19 were employed—2 scientists, 13 technical and maintenance personnel, and 4 administrative and clerical personnel.

National Center for Atmospheric Research

The National Center for Atmospheric Research (NCAR), during its fourth year, made substantial progress toward fulfilling its purpose of stimulating the basic research required to further our knowledge of the atmosphere and of providing research facilities for use jointly by the NCAR staff and by visitors from universities and other research organizations.

The primary activities of NCAR are: (1) to conduct a broadly based research program in pursuit of a fundamental understanding of atmospheric processes, to encourage postdoctoral studies related to atmospheric problems—particularly by talented young people who may have received their training in other but related specialities, such as physics, chemistry, and fluid mechanics—and to attract talented scientists and students to the atmospheric sciences; (2) to serve as a research and facility planning center to promote the development of large-scale research programs involving a number of institutions or to bring about the creation, under NCAR direction or otherwise, of needed major facilities for use jointly by scientists from several institutions; (3) to manage and operate joint-use facilities where clearly established needs are shown, and where no other institution is in a position to provide such facilities more efficiently.

NCAR's efforts have been carried forward through three major divisions, the Laboratory of Atmospheric Sciences (LAS), the High Altitude Observatory (HAO), and the Facilities Division (FAC). During the past year plans were completed for a fourth major division to be known as the Postdoctoral Program. The program, which began formally on July 1, 1964, calls for the initiation of postdoctoral studies, with emphasis on allowing new Ph. D's in the atmospheric sciences to place their special fields in a broad context, and to bring into the atmospheric sciences new Ph. D's from relevant basic disciplines, such as physics and mathematics. The program will include seminar series concentrating on fundamental and often neglected research problems in the atmospheric sciences, and is expected to strengthen the theoretical base of NCAR research programs and promote syntheses among scientific viewpoints.

Closely associated with the postdoctoral program are the programs for visiting scientists, conferences, and for UCAR fellowships. During the year, visiting scientists from both the United States and eight foreign countries have been conducting research at NCAR for periods ranging from 2 weeks to more than 6 months. Also, during the year, many scientists attended conferences and seminars for which NCAR was either sponsor or host. These activities demonstrate the vigor and success with which NCAR is becoming a center for research planning, for discussion of research results, and for stimulation of research workers.

The University Corporation for Atmospheric Research has received a grant from the Kettering Foundation for the support of atmospheric science graduate fellowships. These nominally 1-year fellowships provide stipends and tuition for study at the graduate school of the fellow's choice. They also provide for summer appointments at NCAR, where the fellows work with members of the NCAR senior scientific staff. Extensions of an additional year were recently granted the first two fellowship winners, and a third fellowship was awarded for the coming academic year.

The Laboratory of Atmospheric Sciences (LAS) added three new research programs during the past year—photochemistry of the higher atmosphere, plasma physics, and synoptic meteorology. They will fill significant gaps in the LAS effort. The remainder of LAS programs are concerned with fundamental studies in atmospheric dynamics and the general circulation, atmospheric physics, atmospheric chemistry, and the interaction between the atmosphere and the underlying ground or ocean surface.

Basic studies begun during the year include: the interrelation between coalescence of raindrops and chemical reactions in the atmosphere, and their effect on atmospheric dynamics; comparison of the dynamics of hurricanes with those of large-scale circulations; pure fluid dynamical problems related to the theory of turbulence and to problems in magnetohydrodynamics; in interrelation between nucleation and coalescence of water droplets and the electrostatic regime of thunderstorms; and the development of stable applications of numerical techniques useful in the studies of turbulence, sea-atmosphere interactions, hurricanes, and of atmospheric dynamics in general.

The High Altitude Observatory, established in 1940 and integrated with NCAR in 1962, continued its research programs on the solar atmosphere, the terrestrial atmosphere and ionosphere, solar-terrestrial relationships, and planetary atmospheres. Observations of the July 1963 solar eclipse from 10 temporary stations in Alaska, Canada, and Maine revealed previously unknown and as yet unexplained motions in the solar corona. They may aid in understanding the intense heating of the sun's upper atmosphere and of the production of variable solar emissions that affect the earth's upper atmosphere and intensify the Van Allen Belts. Observations from a balloon flown from the NCAR balloon flight station at Palestine, Tex., in March 1964 have extended these studies to longer time scales. In cooperation with NASA, work has begun on a satellite-borne coronagraph to extend them even further. In addition, a cooperative program with the University of Hawaii is being conducted to improve the photoelectric measurements of the corona.

Other programs of the High Altitude Observatory include studies of the radio emissions from Jupiter and from the sun studies in atmospheric radiation, dynamics of the stratosphere, geomagnetism and the ionosphere, theoretical studies of stellar interiors, laboratory studies in vacuum spectroscopy, and various solar studies.

The Facilities Division (FAC) of NCAR continues its growth although at a considerably slower rate than originally envisioned. The reasons for this slower rate of growth include limited availability of funds, need to obtain congressional authorization for airplanes, need for coordination with interested Federal agencies to decide whether NCAR or some other group could best establish and operate a necessary facility, and, in at least one case, deliberate caution in order to gain operating experience before committing large sums of money.

In August 1963, the Scientific Balloon Flight Station, at Palestine, Tex., became fully operational. Since then, approximately 50 flights (through July 1964), carrying experiments of some 20 scientists from various universities and research groups, have been carried out. At the beginning of the 1964 summer season, balloon flights were being launched from the station at the rate of two per week. Other activities of the balloon facility included: completion of an investigation, with positive results, of the feasibility of using Page, Ariz., as a supplementary flight station for long-duration winter balloon flights; development and fabrication of a standard command-and-control telemetry system for balloon-borne experiments; completion of the engineering design of an inflation-and-launch shelter, for possible erection at Palestine, in order to reduce delays and losses of balloons and helium; continued work in balloon technology on such problems as balloon materials, balloon design, and launching and recovery methods.

In January 1964, NCAR began operation of a CDC 3600 Computer to serve the computational needs of NCAR scientists, especially those working on methods of improving mathematical models of the atmosphere and on other dynamical problems. Plans were developed for use of the computer by nonstaff atmospheric scientists.

Development of an Aviation Facility began in early 1964, following the recommendation of a survey group composed of university and Government research scientists. The survey group, under the chairmanship of Robert A. Ragotzkie, of the University of Wisconsin, found a significant gap existing between the light-plane capabilities of the universities and the mission-oriented activities of Government services which generally use heavy aircraft. The survey group recommended that NCAR begin operating aircraft to serve the needs of its own scientists as a pilot project for future development to serve the operational needs of university scientists. In May 1964, operation of a Queen Air 80 aircraft, under a lease supported by NCAR's private management corporation, was initiated to support NCAR research on cloud electrification and its influence on precipitation-producing processes. The survey group also recommended that NCAR immediately initiate information and liaison services, as well as development work on aircraft research instrumentation and data-handling problems.

A second survey group was formed in September 1963 to determine the national need for facilities to study atmospheric phenomena that occur on a scale too small to be detected by existing weather networks, but which contribute significantly to large-scale weather processes. The survey group, under the chairmanship of Hans A. Panofsky, of Pennsylvania State University, has recommended that a facility be established to develop, acquire, maintain, and operate instrumentation and data-handling equipment, with special emphasis on systems capable of determining detailed profiles of wind, temperature, and humidity in the first 50,000 feet above the earth's surface. The NCAR staff has begun development studies of such a system, and will continue the study during the coming year.

Ground was broken in June for the permanent laboratory of NCAR on the 530-acre Table Mountain site, just southwest of Boulder, Colo. The complex will consist of two 5-story office-and-laboratory towers and a 2-story central building, with an underlying basement connecting all three elements. Special care has been taken to preserve the natural beauty of the site, which lies 600 feet above Boulder. The site was given to the National Science Foundation by the State of Colorado, and water is being supplied to the site by the city. The construction schedule calls for completion during the first half of 1966. Meanwhile, NCAR continues to be housed in four buildings leased from the University of Colorado.

Foundation funding of NCAR during 1964 totaled $9.3 million—$4.8 million for program development and operations, $1.1 million for scientific support equipment, and $3.4 million for site development and facilities. The NCAR staff, supported by the Foundation, consisted of 154 scientists and engineers (134 full time and 20 part time) and supporting personnel. In addition there were 21 visiting scientists and 21 visiting students at the Center who because the duration of their visits was less than a year are not included in the total.

NATIONAL RESEARCH PROGRAMS

Among the Nation's basic research activities are some that cannot be administered by a single investigator or laboratory. This may be due to geographical location with the concomitant need for large-scale logistic support, the requirement for international cooperation because of the global nature of the activity, or the complexity and cost of the equipment. Because of these factors, such programs of necessity require coordinated planning and funding on a national basis and may be designated as national research programs. Usually such a program is one which has been officially endorsed by the U.S. Government. The responsibility for coordinating governmental and private contributions to the program is then assigned to a single Federal agency.

National research programs usually originate in the scientific community, not in the Federal Government. Only after a consensus is reached as to their desirability is a request for support submitted to the Government. Frequently such requests are transmitted through the National Academy of Sciences, which not only acts for the scientific community in its representations to the Government but is for the most part also the vehicle through which U.S. scientists adhere formally to international scientific organizations.

Within the Foundation a national research program will normally be characterized by an identifiable budget and an identifiable seat of responsibility. Proposals for support of research under a national research program are evaluated by the Foundation staff assisted by advisory panels and committees of specialists in the pertinent field or fields in much the same manner as is used for other basic research projects.

During fiscal year 1964, six national research programs were in operation under NSF aegis—U.S. Antarctic Research Program (USARP), the International Indian Ocean Expedition (IIOE), Deep Crustal Studies of the Earth (Project Mohole), the International Years of the Quiet Sun (IQSY), Weather Modification, and the United States-Japan Cooperative Science Program. The Foundation plays a coordinating and funding role assigned by legislation or executive order. In every case, these national research programs can only expend funds specifically approved by the President and the Congress. Because of its complexity and pioneering nature, Project Mohole has also been designated as a national research program by the Foundation.

A national program may or may not be limited in time. The International Geophysical Year of 1957–58 has already been completed. The Indian Ocean Expedition will complete its field work at the end of calendar year 1964, and the International Years of the Quiet Sun will have completed the observations at the end of calendar year 1965. The exploration of the Antarctic continent in cooperation with other nations, research in weather modification, and the cooperative United States-Japan program are likely to continue for a considerable time.

The International Upper Mantle Project has most of the characteristics of a national research program although it has not been formally recognized as such. Its purpose is to determine the composition, structure, and dynamics of the crust and upper 1,000 kilometers of the mantle of the earth. It is an important region in that it presumably holds the secrets of mountain building, the origin of continents and oceans, the source of the earth's internal heat, the driving force for continental drift, and the causes of volcanoes and earthquakes; many primary ore deposits also originate here. The Project includes the study of seismic waves generated by earthquakes and explosions, the variations of heat flow from the earth, the interpretation of the record of ancient magnetic fields as recorded in the rocks, the systematic study of the magnetic and gravity fields of the earth in special regions, the direct evidence from deep drilling, and the determination of the characteristics of earth materials under laboratory conditions simulating the high pressures and temperatures presumed to exist in the earth. This concerted worldwide field and laboratory attack on the largely unsolved fundamental problems in the earth sciences will extend through 1967.

United States Antarctic Research Program (USARP)

The Antarctic continent and surrounding ocean areas provide scientists with a unique research laboratory. The Antarctic atmosphere is essentially dust-free. The surrounding oceans contain one of the world's richest populations of marine flora and fauna presenting an ecological pyramid from phytoplankton to whales. The Antarctic icecap is about two-thirds the size of all North America and contains about 90 percent of the ice on the earth's surface. Locked in this ice are approximately 8 million cubic miles of fresh water. In addition, Antarctica is the coldest area in the world, with a record low temperature of —127° F. This "heat sink" has a significant effect not only on air mass dynamics and ocean circulations of the Southern Hemisphere but of the entire globe. These factors combine to make Antarctica a fertile area for the conduct of basic research in the life, earth, and atmospheric sciences.

Antarctica is the one location where international cooperation has been guaranteed by a treaty which reserved the area for peaceful purposes only. On December 1, 1959, the 12 nations that took an active part in Antarctic exploration during the International Geophysical Year (IGY) signed the Antarctic Treaty. Free access to the entire continent is guaranteed, making possible scientific research unhampered by political barriers. The Treaty provides for unlimited inspection of all installations in Antarctica to ensure observance of the provisions of the Treaty. The United States exercised this treaty right in 1964 when it undertook a program of inspection of stations maintained by other treaty nations. The nations with active programs in Antarctica at the present time are Argentina, Australia, Belgium, Chile, France, New Zealand, South Africa, the Soviet Union, the United Kingdom, and the United States.

The purpose of the United States Antarctic Research Program is to take advantage of this research laboratory in all ways that will benefit the United States. This is done through programs in biology, earth sciences, atmospheric sciences, and in cartography, all based on research proposals submitted by interested scientists at universities, research institutions, or Federal agencies. During 1964 field research was carried out at four permanent stations—McMurdo, Pole, Byrd, and Eights. In addition, Hallett Station was operated jointly with New Zealand. NSF also maintained the 266 foot research vessel *Eltanin* as a floating mobile station for U.S. Antarctic research.

By direction of the President, the National Science Foundation bears the responsibility for planning, coordinating, managing, and funding the U.S. Antarctic Research Program. The Department of Defense is charged with planning and carrying out operations in support of all programs for Antarctica; the Department of State is responsible for assuring coordination among the several agencies involved in Antarctic matters. The Committee on Polar Research of the National Academy of Sciences provides broad program recommendations and indicates new areas of research to which attention might be given. Through the Committee, the Foundation is also advised of the recommendations of the Scientific Committee on Antarctic Research (SCAR) of the International Council of Scientific Unions (ICSU).

In fiscal year 1964 summer field activities in biology, geology, and glaciology were supported at an alltime peak. The numbers of biology and geology programs, undertaken largely by university teams, are close to the maximum that can be effectively supported in the field and on the ship.

The *Eltanin* continued her operations in a most successful manner and, as the fiscal year ended, was completing her 13th cruise, the 5th for the year. At sea for more than 300 days she covered over 40,000 miles of the southern oceans. Each cruise took her to the edge of the ice pack and into the loose ice as far as safety considerations would allow. The 15 scientific programs aboard included meteorology, upper atmosphere physics, marine biology, physical oceanography, and bottom coring and photography.

Among the more interesting projects in the 1963–64 Antarctic summer were ecological and physiological investigations of the Weddell seal. The seal studies, the first to be conducted by U.S. investigators, were relatively simple because of the tranquility of the seals when on the ice away from natural predators. Also, in large areas of solid ice cover, the seals repeatedly return to man-made ice holes to breathe. By attaching instruments to the animals, scientists made special studies of their underwater habits. Pressure devices showed, for example, that dives to 1,500 feet are quite common. With the aid of tranquilizers three Weddell seals were brought to this country to a specially cooled aquarium of the New York Zoological Society, where further physiological studies are being made. These are believed to be the first Weddell seals transported alive to the Northern Hemisphere.

The geological activities of the 1963–64 summer were the most extensive yet attempted by the United States in Antarctica. Major geological parties were located in the two largest interior ice-free ranges in West Antarctica. Using two turbine helicopters, the University of Minnesota completed the three-summer program of field mapping of the Ellsworth Mountains. The Ellsworths consist of extremely thick and highly folded early Paleozoic strata, and large collections of Cambrian fossils were made. Another geological team, from the U.S. Geological Survey, worked in the Pensacola Mountains for the second summer. The results of exploration in these two large interior ranges and the application of new techniques of geochemistry and geophysics have altered previously held concepts of Antarctica's geological structure.

A stake network 60 miles long and about 3 miles wide was installed from Byrd Station upslope towards the West Antarctic ice divide, with stake separation measured by electronic devices. Remeasurement in about 4 years will provide information on the ice creep related directly to the question of whether the volume of the inland ice is increasing or decreasing, and on the particle paths from which the history of the ice can be determined.

Fiscal year 1964 funding for the Antarctic Research Program totaled $7.4 million and supported 63 field projects involving 196 people.

Deep Crustal Studies of the Earth (Project Mohole)

Eighty percent of the earth's volume is composed of the rocks making up the mantle. It has often been postulated that these rocks may be seen in some places at the earth's surface, but it has never been proved. Advances in technology in the offshore drilling industry indicate that it is now possible to penetrate the earth's crust and sample the mantle by core drilling. This feat appears even more certain of success since nearly concurrent advances in marine geophysics show that the mantle is within about 6 miles of sea level in several localities beneath the ocean basins. The primary aim of Project Mohole thus involves a new and untried engineering experiment—to drill to 35,000 feet below sea level from a floating, unanchored platform.

The scientific benefits to be derived will contribute to the solution of some of the most provocative problems of geology. These include a better determination of the age of the earth and of the amounts and distribution of its elements, and proving or disproving the theories of continental drift. Important subsidiary problems concern the age of the ocean basins, the presence or absence of sediments older than cretaceous in the oceans, and information bearing on the origin of the moon. A major problem is the nature of the density change that differentiates the crust of the earth from the mantle. This change is known by an increase in velocity of elastic wave propagation and is called the Mohorovicic Discontinuity after its discoverer. Because solutions to these great problems require a more complete understanding of the makeup of the mantle, Project Mohole is best thought of as a project in planetology.

A key development in the progress of Project Mohole in fiscal year 1964 was the decision to design and construct a large floating platform from which the drilling operations will be conducted. The platform will be used initially for drilling to intermediate depths, with the dual purpose of exploring selected sites for scientific purposes, and of developing the technical and operational ability to drill, perhaps 18,000 feet, into the ocean floor in deep water. The attempt at penetration to the mantle will be undertaken only when the platform and drilling systems have been thoroughly tested and operating techniques developed.

For the demands of this task, a stabilized platform has many advantages over a ship hull. There is freedom in the design of a stabilized platform to select pitching, rolling, and heaving periods as desired. The ship hull is less attractive because of the relatively short pitching and heaving periods. The stabilized platform is a safer craft from which to work because it has longer natural motion periods, having only one-half to one-tenth the amplitude of motion of a ship.

The Mohole drilling platform represents an advance in the state of the art rather than a radically new concept, and offers maximum stability and operational capability. The design has benefited from the experience gained by the oil industry in the use of numerous floating platforms and from the experience in earlier phases of the Mohole Project, as well as general advances in naval architecture and marine engineering. The platform is still under study, both in model basins and on the drawing board, but the basic design and structural plan have been agreed upon.

Other important phases of Project Mohole now receiving attention or to be studied in the near future include the drill string, the riser pipe or casing, the positioning system for the drilling platform, and the selection of drilling sites.

Total funds expended on Project Mohole through the 1964 fiscal year amounted to $12.9 million, of which $8.0 million was obligated in 1964.

International Indian Ocean Expedition (IIOE)

The Indian Ocean is perhaps the least known of any of the world's large bodies of water. One quarter of the world's population lives in countries bordering this ocean, an unexplored frontier whose conquest may well provide the resources which can promote the economic well-being of the region in addition to advancing scientific knowledge. Twenty countries provided research vessels or shore stations for this Expedition, and nine others have or will have scientists conducting research aboard ships or at shore facilities of other nations. Special courtesies have been extended to ships visiting Indian Ocean ports, such as exemption from harbor fees and fuel taxes, and special customs facilities for scientific equipment and specimens. U.S. participation in the International Indian Ocean Expedition was approved by the President in 1960, and the National Science Foundation was directed to plan and coordinate Federal support for U.S. participation in the program. The United States has 14 ships and 5 aircraft taking part in the expedition. In 1964 the Foundation provided $4.9 million in support of the U.S. effort.

The U.S. program for the International Indian Ocean Expedition is devoted to four great areas of interest. The first concerns the problem of why there is an ocean basin in the first place; what are the forces that have shaped and are continuing to shape the basin; what are the resemblances between this piece of the earth's crust and any other; and how does the basin of the Indian Ocean differ from the other ocean basins? The second involves the chemical and physical description of the ocean's waters, and the study of their motions. The third area of interest is the living populations, plant and animal, of the Indian Ocean. The fourth area is concerned with interaction between this ocean and the atmosphere. Research programs of each U.S. vessel participating in the IIOE contribute to at least two of the four fundamental areas of interest; many contribute to three; and some to all four.

The Indian Ocean is the only great water body that does not extend from the polar regions in one hemisphere across the equator to the polar regions in the other hemisphere. Because of this unique distribution of land and ocean, the Indian Ocean region is the seat of the greatest monsoon systems known. IIOE meteorological research has contributed much to the understanding of the monsoon.

Monsoons are seasonal winds that blow in response to the change in the differences in temperature between land and sea. When the sun moves north of the equator in the Northern Hemisphere summer, Asia is rapidly warmed. Air over the land becomes warmer than the air over the ocean. The result is air flowing in from the sea at low levels, ascending over the land, and producing clouds and rain.

The desert areas of North Africa heat rapidly in the same way as Asia. South Africa cools at the same time (since it is winter in the Southern Hemisphere), so that a massive flow of air moves from south to north across the African equator. The result of all this is a huge wind gyre (vortex) which blows from southwest to parallel the African and Arabian coasts and finally sweeps across India, Burma, and the Indo-China Thailand Peninsula as the southwest monsoon. Six months later a complete reversal has taken place.

The monsoon pattern must affect the underlying Indian Ocean. Winds generate waves and ocean currents, and these in turn redistribute the cold and warm waters of the ocean and their chemical constituents. The biological population of the ocean is affected. In some areas in one season, wind-driven mixing ensures the spread of nutrients, but in the other season it may be that no nutrients are distributed. Thus, the life of the ocean is probably very largely seasonally influenced and itself takes on a monsoon character.

A number of effects of the complex circulation of currents in the Indian Ocean have been observed through the IIOE. U.S.S.R. vessels sailing in the Arabian Sea found that the northern Arabian Sea had an excess of hydrogen sulphide presumably caused by the mass deaths of fishes due to oxygen deficiency in the water. This mass destruction of fishes is believed to be periodic. The U.S. vessel *Anton Bruun* found that the Andaman Sea, east of the Bay of Bengal, is not oxygen poor, in contrast to the other region. Many large schools of pelagic fish, those which live in the open sea and not on the bottom, were found. This indicates possibilities for commercial fishing close at hand that could provide large amounts of food for the people of India and southeast Asia.

Geophysical studies of the Indian Ocean have confirmed the existence of a midoceanic ridge with an associated rift valley, similar to the Atlantic ridge; new submarine canyons and deep ocean trenches have also been discovered.

Weather Modification

Control of the weather has been the dream of mankind for many years. The promise of useful weather modification techniques is sufficiently great that a coordinated national effort has been deemed desirable. Public Law 85–510, approved by the President in fiscal year 1959, directed the National Science Foundation to support study, research, and evaluation in the field of weather modification. The Foundation also serves as coordinator of the entire Federal effort in weather modification and publishes an annual survey of the weather modification activities sponsored by the Federal Government.

The past year has been characterized by an increasing amount of attention to the problem of weather modification on the part of a number of Federal agencies, as well as by the scientific community and private sectors of the economy. The Interdepartmental Committee on Atmospheric Sciences (ICAS) has devoted considerable attention in its meetings to the problems of weather modification. The Committee on Atmospheric Sciences of the National Academy of Sciences formed a panel on the subject, and the National Science Foundation, under authority contained in the National Science Foundation Act of 1950, appointed a Special Commission on Weather Modification. The Commission in coordination with the NAS panel will devote its attention to the scientific, legal, economic, and social aspects of the problem.

Until a few years ago, the only technique of weather modification under serious consideration was cloud seeding in an attempt to induce precipitation. However, while cloud seeding remains important, and its full usefulness has yet to be realized, it is clear that this is only one possible way in which a cloud or single storm may be modified. Other methods, when thoroughly investigated and developed, may prove to be of equal or greater effectiveness.

Processes of precipitation are gradually being determined through basic research. It is now clear that rain drops can be condensed from water vapor in a number of ways. When the variety of processes is better understood, the chances are good that new techniques for stimulating rain drops will be devised.

The advent of large electronic computers has made possible the testing of mathematical models of the atmosphere. The accuracy of these models is determined by the degree to which they simulate actual weather conditions. With the development of satisfactory models will come the opportunity to determine theoretically the effect of man-made changes on the atmosphere processes. These changes might produce beneficial effects such as breaking a drought, or harmful effects such as freezing crops. Only those ideas which have the greatest potential for good would be tested in the real atmosphere.

These models will make possible the testing by computer simulation of such imaginative large-scale weather modification ideas as damming the Bering Strait between Alaska and Siberia, laying a chemical film on the ocean to lessen evaporation, or changing the radiation balance of the polar regions by coating icecaps with carbon black.

In 1964, 20 projects were initiated at a cost of $1.5 million.

United States-Japan Cooperative Science Program

This program is a unique experiment in international scientific cooperation. It is based on a bilateral agreement between President Kennedy and Prime Minister Ikeda in June 1961 to strengthen scientific cooperation between the United States and Japan. The United States-Japan Joint Committee on Scientific Cooperation, consisting of distinguished United States and Japanese scientists, was established to recommend techniques and areas for increased cooperation, to review and evaluate programs undertaken, and to serve as an annual forum for discussion of common problems of United States and Japanese science.

The National Science Foundation was asked to take responsibility for coordination of U.S. scientific interests in the program. These responsibilities include the appointment and support of specialized advisory panels, administration, coordination, and financial support of the U.S. share of joint projects.

Three types of activities have been initiated—cooperative research projects; scientific seminars, conferences, and planning meetings; and visits by scientists of one country to the other for purposes of research or lecturing. American funds are used only for support of American participation; Japanese funds support all Japanese work. Cooperative projects must be of benefit to both United States and Japanese science, and involve Americans and Japanese working together in the United States, Japan, or elsewhere in the Pacific area. Through the 1964 fiscal year, 33 cooperative projects had been started in the areas of earth, biological, atmospheric, and medical sciences. Projects included studies of deep sea seismology, satellite meteorology, Pacific volcanoes, cloud physics, heat flow, paleomagnetism, mammals of Japan, cancer chemotherapy, Pacific area insects, bioluminescent marine organisms, and rice diseases and parasites.

Twenty seminars and planning meetings to discuss mutual interests and to lay plans for cooperative projects have been held on such important subjects as coastal engineering, mechanical language translation, neurophysiology, hurricanes and typhoons, earthquake prediction, educational curricula, and abstracting and indexing of the scientific literature.

By the end of fiscal year 1964, a total of 200 Americans from 74 United States institutions and 371 Japanese from 87 Japanese institutions had participated in activities sponsored through this program.

During the 1964 fiscal year, 5 projects were supported by the Foundation at a cost of $448,000, plus $260,000 for meetings, exchange of scholars, and other similar activities.

International Years of the Quiet Sun (IQSY)

IQSY is an outgrowth of a previous program, the International Geophysical Year, of 1957–58, which was itself the largest international program of exploration ever undertaken. The IGY was a comprehensive examination of the earth, its atmosphere, and its spatial environment, during a peak of the sunspot cycle characterized by unusually high solar activity. Many of the fields of study involved phenomena which occurred in response to activity on the sun. The very advantage of large solar activity resulted, however, in an overlap of events which often made it difficult to disentangle the exact sequence of cause and effect. Furthermore, during sunspot maximum the ionosphere and the earth's magnetic field never get a chance to subside back to an undisturbed state before the next disturbance occurs.

IQSY has developed as a program that can take advantage of the opportunities for studying solar-terrestrial relationships at the minimum of the sunspot cycle. Each of the more than 60 countries involved in IQSY has planned its own program coordinated in consultation with the others. Wherever practicable many IQSY observations are made on a continuing or a daily basis. Coordination of intermittent projects is accomplished through a program of World Days and World Intervals. The World Data Center system, developed for IGY, has remained in operation, and all IQSY data are available to all scientists through this system.

The National Science Foundation obtained authorization for U.S. participation in the IQSY from President Kennedy, who, at the same time, designated the Foundation as the agency to correlate the Federal Government's regular activities that contribute to the program, and to coordinate and to arrange the budget for the additional activities.

The U.S. program for IQSY consists of researches in the fields of meteorology, geomagnetism, aurora, airglow, ionospheric physics, radio astronomy, solar activity, the interplanetary medium, cosmic rays, trapped radiation, and aeronomy.

The observational period of the IQSY program runs through calendar years 1964–65. During the early part of the program it has been quite clear that solar activity has been falling off. The exact time of solar minimum and the interpretation of the observations secured will be subject to evaluation during the coming year.

The Foundation funded a total of 48 projects during 1964 at a cost of $3.7 million.

SPECIALIZED RESEARCH FACILITIES

In many fields of science, continued progress in research is increasingly dependent upon the availability of ever more complex and specialized equipment and facilities. Unfortunately, as the required facilities become more and more expensive, the universities and other nonprofit research institutions become less able to provide the necessary funds. Therefore, the Foundation has been providing limited assistance to these institutions for the acquisition of specialized facilities, but only when the need is urgent, when it is clearly in the national interest, and when necessary funds cannot be obtained from other sources. There is no fixed requirement as to the amount of funds the institution must itself raise before becoming eligible.

Oceanographic Research Vessels and Facilities

Since fiscal year 1960 the Foundation has provided about $26 million for the construction or conversion of research vessels and shore facilities of oceanographic institutions. Of this total, $5.3 million was granted in 1964.

A grant was made to the University of Hawaii for the conversion of the *Territu,* which will conduct oceanographic research in the mid-Pacific. Other grants for oceanographic research facilities provided for construction of research laboratories, for pier construction, and associated uses.

The most recent vessels to join the oceanographic research fleet are the 180-foot *Yaquina* and the 117-foot *Eastward. Yaquina,* commissioned in September 1964, was converted from an army freighter (FS) and is operated by Oregon State University. *Eastward,* launched in June 1964, is one of the very few ships designed specifically for biological oceanography. This vessel will be used by Duke University to study the deep ocean, as well as shelf and shore waters.

Biological Science Research Facilities

This program is designed to support installations that are unique either in geographical location, purpose, regional usage, or a combination of these, and that are not usually a part of the normal departmental organizational structure of a college or university.

This specialized biological facilities program provides support for: (1) construction, renovation, and improvement of research facilities for inland field stations, marine biological laboratories, and private, non-profit research institutions; (2) improvement of facilities for maintaining research materials, including museum research collections; (3) development of new facilities, including unique designs of existing types of facilities such as large controlled-environment laboratories, a national repository of micro-organisms, a crystallography center, and other new departures; (4) unique, specialized facilities on academic campuses not usually considered for support by the graduate-level facilities program.

Nineteen grants totaling $3.5 million were awarded during the 1964 fiscal year in this program. Among them was the grant to the University of Michigan to aid in the construction of an all-weather aquatic biology laboratory at the university's field station at Douglas Lake. The stage has now been set whereby theories based on data derived from taxonomic and descriptive studies in the field can now be tested experimentally in this specialized laboratory.

Illustrative of the range of biological research facilities supported by the Foundation are those for ornithological research, for ichthyological research, and for storage of entomological collections.

A major grant was made to Duke University for a portion of the cost of a two-unit phytotron, one unit of which is to be constructed at Duke University, the other at North Carolina University. These installations will provide the means whereby such environmental factors affecting plants as intensity, duration, quality and cyclical variation of lighting; temperature variations; humidity; velocity of air movement; and radiant heat may be controlled and adjusted individually or in combination in a reproducible fashion.

University Computing Facilities

The number and value of computer installations at universities and colleges in this country has been increasing at a rate of approximately 45 percent each year for the last 6 years.

This growth has been stimulated by the vital role which computers now play in virtually every scientific field. The rapidity at which this field is expanding is indicated by the current yearly industrial sales estimate of more than $2.5 billion—scarcely more than 15 years since computers first became available commercially.

The National Science Foundation has established a program to assist universities in meeting the substantial investments in computing facilities needed to conduct research for the whole institution rather than for just one department or for only one project.

Many universities that established computing centers in the late 1950's with machines whose cost was between $50,000 and $100,000 now face replacement costs of more than $500,000 for adequate equipment, while schools with more extensive research programs now must install equipment costing from $1 million to $3.5 million. To this cost must also be added the other operating costs of the center which may be comparable to the equipment cost.

This pattern of rapid growth is characteristic of computing facilities which successfully meet the widening needs of the research activities at their institutions. It is not unusual, therefore, for the Foundation to receive and give favorable consideration to a proposal for assistance in acquiring a large computer from an institution which a few years earlier had received a grant for a smaller machine. Because of the magnitude of the need, however, the Foundation has been able to provide only limited support for these facilities. In fiscal year 1964, NSF made 18 grants totaling $4,517,000.

Currently the Foundation is assessing the impact of computers on research in the natural and social sciences. This evaluation is part of a study being conducted by the National Academy of Sciences-National Research Council's Committee on Academic Uses of Computers. In addition, the study will estimate the total national needs of colleges and universities for computing facilities in the support of research and training.

University Nuclear Research Facilities

Thirteen universities received a total of $5 million in 1964 for nuclear research facilities. Of these, five universities acquired facilities for elementary particle research.

One of the grants made was for development and construction of a large facility at the University of Utah for the measurement of neutrino particles coming from outer space, or from the earth and atmosphere acting as a target for other cosmic ray particles. The unit, located in a nearby mine for shielding purposes, will also serve as a detector of high-energy cosmic-ray muons.

A grant was made to Cornell University for design study work on a 10 billion-electron-volt synchrotron. Successful development studies were carried out on accelerator components in preparation for utilizing the large-radius, circular synchrotron.

Seven grants were made to permit expansion of existing facilities used for nuclear structure research. These grants will permit the acquisition of needed large auxiliary equipment, such as multiparameter analyzers and bending magnets.

University Atmospheric Sciences Research Facilities

For the last 2 years, the Foundation has been providing support for the acquisition of essential facilities and equipment for field and laboratory research. Without the availability of such facilities, progress in the atmospheric sciences would be extremely limited. In fiscal year 1964, 14 grants totaling $700,000 were awarded.

One of these grants was for completion of the Irving Langmuir Laboratory for Atmospheric Research, part of the New Mexico Institute of Mining and Technology. The facility is located atop a 10,000-foot mountain in central New Mexico from which approximately 20,000 square miles of desert, steppe, and mountain terrain can be studied by radar, photographically and visually.

Another grant will fund the construction of a stable meteorological buoy. This buoy will permit the making of systematic measurements, at various sea locations, of air temperatures and wind profile, surface currents, and wave motion. Observations will be possible with this buoy from points 50 feet above the water line to the surface itself.

Social Science Research Facilities

A specialized social science research facility is considered to be a national or regional research resource which is unique, or rarely duplicated, in purpose, design, or location. Typically it involves active participation by scientists from a number of universities, with the intent that ultimately it will be available for use by qualified scientists from all parts of the country. This facilities support program aids independent nonprofit research organizations as well as university-affiliated organizations which function as suppliers of extraordinary data or data services.

Of the six grants totaling about $1 million made during 1964, the largest portion of the funds went to three institutions which are currently performing valuable services for social scientists at universities throughout the nation.

One grant supported the construction of a new facility which will enable the Educational Testing Service to pursue highly controlled experiments in the study of individual differences in learning, personality, and motivation. Another grant supported the construction of larger quarters to house the National Opinion Research Center, enabling the center to provide even greater capability in conducting scientific investigations based upon large-scale systematic surveys. The third grant was for the renovation of a facility on behalf of the Human Resources Area Files. This organization, in addition to its research services to major universities, continues to provide low-cost microfilm copies of research and training materials to small colleges and other institutions with limited resources in the social sciences.

SCIENCE EDUCATION

Science education is an enterprise that recognizes no boundaries in age or in prior sophistication. A kindergarten child can be introduced to scientific thinking through experiments in force and motion, or through exercises in growing things. On the other hand, a college professor with an advanced degree in, for example, physics can profit from being a student once again in a seminar on special problems in high energy physics.

These examples represent the range of NSF-supported efforts to assure not only high quality initial training for students of science, but just as importantly, their updating or retraining to match the pace of scientific discovery and the ever-broadening sphere of scientific knowledge.

The Foundation's mandate is "to strengthen basic research and education in the sciences," and the Foundation believes that improvement of science education should be vigorously pursued and supported throughout our schools and colleges. In pursuit of this aim, the NSF staff, with the advice and counsel of scientists from universities, colleges, and research establishments, have laid out some specific goals. Significant improvement in science education requires that we improve the subject-matter competence of teachers of science, mathematics, and engineering; provide modern materials of instruction and courses of study; provide, through fellowships and advanced science seminars, support which will enable the most talented of the science graduate students and established scientists to obtain the best advanced training available; provide specialized training in science for high-ability college and high school students; and provide the specialized facilities and equipment which are necessary to scientific study. Such efforts must be vigorously pursued if the Nation is to maintain an adequate supply of well-trained scientists and engineers.

In pursuing its various aims for educational improvement, the Foundation has adopted a clear and firm policy of avoiding Federal encroachment into the control of education. The above-mentioned goals as well as the means chosen to achieve them were developed in consultation with members of the academic community at all educational levels.

Teacher education in subject matter is supported by the Foundation, but the institutes and conferences providing such training are planned and directed by university and college professors. The Foundation does not determine the academic program nor the administration of the program, including the selection of participants, except to establish the general principles to be followed in selection. These matters are considered to be primarily in the realm of academic responsibility rather than governmental. Thus, the director of each institute is responsible for planning the special courses, securing the teaching staff, selecting the participants, and awarding stipends.

Efforts to improve course content are supported through grants to professional societies, universities, or specially organized interinstitutional groups of scientists and educators. Such projects come into being when scientists of high professional stature and teachers of recognized competence and experience determine that an urgent need for improved course materials exists in a particular field. These individuals develop the plans and propose the action to be taken. Projects for course content improvement are selected for support on the basis of their merit.

In making its decision to support a project or program the Foundation is guided by the advice of panels of scientists and educators who are drawn from various institutions of higher learning in the United States. These panels review and evaluate each request for support, and recommend those proposals which are considered to be highly meritorious. The judgment of the Foundation's staff in making the final selection of proposals to receive support is supplemented with the advice of these consultants. In this way the direction of science education is left to the scientific community and professional educators, and the Foundation maintains a position of noninterference with control of education while still providing the necessary support for efforts which concern the Nation as a whole.

UNIVERSITY- AND GRADUATE-LEVEL PROGRAMS

Graduate Students and Advanced Scholars

From the beginning of its existence the Foundation has stressed the importance of providing support for graduate students and advanced scholars of outstanding ability in the sciences. These individuals represent the backbone of the Nation's scientific potential. Opportunities for advanced scientific training for them are made available through both research and educational programs of the Foundation. A substantial number of graduate students, serving as research assistants, receive skilled guidance and training while working under the leadership of principal investigators of NSF-supported research projects. An estimated 6,900 research assistants participated in such projects in fiscal year 1964. The Foundation also offers fellowships which range from predoctoral to senior postdoctoral levels and provide the recipients with opportunities to continue their scientific education to the most advanced level of which they are capable. Applicants who receive NSF fellowship awards are survivors of an exceedingly rigorous national competition and are selected solely on the basis of their ability. Stipends and appropriate allowances are provided in all NSF fellowship programs.

Since the inception of NSF fellowship programs in 1952, the number of applications for fellowships has followed a steady upward course. For the first time political science will be included in the scientific field coverage in fiscal year 1965. Undoubtedly this additional field will serve to create a further increase in applications for fellowships.

This year, as in previous years, the largest numbers of fellowships awarded were in the Graduate and Cooperative Graduate Fellowship Programs. These programs provide support to unusually able students who are studying for a master's degree or a doctorate in science, mathematics, or engineering. The awards enable the recipients to complete their studies with the least possible delay. Graduate Fellowships differ from Cooperative Graduate Fellowships in that the former are awarded on the basis of a nationwide competition among candidates in which they apply directly to the Foundation and awardees may attend the graduate school of their choice. The Cooperative Graduate Fellowships Program is administered jointly by cooperating universities and the National Science Foundation, and individuals seeking awards in this program must apply through and be initially evaluated by the universities which they expect to attend as fellows. The Foundation received 12,749 applications in these two programs (an increase of 19 percent over the number received in fiscal year 1963). Approximately 3,000 of the 3,226 awardees accepted fellowships to begin tenure during the 1964–65 academic year, representing 2.4 percent of the Nation's graduate enrollment in the disciplines which the Foundation supports.

Other fiscal year 1964 fellowship awards for graduate and advanced level study were: 96 Senior Postdoctoral Fellowships, 240 Postdoctoral Fellowships, 908 Summer Fellowships for Graduate Teaching Assistants, 325 Science Faculty Fellowships, and 292 Summer Fellowships for Secondary School Teachers. (See table 7 for distribution of awards by program and field.)

Senior Postdoctoral Fellowships are awarded to scientists who have had their doctoral degrees for at least 5 years and who have demonstrated marked ability and special aptitude for productive scholarship in the sciences. Awards provide opportunity for highly specialized study and research during a period of leave. The program is flexible in nature so that it can be adjusted to the individual needs of the fellow.

Postdoctoral Fellowships are intended primarily for scientists who have recently received a doctoral degree and who need and are qualified for additional advanced training preparatory to undertaking specialized scientific work.

Summer Fellowships for Graduate Teaching Assistants are designed to make it possible for graduate teaching assistants in science, mathematics, and engineering to continue their academic study on a full-time basis during the summer, and to help improve the attractiveness of teaching assistantships as a means of graduate student support. The program is administered by each cooperating graduate institution for its own graduate teaching assistants.

Science Faculty Fellowships are intended particularly for the many college teachers of science, mathematics, and engineering who were drawn into teaching after receiving only a nominal amount of postbaccalaureate training, as well as for those who have been teaching for a long period of time with only scant opportunity for "refresher training" in their fields of specialization.

Summer Fellowships for Secondary School Teachers are awarded to those secondary school teachers of science and mathematics whose academic preparation will enable them to undertake further studies at advanced levels comparable to those of other graduate students in science and mathematics. The program is in addition to, and separate from, the Foundation's continuing institute programs for the supplementary training of teachers.

In addition, the Foundation awarded 43 Senior Foreign Scientist Fellowships to scientists from other countries who are invited by host universities in this country. Recipients of such awards conduct seminars, undertake research, and in other appropriate ways share their knowledge with faculty members and students at U.S. graduate schools.

Recently much stress has been placed on the problem of graduate education in engineering, mathematics, and physical sciences. In its report of December 12, 1962, on this subject, the President's Science Advisory Committee urged that immediate steps be taken to increase the number of master's and doctoral degrees awarded each year in these disciplines. Thus, the Foundation is now giving attention to new forms of support of graduate training in certain specialized areas of science which are known to be, or will be in the foreseeable future, in short supply of highly trained manpower.

Graduate education for engineers was the first to receive such supplementary NSF support, since manpower statistics indicated that engineers in particular were in need of advanced training; only 1 percent of the engineers in the United States holds the doctoral degree and 7 percent hold master's degrees. By comparison the percentage of U.S. scientists holding graduate degrees is substantially higher; 19 percent hold the doctoral degree, and 38 percent hold master's degrees. Further, the engineers of today and tomorrow must be prepared to meet many additional and varying demands of their profession. They must keep abreast of new science and technology, and know more science than their predecessors

Table 7.—National Science Foundation Fellowship and Traineeship Awards Offered by Program and Field, Fiscal Year 1964

Field	Total	Graduate	Cooperative graduate	Graduate traineeships	Graduate teaching assistants	Post-doctoral	Senior post-doctoral	Science faculty	Secondary school teachers	Senior foreign scientists
Engineering	2, 051	265	320	1, 220	108	17	9	105	....	7
Mathematics	1, 048	372	236	....	175	26	7	82	142	8
Physical sciences:	1, 856	714	495	....	364	104	39	61	60	19
Astronomy	37	16	11	....	1	4	2	3	0	0
Chemistry	772	234	183	....	228	52	16	17	37	5
Earth sciences	174	77	28	....	41	8	5	6	6	3
Metallurgy	30	10	12	....	7	0	0	1	....	....
Meteorology	4	1	1	....	0	2	0	0	....	....
Oceanography	9	4	2	....	0	0	1	1	....	1
Physics	830	372	258	....	87	38	15	33	17	10
Subtotal	4, 955	1, 351	1, 051	1, 220	647	147	55	248	202	34
Life sciences:	825	311	137	....	133	73	28	55	81	7
Agriculture	14	4	2	....	2	1	1	2	1	1
Biochemistry	148	78	26	....	8	19	7	1	6	3
Biology, general	152	43	19	....	21	6	4	12	47	0
Biophysics	68	42	10	....	2	8	2	2	2	0
Botany	101	31	27	....	23	11	3	4	2	....

Genetics	47	20	13	....	5	4	2	2	1	....
Medical sciences	20	2	2	....	5	6	1	3	....	1
Microbiology	31	14	5	....	6	1	2	3	0	0
Pathology	2	0	1	....	0	0	0	1	....	....
Psysiology	68	36	11	....	5	7	4	5	....	....
Zoology	174	41	21	....	56	10	2	20	22	2
Social sciences and psychology:	559	238	138	....	128	20	13	20	0	2
Anthropology	49	29	8	....	8	2	2	0	0	....
Archaeology	19	13	1	....	5	0	0	0	....	....
Economics	168	62	43	....	51	3	2	7	....	....
Geography	14	2	2	....	6	0	0	3	....	1
History and philosophy of science	37	19	7	....	1	4	2	4	....	0
Linguistics	10	7	3	....	0	0	0	0	....	....
Psychology	197	87	53	....	38	9	6	3	0	1
Sociology	58	18	18	....	17	2	1	2	....	....
Social sciences, other	7	1	3	....	2	0	0	1	....	....
General science	11	....	....	....	....	....	....	2	9	....
Subtotal	1, 395	549	275	....	261	93	41	77	90	9
Totals	6, 350	1, 900	1, 326	1, 220	908	240	96	325	292	43

knew. Basic engineering training alone does not adequately equip them to cope with the swift advances in engineering.

In answer to the engineering education problem the Foundation established the Graduate Traineeship Program in fiscal year 1964. The role of the Foundation in this program is to select those institutions or departments which are to receive grants, with selection of individual participants being left to the department or university. Eligibility is restricted to institutions conferring doctoral-level degrees in at least one of the areas of engineering. An important criterion for selection is the capacity of the department to train additional students and/or accelerate the progress of students presently enrolled in advanced degree programs.

Response to the traineeship program in its first year indicated a high degree of interest on the part of institutions and students. A total of 109 different institutions (virtually all of the schools that offer advanced degrees in engineering) received grants, which will support training for a total of 1,220 graduate students in engineering. In 1965 the Graduate Traineeship Program will be extended to include the fields of mathematics and physical sciences.

Improving Graduate Courses

Graduate education is in a state of ferment across the Nation. Not only are institutions which previously did no graduate work now offering advanced degrees, but well-established graduate schools are offering advanced degrees in new, interdisciplinary fields. Further, even traditional departments in established schools are revising, updating, and improving their graduate work. Since each department in each university has its own ideas about improving its programs, the Foundation has not tried to establish a formal program to assist with this problem; instead it pursues a course of searching for and testing a wide variety of plans for educational improvement. Individual departments or coalitions of cooperating departments or institutions are invited to submit plans that seem to them best suited to their individual situations.

Typical requests for graduate science-education improvement projects are for support to introduce new courses or degree work. (For example, a university not offering an advanced degree in a standard area wishes to begin to do so and believes it has the strength to do so; an institution offering advanced degrees in the traditional disciplines wishes to introduce a new interdisciplinary or extradepartmental degree; or a department in which classical, descriptive geology has been emphasized wants to introduce modern, analytical earth science.) Comparatively modest, rather short-range and specifically planned support is needed to enable the institution to make the crucial first step. This type of valuable activity is encouraged by the Foundation, although only small-scale support can be provided at this time.

COLLEGE- AND UNDERGRADUATE-LEVEL PROGRAMS

Undergraduate Students

The ever-increasing number of students who seek a college education and the rapid growth of scientific knowledge complicate the tasks of undergraduate institutions in providing scientific instruction which meets modern needs.

The Foundation believes that the most promising undergraduate students majoring in the sciences should be encouraged to continue their studies beyond the baccalaureate, and should be as ready as possible to make a smooth transition from undergraduate to graduate work. The Undergraduate Research Participation Program has aided these objectives by making it possible for about 1 percent of the Nation's ablest undergraduate science students to engage in research under faculty direction. This program provides support to colleges, universities, and nonprofit research institutions for conducting activities in research which will contribute to the scholarly development of talented undergraduates interested in the sciences. In many instances, projects for undergraduate participation are part of current research activity being conducted on campus, under appropriate direction, and with adequate primary support. In other cases—particularly in the smaller colleges—science departments, without major involvement in research but with competent staffs, conduct projects for a small number of able undergraduates. During the summer the students participate on a full-time basis; during the academic year many projects provide for part-time student participation. In these projects each undergraduate participant becomes the junior colleague of an experienced scientist in investigating a research problem. The collaboration is mutually advantageous. The student learns scientific research methods in the most effective way possible—by practicing research techniques under the tutelage of an established researcher—and many senior scientists find real stimulation in these close contacts with first-class young minds. Support for such efforts is gradually increasing; approximately $6.1 million was awarded by the Foundation in fiscal year 1964.

College Faculty

In coping with the problem of college faculty improvement, NSF-supported institutes and conferences are designed to offer supplementary training that is not ordinarily available in the regular offerings of graduate schools. Teachers are grouped so as to be homogeneous in ability and in need for training. Most of these institutes and conferences are at an advanced level, but with the more recent increases in the number of science faculty who are not fully trained in science, more institutes are emphasizing instruction in basic subject matter and a greater duration of study.

Two types of institute programs are available to college teachers: Summer Institutes and Academic Year Institutes. Summer Institutes vary considerably in the number of teacher-participants and duration of summer study, but 35 participants and 7 weeks are average. Subject-matter offerings are ordinarily in a single area (e.g., biology). In these institutes teachers have an opportunity to hear lectures by scientists of stature, to discuss new scientific concepts and developments, and to benefit, in general, by being exposed to progress and advanced thinking in their fields. Graduate credit is frequently available to those teachers successfully completing the work. Academic Year Institutes are conducted on a full-time basis for 9 to 12 months and provide an opportunity for intensive study of an appropriate sequence of courses in subject matter of the teachers' disciplines. Through such study, participating teachers may obtain a master's degree. Both types of institute programs offer especially designed courses for groups of teachers with particular subject-matter needs. The program of Conferences for College Teachers affords teachers who have other commitments during the summer an opportunity to participate in an intensive study of recent developments in their specific fields for a period of 1 to 4 weeks. Most of these conferences are held during the summer. A typical conference enables a group of college teachers with similar backgrounds to work together under the guidance of specialists in a particular subject-matter area.

Fiscal year 1964 grants for these supplementary training programs will support approximately 3,800 participants, an increase of 17 percent over the previous year's participation. The average period of training has been increased, with greater emphasis on year-long programs at academic year institutes for college teachers most in need of substantial training—those who have not yet reached the master's degree level. These teachers are principally from community colleges, junior colleges, and teacher training institutions. The wide-spread effect of these programs on the academic community is demonstrated by the fact that participants this year come from 890 colleges and 358 junior colleges.

The variety of subject-matter programs offered in the institutes has increased; notably, there are more offerings in the social sciences and more opportunities for technical institute faculty to study the sciences which are basic to the subjects they teach.

Other study opportunities for college teachers are made available through NSF Science Faculty Fellowships and the Research Participation for College Teachers Programs. The Science Faculty Fellowship Program is particularly important for faculty of colleges and universities that do not produce large numbers of science doctorates but do turn out a significant number of undergraduate students who continue on to graduate school. In fiscal year 1964, for example, 81 percent of the individuals who were offered awards were college teachers from such "smaller schools," and there is considerable evidence that these key teachers return to strengthen their institutions at the conclusion of their training. Opportunities for research participation are of obvious benefit to college teachers. Each participant works as an associate of experienced scientific investigators. For some teachers this summer program will be a first experience in research; for others it will constitute an awakening of an interest long held dormant by the pressures of heavy teaching loads and extracurricular duties at their home institutions.

Improving Undergraduate Courses

Significant activity for improving courses is in progress at the undergraduate level. Assisted by NSF grants, mathematicians, scientists, and engineers are creating new models of undergraduate courses and curricula which authentically reflect contemporary knowledge, modes of inquiry, and organizing ideas across the whole range of the sciences. It is hoped that the results of their work will be useful to faculty members and to producers of educational materials throughout the Nation.

Plans for undergraduate course-content improvement projects come into being when scientists and teachers determine that an urgent need for improved instructional materials exists in a particular scientific field. Such individuals propose the action to be taken, which may be the writing of new textbooks, making instructional films, or developing teaching apparatus. Proposals are submitted by individual scientists or groups of scientists through a sponsoring university or professional society, and all proposals are judged on the basis of their relative merit. Selection of proposals to be supported is based on the involvement of the best scholars available in efforts that give promise of wide usage. Projects that receive support range all the way from efforts centered in one individual on a particular campus to group efforts such as special college commissions which draw participants from all parts of the United States and from all types of colleges and universities.

Since there is currently so much activity in curriculum development, both with and without NSF support, it has seemed desirable in some areas to assist the establishment and operation of coordinating groups that can help to reduce needless duplication of effort, detect omissions, stimulate needed projects, and serve as information sources. Such NSF-supported "nerve center" groups for the improvement of course content in mathematics, biology, chemistry, physics, geography, engineering, and agriculture have become increasingly active. A noteworthy feature has been collaboration among various scientific commissions in involving the scientific communities they represent in exploring problems of mutual interest. The Commission on College Physics and the Advisory Council on College Chemistry jointly sponsored a conference on science materials for prospective teachers in elementary schools; as a result, several working groups are being organized to develop new courses. The Commission on the Undergraduate Program in Mathematics has obtained assistance from the Commission on Engineering Education in developing a sourcebook of engineering applications of contemporary mathematics. Mathematicians have also sought the advice of several other groups in developing and reviewing recommendations on mathematics programs for students interested in the physical sciences and engineering, and in the biological and social sciences. The Commission on College Physics has taken a leading role, again with some participation by other commissions, in the initial exploration of the desirability and feasibility of inter-institutional regional centers for science teaching development. During the summer of 1964 the physics group will also sponsor a working conference on a curriculum for college majors who do not intend to go into research in physics. A related project sponsored by the University of Colorado will bring a group of scientists together to deliberate on suitable science content for non-science majors.

In engineering, certain institutions have shown special interest in a variety of attempts to exploit a systems approach for advanced undergraduate education (this approach emphasizes the application of conventional engineering disciplines in the development and matching of the components of the desired end product, such as an airplane, automobile, or satellite). Instruction in design, considered to be the distinctive feature of engineering as contrasted with science, is also receiving attention. Engineering educators are showing an increasing interest in the potentialities of the use of films in instruction; a major NSF project is continuing in fluid mechanics and another has been started in electrical engineering.

A key problem, directly related to course content improvement, is the urgent need for modern scientific instructional equipment in many of our undergraduate institutions. Recent surveys of the national requirement for additional scientific equipment indicate that undergraduate institutions should spend more than $1 billion for such equipment in the next 10 years. Not only do increasing college enrollments call for more equipment, but existing equipment is made obsolete by rapid advances in science and engineering and by the increasing readiness of entering students to undertake relatively sophisticated studies. The Foundation's role in this area is not narrowly defined as that of providing equipment through matching-fund grants. Rather, each request for funds is judged in terms of the total curriculum plan in which the equipment request is contained. Thus, the program simultaneously serves to encourage local course content improvement. In order to advance this objective, awards are based on the institution's evidence of realistic self-examination and detailed planning, carried out by a competent staff.

Activity in the Undergraduate Instructional Scientific Equipment Program reached an all-time high this year. Grants for equipment totaled nearly $9 million, more than $1 million greater than the amount obligated in fiscal year 1963. A most gratifying fact is that the number of institutions receiving grants under this program increased substantially, from 346 in fiscal year 1963 to 648 in fiscal year 1964. Of the 648 institutions receiving grants, 294 had never before received assistance under this program.

NSF-supported visits of outstanding American scientists to college campuses also contribute to the enrichment of educational programs. The visiting scientist, who is invited by the college or university, usually gives at least one formal lecture, conducts classes or seminars in his specialty, engages in informal discussions with students concerning subject matter, research, or careers, and confers with faculty members and administrative personnel on matters of educational policy and curricula. Though everywhere serving to stimulate scientific activity, the visitors are particularly effective in those institutions which need and seek expert advice on the improvement of science education.

With the avowed purpose of searching for and testing appropriate means of providing comprehensive support for improvements in educational programs, the Foundation makes grants for some highly specialized efforts of individual institutions or associations of several cooperating institutions. Such activities, tailored to the needs of a specific department, institution, or group of institutions, may be supported if they meet two requirements. The first is the value of the proposed activity as an experiment in undergraduate science education, the results of which would be useful to other colleges and universities and to other programs within the Foundation. The second is the value of the proposed activity in creating a definite upward movement in the quality of the particular unit being supported.

A few examples may serve to illustrate the nature of these specialized efforts. An association of 10 colleges in Minnesota, Wisconsin, Iowa, and Illinois—known as the Associated Colleges of the Midwest (ACM)—is working in cooperation with the University of Costa Rica to establish in a tropical region an undergraduate training program in the environmental sciences. Experience and research opportunities provided by this training will be of benefit to the members of the ACM faculties as well as the undergraduate students. Similar off-campus cooperative programs for teachers and students are supported by three other grants. The four grants made in fiscal year 1964 for this type of activity amount to a total of some $200,000, covering about 3 years of support. At Duke University, as part of a general reorganization in the College of Engineering, the entire undergraduate curriculum in engineering is being studied and revised. Graduate education development grants for similar activities have been made to two other institutions this year; the total dollar amount invested for the three grants is about $285,000, which covers 7 years of support. At the University of Michigan, new materials in the use of computers in engineering design will be developed and taught to groups of engineering faculty members. About $440,000 has been awarded this year for the support of this effort and two similar activities providing for development of instructional materials and the training of teachers in the use of these materials.

SECONDARY SCHOOL PROGRAMS

Secondary School Teachers

More than a decade ago the Foundation became concerned about the subject-matter competence of secondary school teachers of science and mathematics. At that time it was fairly well known that science training provided by the high schools was often of such poor quality that colleges and universities were handicapped in the kind of training they could offer to college-level students. Consequently, the Foundation began to experiment with summer institutes for secondary school teachers of science and mathematics. These summer institutes proved to be very successful, and in response to the wishes of the Congress they were vastly increased in number. Today institute training for secondary school teachers represents the Foundation's largest single effort in support of education in the sciences ($39 million).

Institute activities are now available to secondary school teachers not only during their summer vacations but also during the academic year. The Summer Institutes provide about 2 months of concentrated study for groups of teachers with good, average, or inadequate backgrounds in the subjects they teach; the courses are designed to meet the needs of each specific group. Academic Year Institutes give the teachers an opportunity to study intensively an appropriate sequence of courses in the subject matter of their disciplines on a full-time basis for 9 to 12 months. In contrast, the In-Service Institutes offer instruction on a part-time basis during the academic year, so that teachers may receive training while still teaching full-time in their schools. Training usually includes classroom instruction, seminars, and laboratory experience especially designed to aid teachers in improving their courses and teaching methods. Approximately 35,200 secondary school teachers of science and mathematics will receive institute-type training as a result of grants made in fiscal year 1964. This number represents about 16 percent of the U.S. teachers of these subjects.

The Foundation is aware that more teachers desire and need supplementary training and that their number is growing. Because there is an annual increase in the total number of teachers employed and because the number of science and mathematics teachers supported in institutes has remained fixed at about 35,000 a year for the last 3 years, the share who receive training has declined from 19 percent in fiscal year 1962 to the present 16 percent. Under current budget projections for fiscal years 1965 and 1966, approximately the same numbers will be supported—which means that the percentage will drop to about 14 percent. There is no doubt that providing the necessary supplementary training will continue to be a problem which requires close attention. The Foundation's institute programs have helped many science and mathematics teachers to improve their competence. Beginning in 1954 with one summer institute for 26 secondary school teachers of science and mathematics, NSF-supported institutes for secondary school teachers reached a record high of 782 providing training for 35,200 teachers in 1964. To date 210,000 institute training opportunities for teachers at this level have been supported by the Foundation. Clearly, steady prog-

Table 8.—Percentage of Eligible Teacher Population Attending NSF Institutes, 1964

Teaching Level	Number of institutes	Teachers attending	Eligible teacher population	Percent attending
COLLEGE:				
Academic Year Institutes	22	226		
Summer Institutes	75	2,471		
In-Service Institutes	4	78	125,000	3.0
Conferences	35	1,052		
	136	3,827		
SECONDARY SCHOOL (grades 7–12):				
Academic Year Institutes	59	1,707		
Summer Institutes	439	20,411		
In-Service Institutes	282	13,085	220,000	16.0
Conferences	2	55		
	782	35,258		
ELEMENTARY SCHOOL:				
Summer Institutes	37	1,236		
In-Service Institutes	70	2,118		
	107	3,354	[2] 1,100,000	0.3
Totals	[1] 1,025	42,439	....	....

[1] Actual number is 1,002, since 23 institutes serve 2 academic levels.

[2] Includes all elementary school teachers, since nearly all teachers on this level teach science and/or mathematics.

ress in this area of need is being made. Nevertheless, the need for supplementary training will not decrease since some 25,000–30,000 new teachers of these subjects are employed as replacements and additions each year, but less than half of these college graduates are certified to teach science or mathematics.

Thus, until a significantly greater number of properly qualified science teachers graduate from colleges and universities each year, the need for institutes will continue to exceed the present NSF funding levels. Methods by which this gap between demonstrable needs and available funds can be covered through greater emphasis on in-service institutes (those conducted locally after school hours and on Saturdays during the school year) and other low-unit-cost programs are being explored. It is evident that solutions to this problem are urgently required.

Special training that increases the teacher's subject-matter understanding is provided through the Research Participation for High School Teachers Program, which affords teachers an opportunity to work with experienced scientific investigators in the laboratory or in the field during the summer. This training may include appropriate seminars on scientific subjects and research techniques designed to improve the teacher's competency in the teaching of science. Opportunities for 8 to 12 weeks of such research training and experience were provided in the summer of 1964 for 354 secondary school teachers of science, all of whom possessed the necessary background in science to qualify for this rigorous type of training. Eighty-six of these participants will receive a small amount of financial aid to assist them to continue their research at their high schools during the school year.

Improving Secondary School Courses

Improvement of courses of study in science and mathematics and of the devices to teach such courses effectively at the secondary school level represent a major goal of the Foundation's educational efforts. Not many years ago students all over the Nation were studying from books which were well-written but, quite literally, antiquated in content. High school courses in mathematics and the sciences tended to bear little relevance to science as it is today and as it is understood by those research scientists who stand at the forefront of their respective fields. The Foundation's approach to this problem was to encourage leading scientists to become involved in devising new courses of study which are in fact based on contemporary science.

Large-scale projects concerned with physics, mathematics, chemistry, and biology courses for secondary school students were the first to receive the attention and support of the Foundation. Projects have evolved steadily since 1954 and considerable progress has been made over the years. This year witnessed the publication of commercial versions of the battery of courses and associated materials for high school biology developed by the Biological Sciences Curriculum Study, as well as books and films for alternative high school courses in chemistry prepared over the last several years by the Chemical Bond Approach Project and the Chemical Education Material Study. More than 250,000 students, from almost every State, are already using the biology courses; another 200,000 are using one or the other of the chemistry programs. Mathematics texts developed by the School Mathematics Study Group are available to interested schools and individuals and are being used extensively. The commercial version of the Physical Science Study Committee's High School Physics, published in 1960, is estimated to be used by 160,000 students.

The Foundation does not support or encourage activities which could reasonably be construed as constituting an endorsement of courses, textual materials, and related instructional devices by the Federal Government or an attempt by the Government to persuade school systems to adopt such materials. Fundamental policy in American education places responsibility for the choice of curricula for elementary and secondary schools, colleges, and universities in the hands of teachers, school administrators, school boards, faculties, and other appropriate local authorities. Hence, the Foundation directs that funds granted for course content improvement projects shall not be used in any way to promote the adoption of the products of such projects by schools or colleges. Grants are to be used only for the development of new instructional programs and materials and for the dissemination of information about them. Textbooks, laboratory guides, films and other audiovisual aids, laboratory demonstration apparatus, supplementary readings and other materials produced by NSF-supported projects are made generally available through commercial channels, at prices competitive with similar materials from other sources. There is no financial advantage for schools in using the products of Foundation-supported endeavors. The Foundation's position is simply that the new course materials have been prepared by leading scientists and teachers and that their own merit should determine their adoption or rejection by schools, in competition with other available materials.

A recent development in curriculum reform is the attention being given to the social sciences. In the past year the Foundation has provided support for preparing anthropological materials for high school courses in social studies, and for curriculum projects in sociology and geography (all sponsored by principal professional societies in these fields).

Several NSF-supported projects are specifically concerned with science for junior high schools, a level widely believed to require great improvement. Princeton University is sponsoring preparation of laboratory-centered materials for grades 7 and above, using study of the earth to uncover fundamental ideas about time, space, matter, and energy. Responding to widespread demand from schools, the Earth Science Curriculum Project of the American Geological Institute will have a first version of a ninth grade course ready for school trial in 1964–65. Educational Services Incorporated is designing a general course in physical science, built around the investigation of the nature and behavior of matter, to be used in junior high schools as preparation for the study of high school biology, physics, and chemistry.

Another of the Foundation's approaches to improving the science and mathematics offerings in secondary schools is to foster collaboration between colleges and school systems in carrying out particular science activities. Through NSF-supported Cooperative College-School Science activities, attention is focused on the needs of specific schools, and means are devised to assist the schools in adopting modern science courses. In programs of this nature, secondary school teachers and officials cooperating closely with college scientists have already increased the caliber of science and mathematics instruction in several school systems by providing for the retraining of key teachers, introduction of new courses, and demonstration classes for students.

Secondary School Students

The problem of providing specialized training for high-ability secondary school students is also of concern to the National Science Foundation. A significant number of secondary school students—though a small proportion of the population—possess the ability, intelligence, and personal traits to develop into the scientists and engineers of the next generation. Such students must be identified and motivated to study science. Hence, under its Secondary Science Training Program, the Foundation supports especially designed activities for students who are talented in science. These activities permit the student to be brought into close association with experienced scientists through challenging classroom and laboratory training conducted during the summer. By working through interested colleges and research laboratories, the Foundation seeks to set high standards for such training. (A recent trend is the adaptation of these activities to academic-year research training, usually conducted on Saturdays.) During the summer of 1964 the Foundation supported 185 of these special projects through grants totaling \$2.4 million which provided training opportunities for 7,600 students. Training ranged from a course in mathematics conducted at Lehigh University in Bethlehem, Pennsylvania, for commuting students, to research in oceanography conducted at the University of California (San Diego).

Attention is also being given to special training for the economically and educationally disadvantaged students who possess academic ability. This year, for the first time, the National Science Foundation has made a few grants for projects to help such students from urban slum areas to develop their interest and ability in science. For example, 120 students from the urban area of Chicago were chosen for a 6-week intensive course in modern mathematics and physical sciences conducted at the University of Chicago. These students were judged by their schools as having high potential and yet unlikely to be prepared to receive a first-rate college education because the challenge in their normal high school courses is inadequate for them. The intensive and thought-provoking training they received during the summer has awakened academic interest in almost all of these students, and this will be followed by special attention to the students' academic achievements during the ensuing academic year, with the University and the Chicago school officials cooperating in the enterprise. Quite possibly the pool of potential scientific manpower can be enlarged by reaching such students through training especially designed for them. This effort is, of course, experimental, and the results will determine the extent of future support for such activities.

Another NSF-supported activity of benefit to secondary school students of science is the Holiday Science Lectures series. These lectures provide an opportunity for secondary school students to hear working scientists describe their activities, findings, and interpret their significance. Such lectures are presented in several cities during the winter and spring holidays. An estimated 4,000 high school students attended these lectures during the past year.

ELEMENTARY SCHOOL PROGRAMS

Elementary School Personnel

A major consideration in providing supplementary training in science and mathematics for elementary school teachers is the fact that very few of the approximately 1,100,000 elementary school teachers in the United States (kindergarten through grade 6) have any appreciable training in these subjects and are qualified to teach them. Consequently, the Foundation has chosen necessarily to concentrate on training leaders who may, in turn, influence and instruct their colleagues. This training is conducted in summer institutes for which participants are selected on a national scale and in the more numerous in-service institutes, which are oriented to local needs.

The institutes for elementary school teachers are directed toward improving the subject-matter background in science and mathematics of those individuals holding key positions in (1) introducing the teaching of science and (2) improving the teaching of mathematics in the elementary grades. This group of individuals include specialist teachers, subject-matter supervisors, principals, and regular classroom teachers who are leaders in science instruction in their schools. Most of these individuals have had minimal training in either science or mathematics, yet they are being called upon to lead their schools in adjusting to new curricular ideas which introduce science, the scientific method, and an understanding of fundamental mathematical concepts. As a result of grants made in fiscal year 1964, about 3,350 elementary school personnel in the categories mentioned will receive training next year. This represents a 37 percent increase in the number of individuals as compared with last year's participants.

Although funds for institutes for elementary school personnel were increased this year, the Foundation continues to receive many more meritorious proposals for these institutes than it can support and, at the same time, the number of applications received by the grantee institutions is about fifteen times the number of places available. The Foundation is considering means of assisting more teachers. One plan is to encourage local instructional programs supervised by university scientist-educators, but staffed by local secondary or elementary school teachers who have received special training for the purpose. This arrangement should materially reduce the operating costs as well as the manpower demand on colleges and universities.

Improving Elementary School Courses

The lack of clarity concerning what in science and mathematics can and should be taught in the elementary grades has made approaches to improvement at this level particularly difficult to determine. However, in the last few years, greatly increased attention has been given to this question and to the development of appropriate course materials for science and mathematics instruction in elementary schools. Experiments with new course materials have revealed that students at all age levels are capable of understanding subject matter of a relatively high degree of sophistication when the instructional materials are properly designed and appropriately presented.

Course materials in mathematics, developed under an NSF grant to the School Mathematics Study Group, are presently used by many elementary schools in the United States. To cite more recent developments, the Commission on Science Education of the American Association for the Advancement of Science is studying such general issues as: appropriate objectives for science instruction in elementary and junior high schools; variations in scope and sequence of science content; the education or re-education of teachers; effective evaluation of curriculum developments; and cooperative coordination among curriculum improvement projects. In addition, the Commission has prepared and tested a first version of one curriculum stressing basic processes of science for kindergarten through grade 3. During 1964–65 this curriculum will be revised and extended to grade 5 for further experimental trial.

A number of novel approaches to elementary science teaching are being tried out at the University of California, Berkeley; State University of New York, Stony Brook, Long Island; Utah State University, and elsewhere. These experiments may well supply ideas on how to foster in younger pupils an enduring curiosity about scientific studies. One project group is devising ways of leading second graders to an intuitive understanding of the relativity of motion, and fourth graders to a grasp of fundamental ideas of thermodynamics.

The social sciences are also receiving attention at the elementary level. The production of an extensive series of films that will bring basic information on human societies, past and present, into the classroom is being supported by the Foundation as part of an introduction to the social sciences in the elementary grades.

As is true of other educational levels, future changes in mathematics and science instructional materials at the elementary school level will undoubtedly be built upon the rapidly evolving structure and content of the subjects themselves, new insights into the capabilities and needs of our greatly diverse school population, and new possibilities for better instruction which have emerged from the results of earlier work in course content reform.

SCIENCE INFORMATION

Methods of disseminating the results of scientific research are undergoing extensive changes. The time is gone when oral, written, and printed communications on relatively modest scales were sufficient to maintain the effective flow of scientific information. The ever-greater number of scientists and engineers conducting or using the results of research, the increasing complexity of research, and the development of multidisciplinary efforts have combined to make conventional information-dissemination methods seriously inadequate.

The goal of the Foundation's scientific information program is the development of an effective national information network to insure that U.S. scientists and engineers have readily available the world's current and past output of significant scientific and technical literature. A satisfactory information network should include a more efficient system for obtaining information about current research before the results are formally announced perhaps years later; quicker and less expensive methods for producing scientific journals; more comprehensive and useful abstracting and indexing services and techniques; and services and systems that aid the scientist or engineer in locating the specific information on his particular problem.

SCIENTIFIC PUBLICATION

Scientific Journals

The traditional means of promulgating scientific research results has been through scientific journals which are chiefly published by scientific societies. Many of these societies have run into publishing difficulties owing to the increase in the volume of research and the higher costs of printing. Other countries have met this situation by continuing government subsidies of scientific journals. In the United States, the Foundation, adopting the view that the cost of publication constitutes a legitimate part of the cost of research, has encouraged the expansion of the system of page charges whereby the sponsor of the research pays, in effect, for the editorial, composition, and make-ready costs of publishing an article; the subscription price meets the cost of printing and distribution. Now, some 69 U.S. journals assess page charges, and the Foundation is encouraging the expansion of this system.

To make publications more efficient, a number of new printing techniques are being investigated including the use of computer-controlled photocomposition and printing. For example, as part of a project to investigate the use of photocomposition for reproducing structural chemical formulas, the American Chemical Society, working with Foundation support, has developed specifications for the manufacture of a special matrix disc that has been successfully tested in prototype. Because typesetting of formulas has been a slow, expensive, and error-prone process, such advances in the use of photocomposition should prove of great value.

Related Foundation-sponsored work dealing with the possible use of the computer for machine-recording of textual information during the publication of scientific journals has produced promising preliminary results. They indicate that in time, automatically recorded information at the beginning of the publishing cycle could be used mechanically in subsequent operations of a wide variety, thus avoiding repetitive intellectual and clerical effort and thereby saving substantial time, manpower, and funds.

The Foundation continues to offer temporary support for the establishment of new needed nonprofit journals, the elimination of backlogs, and experiments in the more efficient production of journals. In the 1964 fiscal year, 6 such grants were made totaling $180,000.

Other Publications

The publishing of scientific monographs offers a continuing problem. In such fields as taxonomy the effective publication of results cannot be accomplished through journal articles because of the length of the material and expensive features such as color plates. The limited audience does not make this type of publication attractive to commercial publishers even though the material is of high scientific quality. Therefore, the Foundation is presently providing direct financial assistance for the publication of significant scientific monographs that are not commercially exploitable while alternative methods of effective solution of this problem are being explored. In 1964, 17 grants in the sum of $140,000 were awarded for the support of monographs.

ABSTRACTING AND INDEXING

In these times of a continually rising volume of scientific literature, abstracting and indexing services are ever-more essential for locating current and archival information. Coverage of these services has been expanding and speed of production considerably increased. For example, Biological Abstracts, aided by the Foundation, has grown from 40,000 abstracts per year in 1948 to 100,000 in 1963. Nevertheless, this area remains critical. It has been estimated that abstracting and indexing services in the United States cover less than 50 percent of the world's scientific and technical literature. The Foundation has been supporting a considerable amount of work directed toward improving these services, including increases in coverage, improved and more prompt indexing, and better coordination of services, nationally and internationally.

Plans are now being developed at the Chemical Abstracts Service, with Foundation support totaling $390,000, to establish a system of machine control of more than 2 million chemical structures with related technical information as a basis for a national computer-based chemical information service. Recently, a National Academy of Sciences committee, with Foundation support, completed a study of the present uses of non-conventional chemical notations as a background for further investigation to determine their adaptability for use in a mechanized retrieval system.

ORGANIZATION AND SEARCHING OF INFORMATION

Prompt processing of scientific information is essential if scientists and engineers are to obtain useful knowledge of current research. Leading to this end is the development in recent years of increasingly more sophisticated procedures for mechanically storing and retrieving science information. In fact, a number of operating systems already incorporate mechanized procedures to increase the speed or the accuracy and detail with which information can be retrieved.

The real difficulty in devising mechanized systems for organizing and searching large collections of scientific information is not technological; it is intellectual. The storage of information is not the key problem. The difficulty is how to organize the information for effective retrieval. NSF has supported research into development of more effective procedures for subject analysis, indexing, and searching; automatic techniques for grouping related concepts and for assigning documents to the resulting classes and categories; and automatic analysis and indexing of the texts of abstracts of scientific documents. Support of research in this area in 1964 totaled $859,000 for 17 grants.

With the development of new knowledge, techniques, and equipment has come the need for devoting more effort to experimental application of these advances to information systems. Costly failures in the installation of new systems may thus be avoided. The Foundation is, therefore, increasing its activities in this area.

INFORMATION RESOURCES

Scientific information resources of the United States include science information centers, research libraries or libraries with significant scientific literature collections, scientific research organizations, and the scientists and engineers themselves.

In the past it has been difficult for scientists or engineers to locate special information resources. Increased specialization in scientific research has tended to make the search more difficult because of the proliferation of sources of special knowledge or services. To provide a switching point where requests for information can be referred to the proper sources, the National Referral Center for Science and Technology was established in 1963 at the Library of Congress, with Foundation support and guidance. The Center has thus far identified over 11,000 scientific and technical information resources in Government, industry, and the academic community. Already the service has proved its value, and there are indications that this service will result in more effective use of existing information resources as well as point up the need for any necessary new resources.

In fiscal year 1964 the Science Information Exchange, a service to provide information on current projects in research and development sponsored by the Federal Government and other organizations, was placed under the overall direction and financial support of the Foundation. This facility, administered by the Smithsonian Institution, has information on over 40,000 biomedical research projects sponsored by the Federal Government and other cooperating organizations. The coverage is now being extended into the fields of the physical and social sciences. A comprehensive file on research projects is now accumulating rapidly and already contains more than 70,000 active projects.

The research libraries of this country have been investigating ways to improve the effectiveness and efficiency of their services. The Johns Hopkins University and the University of Illinois have, with Foundation support, been conducting system analysis of library operations to determine where presently used techniques can be improved and where mechanization can be introduced. Grants have also been made for experimental programs in the training of science library and information personnel at Georgia Institute of Technology, Lehigh University, and the University of Illinois.

FOREIGN SCIENCE INFORMATION

Scientific research carried on in foreign countries continues to show impressive gains in quantity and quality. When the results of such research are reported promptly and in a form readily available to U.S. scientists and engineers, unnecessary duplication of research can be prevented and useful ideas and information gained.

In the recent past, research results reported in such languages as Russian, Japanese, and Chinese did not become readily known in this country because only a small percentage of United States scientists can read these languages. Now, spearheaded by Foundation efforts, more than 100 journals in these languages are translated into English, either selectively by article or in their entirety. In fiscal year 1964, 54 Foundation-supported journals of translations provided 76,000 pages of foreign articles in English. Of these journals, 10 became financially self-sufficient during the past year, with the prospect that several more will do so in the near future.

Currently, a number of Federal agencies are attempting to make foreign science information available to American scientists and engineers. This effort is supplemented by Foundation programs, using counterpart funds (funds owed to the United States which can be spent only in the debtor country), to bring translated information from Russia and Eastern Europe by way of translating centers in Israel, Yugoslavia, and Poland. In fiscal year 1964, 35,000 pages of journal articles and books, as well as thousands of abstracts and patents were made available to U.S. scientists and engineers.

Since scientific activity is global in scope, unusual opportunities exist to improve dissemination of scientific information through international cooperation. Among the organizations that NSF is cooperating with are: International Federation for Documentation, ICSU Abstracting Board; International Federation of Library Associations, United Nations Educational, Scientific, and Cultural Organization, and the Organization for Economic Cooperation and Development. The Department of Scientific and Industrial Research of the United Kingdom and NSF are collaborating in an attempt to increase coordination of physics and engineering information activities, including abstracting and indexing services.

COMMUNICATIONS PATTERNS AND STUDIES

There still remains an urgent need for vastly improved techniques for the dissemination of scientific information and for a better understanding of the actual dynamics of communication process. In this connection, the Foundation sponsors research into the communication patterns of scientists. A noteworthy example is the American Psychological Association's study of information exchange in psychology.

The kinds of research now being undertaken and planned are expected to produce: (1) descriptive data on the way scientists and engineers now communicate and use information; (2) conceptual models of scientific processes which will clarify our understanding of the larger context in which the communication and use of scientific information takes place; (3) increased understanding of the functions served by information and information services; and (4) acceptable methods and criteria for evaluating objectively the utility of information services to users.

APPENDICES

A listing of grants, contracts, and fellowships awarded in Fiscal Year 1964 appears in a separate publication entitled "National Science Foundation Grants and Awards, Fiscal Year 1964", NSF 65–2. It is available from the Superintendent of Documents, U.S. Government Printing Office, Washington, D.C., at a cost of $1.00.

APPENDIX A

National Science Board, Staff, Committees, and Advisory Panels

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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

Robert E. Connick (Chairman), College 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 Hammond, Department of Chemistry, California Institute of Technology, Pasadena, Calif.

Harold Hart, Department of Chemistry, Michigan State University, East Lansing, Mich.

Werner Herz, Department of Chemistry, Florida State University, Tallahassee, Fla.

Terrell L. Hill, Department of Chemistry, University of Oregon, Eugene, Oreg.

Jacob Kleinberg, Department of Chemistry, University of Kansas, Lawrence, Kans.

Kurt Mislow, Department of Chemistry, New York University, New York, N.Y.

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.

Advisory Panel on Course Content Improvement Programs

Ray E. Bolz, Head, Engineering Division, Case Institute of Technology, Cleveland, Ohio.

Samuel Eilenberg, Department of Mathematics, Columbia University, New York, N.Y.

Ralph W. Gerard, University of California, Irvine, Calif.

William B. Shockley, Applied Electronics Laboratory, Stanford University, Stanford, Calif.

Robert R. Shrock, Department of Geology and Geophysics, Massachusetts Institute of Technology, Cambridge, Mass.

Harold R. Snyder, Department of Chemistry, University of Illinois, Urbana, Ill.

Richard H. Sullivan, President, Reed College, Portland, Oreg.

Donald W. Taylor, Department of Psychology, Yale University, New Haven, Conn.

S. L. Washburn, Department of Anthropology, University of California, Berkeley, Calif.

Advisory Panel for Developmental Biology

Eugene Bell, Department of Biology, Massachusetts Institute of Technology, Cambridge, Mass.

Anton Lang, Division of Biology, California Institute of Technology, Pasadena, Calif.

David M. Prescott, University of Colorado Medical Center, Denver, Colo.

M. N. Runner, Department of Biology, University of Colorado, Boulder, Colo.

John W. Saunders, Jr., Department of Biology, Marquette University, Milwaukee, Wis.

Herbert Stern, Department of Botany, University of Illinois, Urbana, Ill.

A. Sussman, Department of Botany, University of Michigan, Ann Arbor, Mich.

Hewson Swift, Department of Zoology, University of Chicago, Chicago, Ill.

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

O. H. Brownlee, Department of Economics, University of Minnesota, Minneapolis, Minn.

Richard A. Easterlin, Department of Economics, University of Pennsylvania, Philadelphia, Pa.

William L. Garrison, Department of Geography, Northwestern University, Evanston, Ill.

Stephen L. McDonald, Department of Economics, University of Texas, Austin, Tex.

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 Engineering Sciences

R. Byron Bird, Department of Chemical Engineering, University of Wisconsin, Madison, Wis.

Rudolf Herman, University of Alabama Research Center, Huntsville, Ala.

Walter R. Hibbard, Manager, Metallurgy and Ceramics Research Department, General Electric Co., Schenectady, N.Y.

Stothe P. Kezios, Director, Heat Transfer Laboratory, Illinois Institute of Technology, Chicago, Ill.

Gerald A. Leonards, Department of Civil Engineering, Purdue University, Lafayette, Ind.

Ernest F. Masur, Department of Engineering Mechanics, University of Michigan, Ann Arbor, Mich.

John L. Moll, Electrical Engineering Department, Stanford University, Stanford, Calif.

Max S. Peters, Dean of Engineering, University of Colorado, Boulder, Colo.

John R. Ragazzini, College of Engineering, New York University, New York, N.Y.

Samuel Seely, Department of Electrical Engineering, Case Institute of Technology, Cleveland, Ohio.

C. M. Sliepcevich, Department of Chemical Engineering, University of Oklahoma, Norman, Okla.

John Whinnery (Chairman), Bell Telephone Laboratories, Murray Hill, N.J.

Advisory Panel for Environmental Biology

George Bartholomew, Department of Zoology, University of California, Los Angeles, Calif.

John E. Cantlon, Department of Botany and Plant Pathology, Michigan State University, East Lansing, Mich.

W. Thomas Edmondson, Department of Zoology, University of Washington, Seattle, Wash.

Donald S. Farner, Department of Zoology, Washington State University, Pullman, Wash.

Robert F. Inger, Chicago Natural History Museum, Chicago, Ill.

Robert B. Platt, Department of Biology, Emory University, Atlanta, Ga.

Gordon Riley, Bingham Oceanographic Laboratory, Yale University, New Haven, Conn.

Frederick E. Smith, Department of Zoology, University of Michigan, Ann Arbor, Mich.

Edward O. Wilson, Biological Laboratories, Harvard University, Cambridge, Mass.

Advisory Panel for Genetic Biology

Ellis Englesberg, Department of Biological Sciences, University of Pittsburgh, Pittsburgh, Pa.

John Laughnan, Department of Botany, University of Illinois, Urbana, Ill.

Richard Lewontin, Department of Biology, University of Rochester, Rochester, N.Y.

Laurence Sandler, Department of Genetics, University of Washington, Seattle, Wash.

Stanley Stephens, Department of Genetics, North Carolina State College, Raleigh, N.C.

J. Herbert Taylor, Institute of Molecular Biophysics, Florida State University, Tallahassee, Fla.

Robert Wagner, Department of Zoology, University of Texas, Austin, Tex.

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., Chairman, Metallurgical Engineering Department, Drexel Institute of Technology, Philadelphia, Pa.

Malcolm Dole, Chairman, 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

Erwin Hiebert, Department of the History of Science, University of Wisconsin, Madison, Wis.

Gerald Holton, Jefferson Physical Laboratory, Harvard University, Cambridge, Mass.

Grover Maxwell, Center for the Philosophy of Science, University of Minnesota, Minneapolis, Minn.

Ernan McMullin, Department of Philosophy, University of Notre Dame, Notre Dame, Ind.

Richard S. Rudner, Department of Philosophy, Washington University, St. Louis, Mo.

Harry Woolf, Department of History, Johns Hopkins University, Baltimore, Md.

Advisory Panel for the International Years 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

Paul T. Bateman, Department of Mathematics, University of Illinois, Urbana, Ill.

R. H. Bing, Department of Mathematics, University of Wisconsin, Madison, Wis.

Raoul H. Bott, Department of Mathematics, Harvard University, Cambridge, Mass.

Shing S. Chern, Department of Mathematics, University of California, Berkeley, Calif.

Herman Chernoff, Department of Statistics, Stanford University, Palo Alto, Calif.

Irving Kaplansky (Chairman), Department of Mathematics, University of Chicago, Chicago, Ill.

Peter D. Lax, Courant Institute of Mathematical Sciences, New York University, New York, N.Y.

George D. Mostow, Department of Mathematics, Yale University, New Haven, Conn.

A. D. Wallace, Department of Mathematics, University of Florida, Gainesville, Fla.

Advisory Panel for Metabolic Biology

Samuel P. Bessman, University Hospital, Baltimore, Md.

Ernest Bueding, Department of Pathobiology, Johns Hopkins University, School of Hygiene and Public Health, Baltimore, Md.

Howard Gest, Department of Botany, Washington University, St. Louis, Mo.

Martin Gibbs, Department of Biochemistry, Savage Hall, Cornell University, Ithaca, N.Y.

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.

I. Zelitch, Department of Biochemistry, Connecticut Agricultural Experiment Station, New Haven, Conn.

Advisory Panel for Molecular Biology

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, Department of Cytology, Dartmouth Medical School, Hanover, N.H.

William P. Jencks, Department of Biochemistry, Brandeis University, Waltham, Mass.

Michael Kasha, Department of Chemistry, Florida State University, Tallahassee, Fla.

Walter Kauzmann, Department of Chemistry, Princeton University, Princeton, N.J.

John W. Mehl, Department of Biochemistry, University of Southern California, School of Medicine, Los Angeles, Calif.

Daniel Tosteson, Department of Physiology, Duke University, Durham, N.C.

Jerome R. Vinograd, Department of Chemistry, California Institute of Technology, Pasadena, Calif.

Advisory Panel for Oceanographic Facilities

William M. Cameron, Director of Mineral Sciences, Department of Mines and Technical Surveys, Ottawa, Ontario, Canada.

Parke A. Dickey, Head, Department of Geology, University of Tulsa, Tulsa, Okla.

Joel W. Hedgpeth, Pacific Marine Station, Dillon Beach, Calif.

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.

Kenneth Greisen (Chairman), Laboratory of Nuclear Studies, Cornell University, Ithaca, N.Y.

Emil J. Konopinski, Department of Physics, Indiana University, Bloomington, Ind.

Lawson M. McKenzie, Scientific Laboratory, Ford Motor Co., Dearborn, Mich.

Elliott Montroll, 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.

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.

William C. Dilger, Laboratory of Ornithology, Cornell University, Ithaca, N.Y.

Donald R. Griffin, Department of Biology, Harvard University, Cambridge, Mass.

Norman Guttman, Department of Psychology, Duke University, Durham, N.C.

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.

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.

William G. Van der Kloot, Department of Physiology and Biophysics, New York University School of Medicine, New York, N.Y.

A. Van Harreveld, Division of Biology, California Institute of Technology, Pasadena, Calif.

Advisory Panel on Scientific Manpower Information

James W. Cole, Jr., School of Chemistry, University of Virginia, Charlottesville, Va.

Harold Goldstein, Assistant Commissioner for Manpower and Employment Statistics, Bureau of Labor Statistics, U.S. Department of Labor, Washington, D.C.

Albert Kay, Director of Manpower Resources, Office of Assistant Secretary of Defense (Manpower), The Pentagon, Washington, D.C.

Charles V. Kidd, Associate Director for Training, National Institutes of Health, Bethesda, Md.

James C. O'Brien, Director of Personnel, Department of Health, Education, and Welfare, Washington, D.C.

Philip N. Powers (Chairman), Director, Engineering Experiment Station, Purdue University, West Lafayette, Ind.

M. H. Trytten, Director, Office of Scientific Personnel, National Academy of Sciences–National Research Council, Washington, D.C.

J. Fletcher Wellemeyer, (Private Consultant), Washington, D.C.

Dael Wolfle, Executive Officer, American Association for the Advancement of Science, Washington, D.C.

Advisory Panel for Sociology and Social Psychology

Robert P. Abelson, Department of Psychology, Yale University, New Haven, Conn.

James A. Davis, Department of Social Relations, The Johns Hopkins University, Baltimore, Md.

David Gold, Department of Sociology, University of California, Berkeley, Calif.

William J. McGuire, Department of Social Psychology, Columbia University, New York, N.Y.

Albert J. Reiss, Department of Sociology, University of Michigan, Ann Arbor, Mich.

Leo F. Schnore, Department of Sociology, University of Wisconsin, Madison, Wis.

Karl F. Schuessler, Department of Sociology, Indiana University, Bloomington, Ind.

M. Brewster Smith, Department of Psychology, University of California, Berkeley, Calif.

George J. Suci, Department of Child Development and Family Relationships, Cornell University, Ithaca, N.Y.

Advisory Panel for Specialized Biological Facilities

George Anastos, Department of Zoology, University of Maryland, College Park, Md.

Sanford S. Atwood, Emory University, Atlanta, Ga.

Rolf L. Bolin, Hopkins Marine Station of Stanford University, Pacific Grove, Calif.

S. F. Carson, Biology Division, Oak Ridge National Laboratory, Oak Ridge, Tenn.

Leslie A. Chambers, Hancock Foundation, University of Southern California, Los Angeles, Calif.

Jerome Cox, Jr., Central Institute for the Deaf, St. Louis, Mo.

Charles F. Ehret, Argonne National Laboratory, Lemont, Ill.

Robert K. Enders, Department of Zoology, Swarthmore College, Swarthmore, Pa.

Robert L. Fernald, Department of Zoology, University of Washington, Seattle, Wash.

Herbert Friedmann, Los Angeles County Museum, Los Angeles, Calif.

Shelby Gerking, Department of Zoology, Indiana University, Bloomington, Ind.

H. O. Halvorson, Department of Bacteriology, University of Illinois, Urbana, Ill.

Cadet H. Hand, Department of Zoology, University of California, Berkeley, Calif.

Joel W. Hedgpeth, Pacific Marine Station, College of the Pacific, Marin County, Calif.

Theodore H. Hubbell, Museum of Zoology, University of Michigan, Ann Arbor, Mich.

Bostwick H. Ketchum, Woods Hole Oceanographic Institution, Woods Hole, Mass.

F. F. Koczy, Marine Laboratory, University of Miami, Miami, Fla.

Harlan Lewis, Dean of Life Sciences, University of California, Los Angeles, Calif.

William D. McElroy, McCollum-Pratt Institute, The Johns Hopkins University, Baltimore, Md.

John P. Meehan, School of Medicine, University of Southern California, Los Angeles, Calif.

Charles D. Michener, Department of Entomology, University of Kansas, Lawrence, Kans.

Emil M. Mrak, Chancellor, University of California, Davis, Calif.

William Duwayne Neff, Department of Psychology, Indiana University, Bloomington, Ind.

Geoffrey Norman, Department of Botany, University of Michigan, Ann Arbor, Mich.

John L. Patterson, Department of Medicine, Medical College of Virginia, Richmond, Va.

Luigi Provasoli, Haskins, Laboratory, New York, N.Y.

Carl D. Riggs, Department of Zoology, University of Oklahoma, Norman, Okla.

Murray D. Rosenberg, Rockefeller Institute, New York, N.Y.

Seymour Shapiro, Institute of Molecular Biology, University of Oregon, Eugene, Oreg.

Aaron J. Sharp, Department of Botany, University of Tennessee, Knoxville, Tenn.

Albert C. Smith, University of Hawaii, Honolulu, Hawaii.

Athelstan F. Spilhaus, Institute of Technology, University of Minnesota, Minneapolis, Minn.

William C. Steere, New York Botanical Garden, New York, N.Y.

A. H. Stockard, Department of Zoology, University of Michigan, Ann Arbor, Mich.

H. M. Tsuchiya, Department of Chemical Engineering, 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.

Sheldon Wolff, Biology Division, Oak Ridge National Laboratory, Oak Ridge, Tenn.

Advisory Panel for Special Projects in Science Education

R. H. Bing, Department of Mathematics, University of Wisconsin, Madison, Wis.

Marcus E. Hobbs, Department of Chemistry, Duke University, Durham, N.C.

James H. Jensen, President, Oregon State University, Corvallis, Oreg.

Joseph L. McCarthy, Dean, Graduate School, University of Washington, Seattle, Wash.

Robert MacVicar, Dean, Graduate School, Vice President, Academic Affairs, Oklahoma State University, Stillwater, Okla.

John W. Oswald, President, University of Kentucky, Lexington, Ky.

Howard M. Phillips, Sr., President, Birmingham-Southern College, Birmingham, Ala.

Francis W. Sears, Department of Physics, Dartmouth College, Hanover, N.H.

Oswald Tippo, Provost, University of Massachusetts, Amherst, Mass.

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.

Arthur J. Cronquist, New York Botanical Garden, Bronx Park, New York, N.Y.

George F. Edmunds, Division of Biology, University of Utah, Salt Lake City, Utah.

Joel W. Hedgpeth, Pacific Marine Station, Dillon Beach, Marin County, Calif.

Charles B. Heiser, Department of Botany, Indiana University, Bloomington, Ind.

Terry W. Johnson, Department of Botany, Duke University, Durham, N.C.

Everett C. Olson, Department of Geology, University of Chicago, Chicago, Ill.

Bobb Schaeffer, American Museum of Natural History, New York, N.Y.

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

Mary A. B. Brazier, Brain Research Institute, University of California, Los Angeles, Calif.

Joseph O. Hirschfelder, Department of Chemistry, University of Wisconsin, Madison, Wis.

Nathan M. Newmark, Department of Civil Engineering, University of Illinois, Urbana, Ill.

Arthur H. Rosenfeld, Department of Physics, University of California, Berkeley, Calif.

Martin Schwarzschild, Department of Astronomy, Princeton University, Princeton, N.J.

Herbert A. Simon (Chairman), Head, Department of Industrial Management, Carnegie Institute of Technology, Pittsburgh, Pa.

Charles V. L. Smith, Division of Research, U.S. Atomic Energy Commission, Washington, D.C.

Leonard M. Uhr, Mental Health Research Institute, University of Michigan, Ann Arbor, Mich.

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), Dean of Engineering, 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 1964

SALARIES AND EXPENSES APPROPRIATION

Receipts

Appropriated for fiscal year 1964	$353,200,000
Unobligated balance from fiscal year 1963	5,362,987
Less:	
Transfer to General Services Administration for space rental	11,550
Total availability	358,551,437

Obligations

Basic Research and Supporting Facilities:		
Basic research project grants:		
Biological and medical sciences		$39,844,564
Mathematical and physical sciences		51,020,908
Engineering		12,563,738
Social sciences		8,982,969
Subtotal		112,412,179
National research programs:		
Antarctic research program		7,174,712
Indian Ocean expedition		4,859,797
Deep crustal studies of the earth (Mohole)		7,972,046
Weather modification		1,501,513
United States-Japan cooperative science program		708,000
International year of the quiet sun		3,665,900
Subtotal		25,881,968
Specialized research facilities support:		
Biological sciences research facilities:		
Specialized biological facilities	$3,494,651	
Oceanographic research facilities	1,062,865	
		4,557,516
Physical sciences research facilities:		
Oceanographic research facilities	3,934,118	
University atmospheric research facilities	657,000	

Basic Research and Supporting Facilities—Continued		
Specialized research facilities support—Continued		
University physics research facilities	$5,000,000	
		$9,591,118
Specialized social sciences research facilities		966,700
University computing facilities		4,517,000
Subtotal		19,632,334
National research centers:		
National Radio Astronomy Observatory		4,600,000
Kitt Peak National Observatory		4,400,000
Cerro Tololo Inter-American Observatory		1,000,000
National Center for Atmospheric Research		9,290,000
Subtotal		19,290,000
Subtotal, Basic Research and Supporting Facilities		177,216,481
Science Education Programs:		
Fellowships and traineeships		30,105,000
Institutes		43,246,729
Research participation and scientific activitives for teachers		3,714,884
Science education for undergraduate students		6,051,566
Science education for secondary school students		3,918,672
Specialized advanced science education programs		1,567,810
Course content improvement		13,975,712
Subtotal, Science Education Programs		102,580,373
Institutional Science Programs:		
Institutional grants for science		11,380,023
Instructional equipment for undergraduate education		8,650,102
Graduate science facilities		29,984,191
Subtotal, Institutional Science Programs		50,014,316
Science Information Services:		
Dissemination of science information		9,916,945
International scientific information exchange		685,735
Subtotal, Science Information Services		10,602,680

Studies of National Resources for Science and Technology:		
Statistical surveys	$570, 198	
National register of scientific and technical personnel	651, 165	
Analytical studies	517, 927	
Long-range policy studies	119, 700	
Subtotal, Studies of National Resources for Science and Technology	1, 858, 990	
Program Development and Management	12, 052, 685	
Total, NSF	354, 325, 525	
Allocation to other Government agencies	258, 997	
Total obligations, fiscal year 1964		$354, 584, 522
Unobligated balance carried forward to fiscal year 1965		3, 966, 915
Total		358, 551, 437

TRUST FUND

Receipts

Unobligated balance from fiscal year 1963	$6, 688	
Donations from private sources	1, 483	
Total availability		$8, 171

Obligations

Total obligations fiscal year 1964	886	
Unobligated balance carried forward into fiscal year 1965	7, 285	
Total availability		8, 171

APPENDIX C

Patents Resulting from Activities Supported by The National Science Foundation

The Foundation since its last Annual Report has received notification of the issuance of four patents by the U.S. Patent Office covering inventions arising out of Foundation-supported activities.

1. Patent Number 3,109,933 entitled, "Photoelectric High Scanning-Rate Digital Storage and Read-Out Device," was issued on November 5, 1963, on an invention made during the course of research conducted by Dr. Dwight M. Baumann when he was an NSF Fellow. The invention relates to high scanning-rate storage devices and methods, and more particularly, to photographic techniques for high-scanning-rate digital storage and read-out.
2. Patent Number 3,111,512 entitled, "Thiolation of Proteins with N-Acyl-Homocysteine Thiolactone," was issued on November 19, 1963, on an invention made by Rheinhold Benesch and Ruth E. Benesch during the course of research supported by grants to the State University of Iowa, the University of Wisconsin, and the Marine Biological Laboratory. It relates to methods for the introduction of sulfhydryl (—SH) groups and disulfide (—SS—) bonds into macromolecules containing aliphatic amino groups, particularly proteins, and to the novel thiolated proteins and their oxidation products.
3. Patent Number 3,117,210 entitled, "Apparatus for Evaporating Materials," was issued on January 7, 1964, on an invention made by Raymond G. Herb during the course of research supported at the University of Wisconsin. It provides an improved source for evaporating materials used in coating, gettering, ionic pumping of gas, etc.
4. Patent Number 3,127,361 entitled, "Process for Producing Polymers of Tri-O-p-Tolysulfonyl-Sucrose and Polymers of Tetra-O-p-Tolylsulfonyl-Sucrose, and Resulting Polymers," was issued on March 31, 1964, to the United States of America as represented by the Secretary of the Army, assignee of Louis Long, Jr., and Erik Vis, on an invention made during the course of research supported by a grant to the U.S. Army—Natick Laboratories. It concerns tolylsulfonyl-sucrose containing compositions and

processes for making them. These compositions are useful as adhesives, cellular plastics, and for other purposes.

Pursuant to the provisions of the grants and fellowships involved, the Foundation has secured for the Federal Government, royalty-free licenses to utilize the first three inventions described above for governmental purposes.

APPENDIX D

National Science Foundation-Sponsored Scientific Conferences, Symposia, and Advanced Science Seminars Held During Fiscal Year 1964

SCIENTIFIC CONFERENCES AND SYMPOSIA IN THE BIOLOGICAL AND MEDICAL SCIENCES

RESEARCH SEMINARS IN MOLECULAR BIOLOGY—University of California; Meetings scheduled as opportunity arises; Melvin Calvin, Department of Chemistry, University of California at Berkeley.

ANIMAL REPRODUCTION SYMPOSIUM—Corvallis, Oreg.; August 3, 1963; H. H. Cole, Professor of Animal Husbandry, University of California at Davis.

THE XVI INTERNATIONAL CONGRESS OF ZOOLOGY—Washington, D.C.; August 20–27, 1963; Frank L. Campbell, Division of Biology and Agriculture, National Academy of Sciences–National Research Council.

SYMPOSIUM ON FERREDOXINS AND OTHER NON-HEME IRON-CONTAINING ENZYMES—University of Hawaii; August 22–23, 1963; Howard F. Mower-Theodore Winnick, Department of Biochemistry, University of Hawaii, Honolulu, Hawaii.

SYMPOSIUM ON DEVELOPMENTS IN CLASSICAL CONDITIONING—University Park, Pa.; August 1963; William F. Prokasy, Department of Psychology, Indiana University, Bloomington, Ind.

ELEVENTH INTERNATIONAL CONGRESS OF GENETICS—Columbia University; September 2–10, 1963; Francis J. Ryan, Department of Zoology, Columbia University, New York, N.Y.

FIRST INTERNATIONAL CONFERENCE IN ACAROLOGY—Fort Collins, Colo.; September 3–7, 1963; Tyler A. Woolley, Department of Zoology, Colorado State University, Denver, Colo.

SYMPOSIUM ON BACTERIAL ENDOTOXINS—Rutgers University; September 4–6, 1963; Werner Braun, Department of Bacteriology, Rutgers State University, New Brunswick, N.J.

CONFERENCE OF ELECTRON TRANSPORT—New York, N.Y.; September 12, 1963; Britton Chance, Director, Johnson Foundation, University of Pennsylvania, Philadelphia, Pa.; Julius Schultz, Hahnemann Medical College, Philadelphia, Pa.

SYMPOSIUM ON PHOTOSYNTHESIS—Warrenton, Va.; October 14–18, 1963; Frank L. Campbell, Division of Biology and Agriculture, National Academy of Sciences and National Research Council.

A SYMPOSIUM ON SYSTEMATICS: POLLINATION RELATIONSHIPS AND SYSTEMATICS—St. Louis, Missouri; October 18–19, 1963; Robert L. Dressler, Missouri Botanical Garden, St. Louis, Mo.

SYMPOSIUM ON REGULATION OF BIOSYNTHESIS AND TRANSPORT OF MATERIALS ACROSS THE CELL MEMBRANE—New York, N.Y.; November 6–8, 1963; David M. Prescott, Division of Biology, Oak Ridge National Laboratory, P.O. Box "Y", Oak Ridge, Tenn.

BIOLOGICAL SCIENCES SYMPOSIUM—Houston, Tex.; December 1–5, 1963; H. M. Tsuchiya, Department of Chemical Engineering, University of Minnesota, Minneapolis, Minn.

SUPPORT OF THE SIXTH INTERNATIONAL TRANSPORTATION CONFERENCE—New York, N.Y.; February 6–8, 1964; John Marquis Converse-Blair Oakley Rogers, New York University Medical Center, New York, N.Y.

SYMPOSIUM ON GENETICS OF COLONIZING SPECIES OF ANIMALS AND PLANTS—Asilomar, Calif.; February 12–16, 1964; Frank L. Campbell, Division of Biology and Agriculture, National Academy of Sciences–National Research Council.

SYMPOSIUM ON PHOTOSYNTHESIS—Wakulla Springs, Fla.; February 16-21, 1964; Frank L. Campbell, Division of Biology and Agriculture, National Academy of Sciences–National Research Council.

SEMINAR ON THE CURRENT STATUS OF RESEARCH ON APHIDS—University of California; March 23–27, 1964; Edward Sanford Sylvester, Department of Entomology and Parasitology, University of California, Berkeley, Calif.

CONFERENCE ON ESTUARIES—Jekyll Island, Ga.; April 1–4, 1964; George H. Lauff, Sapelo Island Research Foundation, Sapelo Island, Ga.

SUPPORT OF REGIONAL CONFERENCES IN DEVELOPMENTAL BIOLOGY IN 1964—Madison, Wis.; April 3–6, 1964; John G. Torrey, Harvard University, Cambridge, Mass.

BACTERIAL FINE STRUCTURE AND REPLICATION CURRENT RESEARCH IN MEDICAL MYCOLOGY—Washington, D.C.; May 7, 1964; Philipp Gerhardt, Department of Microbiology, University of Michigan, Ann Arbor, Mich.

CONFERENCE ON NEUROSPORA RESEARCH—Houston, Tex.; March 5–7, 1964; Val W. Woodward, Department of Biology, Rice University, Houston, Tex.

THE 29TH COLD SPRING HARBOR SYMPOSIUM—Cold Spring Harbor, N.Y.; June 5–12, 1964; John Cairns, Cold Spring Harbor Laboratory of Quantitative Biology, New York.

The Growth Symposia for 1964, 1965, and 1966—Amherst, Mass.; June 16–17–18, 1964; John G. Torrey, Harvard University, Cambridge, Mass.

Gordon Research Conference on Nucleic Acids—New Hampton, N.H.; June 22–26, 1964; Seymour Benzer, Department of Biological Sciences, Purdue University, Lafayette, Ind.

Gordon Research Conference on Cell Structure and Metabolism—Meriden, N.H.; June 29–July 3, 1964; J. Herbert Taylor, Department of Cell Biology, Columbia University, New York, N.Y.-Walther Stoeckenius, Rockefeller Institute, New York, N.Y.

SCIENTIFIC CONFERENCES AND SYMPOSIA IN THE MATHEMATICAL, PHYSICAL, AND ENGINEERING SCIENCES

International Symposium on the Theory of Models—June 25 to July 11, 1963; University of California at Berkeley. Cochairmen: Professor Leon Henkin, President, Association for Symbolic Logic and Professor Alfred Tarski, University of California. Cosponsors: the Association of Symbolic Logic, the International Union of History and Philosophy of Science, the National Academy of Sciences—National Research Council, the National Science Foundation, and the University of California, Berkeley, Calif.

Conference on Photonuclear Reactions—August 5–9, 1963; Tilton School, Tilton, N.H. Cochairmen: Dr. D. J. Zaffarano, Iowa State University, and Dr. Evans Hayward, U.S. National Bureau of Standards. Cosponsor: the Gordon Research Conferences. (Director of the Gordon Research Conferences is Dr. W. George Parks, University of Rhode Island, Kingston, R.I.)

International Conference on Lattice Dynamics—August 5–9, 1963; H. C. Ørsted Institute, University of Copenhagen, Copenhagen, Denmark. Chairman of the Planning and Executive Committee, Elias Burstein, University of Pennsylvania. Cosponsors: Danish Academy of Technical Sciences, Danish Physical Society, International Atomic Energy Agency, International Union of Pure and Applied Physics, NORDITA, U.S. National Science Foundation, U.S. Office of Naval Research, and the University of Pennsylvania.

XIIIth General Assembly of the International Union of Geodesy and Geophysics—August 19–31, 1963; University of California, Berkeley, Secretary, General Arrangements Committee, Waldo E. Smith, Executive Secretary, American Geophysical Union. Cosponsors: National Science Foundation, National Aeronautics and Space Administration; Department of the Navy, Department of the Air Force, Department of the Army, Atomic Energy Commission, U.S. Weather Bureau, National Bureau of Standards, Department of Health, Education, and Welfare, U.S. Coast and Geodetic Survey.

INTERNATIONAL CONFERENCE ON THE SCIENCE OF SUPERCONDUCTIVITY—August 26–29, 1963; Colgate University, Hamilton, N.Y. Conference Secretary: Roland W. Schmitt, General Electric Research Laboratory, Schenectady, N.Y. Cosponsors: the International Union of Pure and Applied Physics, the Advance Research Project Agency, the National Science Foundation, and the General Electric Company.

FOURTH INTERNATIONAL CONGRESS ON RHEOLOGY—August 26–30, 1963; Providence, R.I. Chairman, Arrangements Committee: Professor R. S. Rivlin, Brown University. Cosponsors: National Science Foundation, Brown University, the U.S. Society of Rheology.

BIENNIEL SEMINAR AND CONGRESS—August 12 to September 4, 1963; University of Saskatchewan, Saskatoon, Canada. Executive Director Leland F. S. Ritcey; cosponsor: Canadian Mathematical Congress.

SECOND INTERNATIONAL SYMPOSIUM ON TEKTITES—September 5–7, 1963; Pittsburgh, Pa. Chairman: Alvin J. Cohen, University of Pittsburgh. Cosponsors: National Science Foundation, the Division of Earth Sciences of the Natonal Academy of Sciences-National Research Council, and the University of Pittsburgh.

INTERNATIONAL SYMPOSIUM ON HIGH TEMPERATURE TECHNOLOGY—September 8–11, 1963; Asilomar Conference Grounds, Calif. General Chairman: N. K. Hiester. Cosponsors: the High Temperature Commission of the International Union of Pure and Applied Chemistry, the Atomic Energy Commission, the Advanced Projects Research Agency, the Office of Naval Research, the National Science Foundation, the Air Force Systems Command (Wright Field), Stanford Research Institute, and private industrial sources.

INTERNATIONAL CONFERENCE ON PRODUCTION ENGINEERING RESEARCH—September 9–12, 1963; Pittsburgh, Pa. Chairman Organizing Committee, Professor M. C. Shaw, Carnegie Institute of Technology. Cosponsors: International Institution for Production Engineering Research (College International Pour L'Etude Scientifique Des Techniques de Production Mecanique (CIRP)), the American Society of Mechanical Engineers, Carnegie Institute of Technology, and the National Science Foundation.

TWELFTH CLAY MINERALS CONFERENCE—September 30–October 3, 1963; Atlanta, Ga. Coordinator, Linn Hoover, Executive Secretary, Division of Earth Sciences, National Academy of Sciences and National Research Councils. Cosponsor: National Academy of Sciences-National Research Council.

SYMPOSIUM ON APPROXIMATIONS—October 21–26, 1963; Gatlinburg, Tenn. Chairman, Program Committee F. W. J. Olver, National Bureau of Standards; Executive Secretary, Organizing Committee for the Symposium, A. S. Householder, Oak Ridge National Laboratory. Cosponsors: Society for

Industrial and Applied Mathematics, the Atomic Energy Commission, the National Science Foundation.

SECOND EASTERN THEORETICAL PHYSICS CONFERENCE—October 25–26, 1963; Chapel Hill, N.C. Chairman, Organizing Committee, Eugen Merzbacher, University of North Carolina.

SYMPOSIUM ON THE THEORY OF NUMBERS—November 21–23, 1963; Pasadena, Calif. Chairman: Gordon L. Walker. Cosponsor: American Mathematical Society and National Science Foundation.

SYMPOSIUM ON THE PRINCIPLE OF UNIFORMITY—November 19, 1963; New York, N.Y. Chairman: Claude C. Albritton, Jr., Southern Methodist University. Cosponsor: the Geological Society of America.

INTERNATIONAL CONFERENCE ON PERMAFROST—November 11–15, 1963; Lafayette, Ind. General Conference Chairman: Professor Kenneth B. Woods, Purdue University. Cosponsors: Purdue University School of Civil Engineering, National Science Foundation, U.S. Army Corps of Engineers, U.S. Navy Bureau of Yards and Docks, U.S. Air Force Cambridge Research Laboratories, Office of Civil Defense, Bureau of Public Roads, Caterpillar Tractor Company, U.S. Army Materiel Command, U.S. Public Health Service, Office of Naval Research, and the Building Research Advisory Board, National Academy of Sciences-National Research Council.

SYMPOSIUM ON GRAVITATIONAL COLLAPSE—December 16–18, 1963; Dallas, Tex. Cochairmen: J. R. Oppenheimer, Institute for Advanced Studies; E. L. Schucking, University of Texas; R. Minkowski, University of California, Berkeley; A. E. Schild, University of Texas; P. Morrison, Cornell University; and Y. Ne'eman, Israel Atomic Energy Commission. Cosponsors: the Southwest Center for Advanced Studies; the University of Texas; Yeshiva University; Aeronautical Research Laboratory, Wright-Patterson Air Force Base; Air Force Office of Scientific Research; National Aeronautics and Space Administration; National Science Foundation; and the Office of Naval Research.

FIFTH SYMPOSIUM ON THERMAL RADIATION OF SOLIDS—March 4–6, 1964; San Francisco, Calif. Chairman: J. C. Richmond, National Bureau of Standards. Cosponsors: National Aeronautics and Space Administration, National Bureau of Standards, Aeronautical Systems Division, U.S. Air Force, and the University of California.

CONFERENCE ON IRRIGATION AND DRAINAGE RESEARCH—March 19–21, 1964; Logan, Utah. Chairman of Program Planning Committee: M. L. Albertson. Cosponsors: American Society of Civil Engineers, Utah State University, U.S. Department of the Interior Bureau of Reclamation, and the National Science Foundation.

SYMPOSIUM ON MATRIX COMPUTATIONS—Gatlinburg, Tenn.; April 1964. Chairman of Organizing Committee: A. S. Householder, Oak Ridge National Laboratory. Cosponsors: Society for Industrial and Applied Mathematics and the National Science Foundation.

CONFERENCE ON PRECISION ELECTROMAGNETIC MEASUREMENTS—June 23–25, 1964; Boulder, Colo. Chairman: Edward W. Houghton. Cosponsors: National Science Foundation, National Bureau of Standards, Institute of Electrical and Electronics Engineers, and the International Scientific Radio Union.

CONFERENCE ON COAL SCIENCE—June 23–26, 1964; University Park, Pa. Chairman: Peter H. Given, Pennsylvania State University. Cosponsors: the Pennsylvania State University, the Fuel Chemistry Division of the American Chemical Society, the Geochemical Society, the Geological Society of America, and the National Science Foundation.

MIDWEST CONFERENCE ON THEORETICAL PHYSICS—June 5–6, 1964; Ames, Iowa. Chairman: Joseph M. Keller, Iowa State University. Cosponsors: Iowa State University and the National Science Foundation.

SCIENTIFIC CONFERENCES AND SYMPOSIA IN THE SOCIAL SCIENCES

CONFERENCE ON RECOVERY OF PLEISTOCENE FOSSILS—Washington, D.C.; March 5, 1964. Chairman: Frank C. Whitmore, Jr., National Academy of Sciences-National Research Council.

CONFERENCE ON THE THEORY OF COLLECTIVE DECISION PROCESSES—Charlottesvile, Va.; October 11–12, 1963. Chairman: J. M. Buchanan, Thomas Jefferson Center for Studies in Political Economy, University of Virginia.

RESEARCH CONFERENCE IN LINGUISTICS AND SOCIAL SCIENCES—Bloomington, Ind.; June 17–August 14, 1964. Chairman: Charles A. Ferguson, Center for Applied Linguistics, Washington, D.C.

ADVANCED SCIENCE SEMINARS

ADVANCED FIELD TRAINING THROUGH RESEARCH PARTICIPATION IN ARCHAEOLOGY—University of Arizona, Tucson, Ariz.; June 12–August 7, 1964. Director: E. Haury.

FIELD TRAINING FOR ANTHROPOLOGISTS IN OAXACA, MEXICO—Stanford University, Stanford, Calif.; June 1–August 7, 1964. Director: A. K. Romney.

SUMMER SEMINAR FOR ADVANCED GRADUATE STUDENTS IN STATISTICS—Colorado State University, Fort Collins, Colo.; June 15–August 7, 1964. Director: F. A. Graybill.

SUMMER INSTITUTE FOR THEORETICAL PHYSICS—University of Colorado, Boulder, Colo.; June 16–August 24, 1964. Director: W. E. Brittin.

SEMINAR IN THEORETICAL METALLURGY—University of Denver, Denver, Colo.; June 15–August 7, 1964. Director: W. M. Mueller.

INTERNATIONAL FIELD INSTITUTE IN ITALY FOR COLLEGE GEOLOGY TEACHERS—American Geological Institute, Washington, D.C.; June 16–August 11, 1964. Director: J. Maxwell.

ADVANCED COURSE IN BIOLOGY: INVERTEBRATE ZOOLOGY—American Association of Museums, Washington, D.C.; June 29–August 7, 1964. Director: W. Hartman.

ADVANCED COURSE IN GEOLOGY: PALEONTOLOGY FOR SCIENCE MUSEUM PERSONNEL—American Association of Museums, Washington, D.C.; June 1–July 10, 1964. Director: J. Howe.

SEMINAR ON HURRICANES—Florida State University, Tallahassee, Fla.; July 6–August 14, 1964. Director: N. E. LaSeur.

CONFERENCE ON ADVANCES IN CARBONATE SEDIMENTATION STUDIES—University of Miami, Miami, Fla.; August 3–20, 1964. Director: G. Rusnak.

WINTER INSTITUTES IN QUANTUM CHEMISTRY, SOLID-STATE PHYSICS AND QUANTUM BIOLOGY—University of Florida, Gainesville, Fla.; December 9–January 18, 1964. Director: P. Lowdin.

COURSE IN FIELD METHODS FOR SYSTEMATIC VERTEBRATE ZOOLOGISTS AND PALEONTOLOGISTS—University of Kansas, Lawrence, Kans.; June 8–July 17, 1964. Director: E. R. Hall.

SUMMER INSTITUTE IN THEORETICAL PHYSICS—Brandeis University, Waltham, Mass.; June 22–July 31, 1964. Director: K. W. Ford.

A SUMMER FIELD PROGRAM IN ANTHROPOLOGY IN YUGOSLAVIA—Brandeis University, Waltham, Mass.; June 15–September 15, 1964. Director: R. A. Manners.

ADVANCED SCIENCE SEMINAR IN OBSERVATIONAL ASTRONOMY—Harvard College, Cambridge, Mass.; June 20–September 5, 1964. Director: W. Liller.

ADVANCED PHYSICAL OCEANOGRAPHY—Woods Hole Oceanographic Institution, Woods Hole, Mass.; June 15–September 4, 1964. Director: B. H. Ketchum.

THEORETICAL STUDIES IN GEOPHYSICAL FLUID DYNAMICS—Woods Hole Oceanographic Institution, Woods Hole, Mass.; June 28–September 4, 1964. Director: W. V. R. Malkus.

SUMMER INSTITUTE OF GLACIOLOGICAL SCIENCES IN ALASKA—Michigan State University, East Lansing, Mich.; July 25–September 8, 1964. Director: M. M. Miller.

FIELD TRAINING FOR ANTHROPOLOGISTS IN U.S. WESTERN GREAT BASIN—University of Nevada, Reno, Nev.; June 1–August 7, 1964. Director: W. L. d'Azevedo.

SUMMER INSTITUTE IN PLASMA PHYSICS—Princeton University, Princeton, N.J.; June 29–August 7, 1964. Director: M. Gottlieb.

SPECIAL FIELD INSTITUTE IN ETHNOLOGY—Museum of New Mexico, Santa Fe, New Mex.; June 10–September 10, 1964. Director: B. Colby.

INTERDISCIPLINARY CONFERENCE ON CELLULAR ULTRASTRUCTURE OF WOODY PLANTS—State University of New York, College of Forestry at Syracuse University, Syracuse, N.Y.; September 20–26, 1964. Director: W. A. Cote.

1964 SYMPOSIUM ON MOLECULAR STRUCTURE AND SPECTROSCOPY—Ohio State University, Columbus, Ohio; June 14–18, 1964. Director: H. H. Nielsen.

STRUCTURE AND DYNAMICS OF THE LIQUID STATE—John Carroll University, Cleveland, Ohio; June 1–5, 1964. Director: J. L. Hunter.

FIELD SCHOOL IN ETHNOLOGY AND LINGUISTICS—University of Oklahoma, Norman, Okla.; June 1–July 31, 1964. Director: W. E. Bittle.

SUMMER INSTITUTE FOR ADVANCED GRADUATE STUDENTS IN ANALYSIS—Lehigh University, Bethlehem, Pa.; June 15–August 7, 1964. Director: E. Pitcher.

INSTITUTE IN CROSS-CULTURAL RESEARCH—University of Pittsburgh, Pittsburgh, Pa.; July and August, 1964. Director: G. P. Murdock.

FIELD TRAINING FOR ANTHROPOLOGISTS IN PUEBLA, MEXICO—University of Pittsburgh, Pittsburgh, Pa.; June 1–August 7, 1964. Director: D. Landy.

SEMINAR ON GENETIC IMPROVEMENT FOR DISEASE AND INSECT RESISTANCE OF FOREST TREES—Pennsylvania State University, University Park, Pa.; August 30–September 11, 1964. Director: R. McDermott.

ADVANCED SCIENCE SEMINAR IN PALEOBOTANY—Lock Haven State College, Lock Haven, Pa.; June 15–27, 1964. Director: P. F. Klens.

SEMINAR ON COMPUTERS IN ENGINEERING AND SCIENCE EDUCATION—University of Houston, Houston, Tex.; June 8–July 31, 1964. Director: E. I. Organick.

SPECIAL SUMMER SESSION ON MATHEMATICAL STATISTICS AND STATISTICAL METHODS IN ENGINEERING AND PHYSICAL SCIENCES—Virginia Polytechnic Institute, Blacksburg, Va.; June 11–July 18, 1964. Director: B. Harshbarger.

CONFERENCE ON THE ROLE OF SIMULATION IN SPACE TECHNOLOGY—Virginia Polytechnic Institute, Blacksburg, Va.; August 10–14, 1964. Director: F. J. Maher.

INSTITUTE FOR THEORETICAL PHYSICS—University of Wisconsin, Madison, Wis.; June 15–August 15, 1964. Director: R. G. Sachs.

ORGANISM-SEDIMENT RELATIONS—Bermuda Biological Station, St. Georges West, Bermuda; August 1–September 26, 1964. Director: K. E. Chave.

SUMMER SESSIONS IN MATHEMATICS—Canadian Mathematical Congress, Montreal, Canada; June 22–August 14, 1964. Director: L. F. S. Ritcey.

ADVANCED SCIENCE SEMINAR IN TROPICAL BIOLOGY OF COSTA RICA FOR COLLEGE AND UNIVERSITY TEACHERS AND SELECTED GRADUATE STUDENTS—Organization of Tropical Studies, Inc., San Jose, Costa Rica; July 6–August 14, 1964 and July 12–August 20, 1964. Director: J. Savage.

APPENDIX E

Publications of the National Science Foundation

This listing includes publications issued by the National Science Foundation during fiscal year 1964. 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. Thirteenth Annual Report, for fiscal year ending June 30, 1963: NSF 64–1, $1.25.
2. Fifth Annual Weather Modification Report, for fiscal year ending June 30, 1963: NSF 64–19, $.25.

DESCRIPTIVE PROGRAM BROCHURES

1. Science Development Program for Colleges and Universities (1964 and 1965): NSF 64–7.
2. Grants for Graduate Science Facilities: NSF 63–48.

MANPOWER AND EDUCATION REPORTS

1. Comparisons of Earned Degrees Awarded 1901–1962—With Projections to 2000: NSF 64–2.
2. Scientists, Engineers, and Technicians in the 1960's: Requirements and Supply: NSF 63–34, $.45.
3. Scientific Manpower 1962 (The latest in a general series which contains the papers of the Conference on Scientific Manpower held in conjunction with the meetings of the AAAS in December of each year): NSF 63–31, $.35.
4. Two Years After the College Degree—work and further study patterns: NSF 63–26, $1.75.
5. Scientific Manpower Bulletins (A series of pamphlets providing manpower information gathered primarily in connection with the National Register of Scientific and Technical Personnel): No. 20. Summary of American Science Manpower, 1962: NSF 64–5.

RESEARCH AND DEVELOPMENT ECONOMIC REPORTS

1. Federal Funds for Research, Development, and Other Scientific Activities (Formerly Federal Funds for Science) Fiscal Years 1962, 1963, and 1964; Volume XII: NSF 64–11, $1.00.

2. Current Projects on Economic and Social Implications of Science and Technology, 1963: NSF 64–10, $.50.
3. Research and Development in Industry, 1961 (Final Report on a Survey): NSF 64–9, $.65.
4. Scientific and Technical Personnel in Industry, 1961: NSF 63–32, $.55.
5. Reviews of Data on Research & Development (A series of bulletins devoted to specific aspects of research and development economics):
   - No. 44. Decision-Making on Research and Development in the Business Firm: NSF 64–6, $.10.
   - No. 43. Scientists and Engineers in Engineering Schools, 1961: NSF 63–44, $.10.
   - No. 42. Research and Development in the Chemicals and Allied Products Industry, 1956–61: NSF 63–41, $.15.
   - No. 41. National Trends in R&D Funds, 1953–62: NSF 63–40, $.15.
   - No. 40. Research and Development in American Industry, 1962: NSF 63–37, $.15.

SCIENCE INFORMATION EXCHANGE 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. 26. Library of Congress: NSF 64–3, $.15.
   - No. 25. U.S. Navy—Part III, Bureau of Ships, Bureau of Naval Weapons: NSF 63–53, $.15.
   - No. 24. U.S. Department of Health, Education, and Welfare—Part III, National Institutes of Health: NSF 63–52, $.15.
   - No. 23. U.S. Department of Health, Education, and Welfare—Part II, Public Health Service: NSF 63–46, $.10.
   - No. 22. U.S. Air Force—Part I: NSF 63–45, $.25.
   - No. 21. U.S. Department of Health, Education, and Welfare—Part I: NSF 63–50, $.25.
   - No. 20. U.S. Navy—Part II, Office of Naval Research: NSF 63–43, $.15.
   - No. 19. U.S. Navy—Part I: NSF 63–42, $.25.
   - No. 18. U.S. Atomic Energy Commission: NSF 63–38, $.15.
   - No. 17. U.S. Air Force—Part IV, Air Force Systems Command: NSF 63–16, $.20.

SCIENCE ADMINISTRATION REPORTS

1. A Case Study of Support of Scientific and Engineering Research Proposals: NSF 63–22, $.65.

U.S. GOVERNMENT PRINTING OFFICE: 1965


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