National Science Foundation Annual Report 1969

NSF 70-1

NATIONAL SCIENCE FOUNDATION

National Science Foundation

Nineteenth Annual Report for the Fiscal Year Ended June 30, 1969

Letter of Transmittal

Washington, D.C.

Dear Mr. President:

I have the honor to transmit herewith the Annual Report for Fiscal Year 1969 of the National Science Foundation for submission to the Congress as required by the National Science Foundation Act of 1950.

Respectfully,

W D McElroy

W. D. McElroy
Director, National Science Foundation.

The Honorable
The President of the United States.

U.S. GOVERNMENT PRINTING OFFICE
WASHINGTON : 1969

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Foreword

This 19th Annual Report of the National Science Foundation presents an account of major activities conducted during fiscal year 1969. The operations described were carried out under the leadership of Dr. Leland J. Haworth who completed his 6-year term as Director of the Foundation on June 30, 1969.

In assuming responsibility as successor to Dr. Haworth, and mindful of the considerable progress that has gone before, I am at the same time acutely aware of the size of challenge we will face in the years immediately ahead. In our proper concern for the quality of human life, both material and intellectual, it is clear that the sciences represent an essential component of the national endeavor which must receive recognition and support from all elements of our society.

As a nation we have become enriched by the bounty of science, and there is no doubt that the material dimensions of our society will continue to be enhanced in the future. But in addition to the enjoyment of all these things, we must look to science as well for the skills and wisdom that will enable us to bring man into harmony with his environment.

We recognize that our social relationships and institutions are undergoing more profound and more rapid change than at any time in the history of man, much of which is due to the accomplishments of science. But we are beginning to learn, too, that change without basic understanding can distort our aspirations. For this reason it is clear that in the national interest we must persevere in mobilizing the capabilities of all the sciences so that the worthy goal of a good and fruitful life for all our citizens can be attained.

W. D. McElroy
Director, National Science Foundation

Introduction and Summary

The period covered by this report, fiscal year 1969, saw U.S. science adjusting to many external and internal challenges. The response to the intellectual challenge was as vigorous as ever. At the microscopic level of the universe, important new discoveries in the biological sciences provided new information on the complex mechanisms of living systems and on the interaction of life with its environment. Macroscopically, major new observations in radio astronomy revealed new facts about novel types of cosmological bodies, and in astrophysics demonstrated new mechanisms of gravitational energy transfer.

Clearly the unraveling of the mysteries of the universe was proceeding without hesitation. Yet the scientific community was faced with serious issues and operational difficulties. Students and scientists examined on an increasingly active scale real or apparent ethical problems related to different types of research activity. Participants in the scientific process as well as other members of society—the ultimate recipient of the benefits stemming from the process—discussed the degree of relevancy of various types of scientific activities. Growing concern was expressed about the effects, frequently still unknown, of scientific and technological progress. Undoubtedly, this more intensive examination of one of the key components of modern American life is healthy for the dynamic evolution of our society. Hopefully, it will lead to a deeper understanding of the role of science and the scientist in our rapidly changing world. However, this appraisal was accompanied by operational impediments which, while sometimes inevitable in view of present problems, could produce long-term adverse effects. Total national support of research and development slowed down and Federal funding of academic science and basic research remained static, therefore supporting only smaller levels of activity. Overall, it became increasingly evident that science and the universities are in a period of changing attitudes, and, as a result, new and important challenges.

A number of important developments, some related to these national trends, occurred in fiscal year 1969 and affected both the organization and programs of the National Science Foundation. A new director, Dr. William D. McElroy, was designated by the President for a 6-year term beginning in fiscal year 1970; first steps were taken toward implementation of Public Law 90–407, the 1968 congressional legislation which amended the National Science Foundation Act of 1950 and made a number of significant changes in the Foundation's structure and responsibilities; funding adjustments were made by NSF to enable it to operate as effectively as possible within the framework of limited fiscal year 1969 congressional appropriations and the requirements of the Revenue and Expenditure Control Act of 1968 which placed expenditure restrictions on all Federal agencies. These and other significant events of the year are summarized below.

New National Science Foundation Legislation

On July 18, 1968, the President signed Public Law 90–407 which amended the National Science Foundation Act of 1950. A number of major changes were effected by the new legislation: (1) alterations were made in the organizational structure of the Foundation and in the responsibilities and duties of the National Science Board and the Director; (2) increased emphasis was placed on applied research, social science activities, programs dealing with computers, and international cooperation; (3) the Foundation is required to receive an annual authorization from Congress for its appropriations; (4) the Foundation is to submit annually (in addition to the annual report of the Foundation) to Congress two other reports—one, an analysis by the National Science Board of the status and health of U.S. science and its various disciplines, the other, an analytical documentation of the total amount of support for research activity received by each college and university or other nonprofit institution from each Federal agency.

A number of steps were taken by the Foundation during the past year to carry out the new Act.

NATIONAL SCIENCE BOARD ANNUAL REPORT.—The first annual report of the National Science Board was forwarded to the Congress, via the President, on February 18, 1969. The report, "Toward a Public Policy for Graduate Education in the Sciences," together with its companion volume, "Graduate Education: Parameters for Public Policy," examines the circumstances that will characterize graduate education between now and 1980.

In addition to noting that graduate enrollments will probably double, resulting in a cost of $20 billion annually by the end of the next decade, the following conclusions and recommendations were made:

"* * * substantially increased funding from the Federal Government, unrelated to the present period of budgetary retrenchment, will be required if these institutions are to meet the expectations of American society.

"The markedly increased demand for graduate education expected in the next decade could be satisfied entirely by selective expansion of the programs of institutions already engaged in graduate education. However, each State and each metropolitan area with a population in excess of 500,000 should have graduate educational resources of high quality and of sufficient capacity to ensure full contribution to cultural, social, and economic development.

"Encouragement should be given to the development of multidisciplinary graduate programs at both the master's and doctoral levels, adapted to the problems of a changing society, combining various of the natural, social, and engineering sciences, and, when appropriate, leading to the award of new types of advanced professional degrees, designed for the preparation of practitioners rather than research-oriented specialists.

"Institutions moving for the first time into graduate work, either at the level of the master's or doctoral degrees, as well as those considering the formation of additional graduate programs, should base their decision on strong academic departments, already in existence, and on the availability of adequate resources to be committed to the graduate program.

"Academic research at the frontiers of knowledge, in its own right, is certainly in the national interest. It is, however, inseparable from the process of graduate education. For this reason, although research grants and contracts have played a unique role in bringing U.S. science to its present eminence, a major restructuring of the instruments of Federal support of graduate education is both timely and necessary for the major expansion expected in the next decade."

The report also recommended that "there be inaugurated a substantial program of institutional sustaining grants." Noting that the present pattern of research grants may be too restrictive to meet new challenges, the Board recommended that grants in support of science be channeled directly to institutions of higher learning and departments within them "to help support salaries and stipends, research facilities and libraries and other general operating expenses." Six specific types of grant programs were recommended.

The second annual report of the National Science Board is currently being prepared and will deal with the physical sciences.

AUTHORIZATION HEARINGS.—In accord with the new legislation, the Foundation's first authorization hearings were held in March 1969 before the Subcommittee on Science, Research, and Development of the House Committee on Science and Astronautics. Congressman Emilio Q. Daddario was chairman for these hearings which lasted nine days. During this time the subcommittee was presented with a comprehensive review of the scope of Foundation programs designed to strengthen the Nation's capabilities in scientific activities.

The hearings before the special subcommittee on the National Science Foundation of the Senate Committee on Labor and Public Welfare took place in May 1969 with Senator Edward M. Kennedy as chairman of the subcommittee.

The President had requested a budget of $500 million for the Foundation. Of this amount $10 million requested for the Sea Grant Program required authorization by the House Committee on Merchant Marine and Fisheries and the Senate Committee on Labor and Public Welfare. The Sea Grant authorization was made for a total of $15 million. Acting upon the recommendations of the House committee concerned with the authorization of the remaining $490 million of the Presidential budget request, the House authorized appropriations of $478 million for the Foundation for fiscal year 1970. The Senate authorization committee recommended $487 million for fiscal year 1970. Both bills would allow an additional $3 million for foreign currencies. At this writing final congressional action has not been taken on the Foundation's authorization bill.

APPLIED RESEARCH.—In response to the legislative change which made possible applied research support, the Foundation studied possible means of implementing such programs. These assessments were undertaken to determine the mechanisms by which the Foundation could best serve national scientific needs through its support of applied research. The resultant conclusions and the Foundation's present position on its role in applied research undertakings were summarized in written material prepared for the House authorization hearings. This material points out the difficulty in attempting to distinguish sharply between basic and applied research. In considering new or expanded proposals for scientific research, in view of its authority to support applied research, the Foundation has adopted the following guidelines:

(a) Proposals must be for scientific research projects which will add to our store of generally useful knowledge.

(b) In making grants to universities and colleges, the Foundation will give preference to proposals for research activities which constitute an integral part of the normal academic program of the institution.

(c) Applied research which is clearly within the jurisdiction of other agencies will not normally be supported.

(d) Criteria for judging projects involving applied research will include: (1) scientific excellence, and (2) potential relevance to the solution of important practical problems.

(e) Proposals for research requiring security classification will not be supported.

(f) The Foundation, in its general support of research, will continue to emphasize the importance of scientific research which contributes to the training of scientists and engineers. Hence, support to nonprofit institutions not directly involved in academic research at the graduate level will continue to be strictly limited.

The Foundation proposes to support interdisciplinary research on critical societal problems, research which will involve activity in both the basic and applied ends of the spectrum. It is also studying the possibility of supporting, at academic and other nonprofit institutions, separately funded and managed applied research programs in special preselected subject areas.

ANNUAL REPORT ON FEDERAL SUPPORT OF SCIENTIFIC RESEARCH.—Data for the first annual report to Congress on financial support received from each Federal agency by academic and nonprofit institutions have been collected and are presently in the process of being tabulated and analyzed. The report will be published in fiscal year 1970.

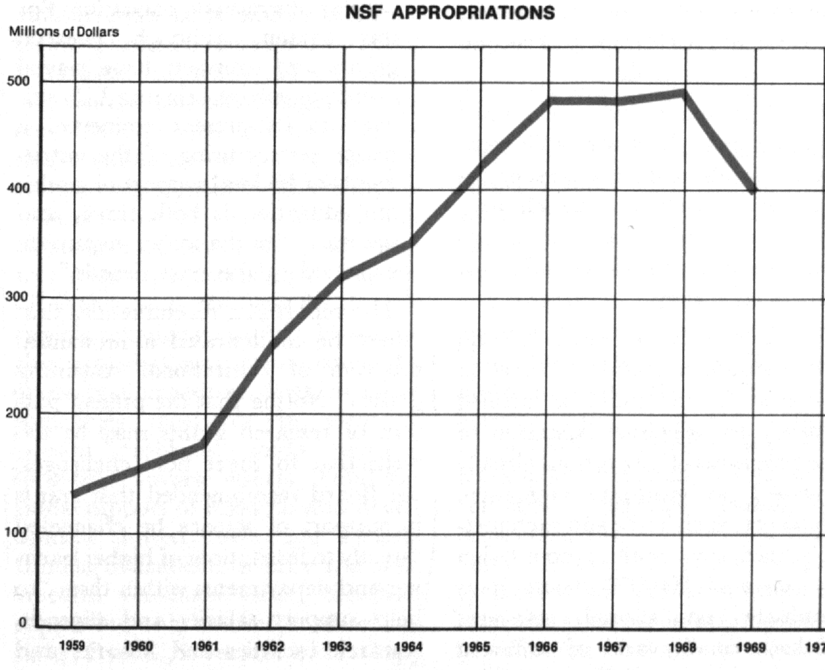
Financial Summary

For fiscal year 1969 Congress appropriated $400 million for National Science Foundation operations, a decrease of about 20 percent compared with the fiscal year 1968 appropriation of $495 million. The following chart shows congressional funding patterns for NSF since fiscal year 1959. It is significant to note that during a period of increasing student enrollments, and at a time of growing awareness of the role of science in contributing toward the solution of critical problems, appropriations for Foundation activities have first leveled off and then dropped. At this writing, the House of Representatives has passed appropriations for fiscal year 1970 totaling $420 million.

Actual obligations by the Foundation in fiscal year 1969 totaled $433 million,[1] a decrease of about 15 per-

[1] This obligational amount consists of the $400 million congressional appropriation plus recoveries and unobligated balances from previous years.

NSF APPROPRIATIONS



cent compared with fiscal year 1968 (see table 1). The decrease in the actual level of activities supported by NSF was even larger, about 20 percent, because the costs of these activities increased between 4–7 percent due to inflationary and increased complexity of research factors.

The fiscal year 1969 reductions in obligations were reflected through lower levels of funding in all major Foundation programs with the exception of the research project support program for which obligations increased slightly, about four percent during the year. The most severe reductions were experienced by the Foundation's facility programs; in fiscal year 1969 NSF obligations for science facilities were less than half of the fiscal year 1968 level.

Federal obligations for academic science remained at the same level in both fiscal year 1968 and fiscal year 1969 ($2.3 billion) while NSF support for this purpose dropped by 14 percent, from $423 to about $364 million. Moreover, total Federal obligations for basic research at universities and colleges also present a static picture over the 2-year period (about $800 million each year) while NSF support declined by 6 percent between fiscal year 1968 and fiscal year 1969.

Foundation obligations for fiscal years 1968 and 1969 are shown in table 2 according to field of science. The Foundation's scientific research awards are made according to field of science. However, other NSF awards, such as those for computer activities or science education, are generally not made on a predetermined disciplinary basis, but relate to the primary objective of the specific Foundation program involved.

Table 2 shows that the overall drop in fiscal year 1969 NSF obligations is reflected in almost all fields receiving Foundation support. In absolute terms only the social sciences and engineering maintained the previous year's level and the sharpest declines occurred in the support of the life sciences and the earth sciences, a decrease largely associated with the considerably lower obligational level of the Foundation's institutional support programs. On a relative basis, each discipline's share of total Foundation funds was approximately the same in both fiscal year 1968 and fiscal year 1969.

Although the total amount obligated by the Foundation in fiscal year 1969 was significantly lower than in 1968, the total number of grants and contracts awarded was not reduced. In fiscal year 1969 the Foundation awarded a total of 8,400 grants and contracts, slightly more than were awarded during the previous fiscal year (8,274).[1] Thus, on the average the size of each award was smaller in fiscal year 1969 than in 1968. Based on total proposals processed, 42 percent of the proposals had to be declined or were withdrawn by the applicant. Furthermore, of the proposals accepted for award, only 50 percent of the funds requested could be made available.

Budgetary restrictions affected Foundation operations in yet another way. The Revenue and Expenditure Control Act of 1968 called for a reduction of expenditures by all Executive departments and agencies in fiscal year 1969. To achieve this reduction, the bill imposed a legal limitation on expenditures made during the year. In line with this requirement the President set an upper limit, on an agency-by-agency basis, on the amount that could be expended in fiscal year 1969. The impact of expenditure limitations was especially severe on the Foundation because it has no direct, massive procurement or operational programs to absorb the reduction. As a result, this action had severe consequences because many of the NSF university commitments are of a long-term character, and in most cases the planned expenditures were based on obligational authority made well before fiscal year 1969.

After extensive review, the Foundation decided to limit expenditures not on a grant-by-grant basis but on

[1] These totals do not include awards for formula-based institutional grants or for individual fellowships. Awards for formula-based institutional grants totaled 497 in fiscal year 1968; comparable fiscal year 1969 awards were postponed, as previously described in table 1. The number of individual fellowships awarded was 2,566 in fiscal year 1969, 2,963 in fiscal year 1968.

Table 1

Obligations of the National Science Foundation

Fiscal Years 1968 and 1969

(Dollars in millions)

	Fiscal year 1968		Fiscal year 1969	
	Amount	Percent	Amount	Percent
Scientific research	$237	47	$225	52
Science education	125	25	107	25
Institutional support of science	83	16	[2] 46	11
Computer activities in education and research	22	4	17	4
Sea grant programs	5	1	6	1
Planning and policy studies	2	(1)	2	(1)
Science information activities	14	3	11	3
International science activities	1	(1)	2	(1)
Program development and management	15	3	16	4
Total obligations	505	100	433	100

[1] Less than 1 percent.
[2] Part of the 1969 decrease in this program relates to the Foundation's decision to change the formula used for the institutional grants from an NSF to a Federal base and, in order to obtain the relevant data from other agencies, fiscal year 1969 awards for this purpose were deferred until early fiscal year 1970. (See p. 85 for further discussion.) Thus while approximately $14 million was obligated in fiscal year 1968 for institutional grants, no such awards at all were made during fiscal year 1969. (Institutional grants constitute one program of the Foundations overall institutional support activity.)
Note.—Detail may not add to totals due to rounding.

Table 2.—National Science Foundation Net Obligations, by Discipline, Fiscal Years 1968 and 1969

(Dollar Amounts In Millions)

	Percent of total		Total		Scientific research		Science education		Institutional support of science	
Fiscal Year	1968	1969	1968	1969	1968	1969	1968	1969	1968	1969
Physical Sciences	29	29	$144.9	$126.5	$79.2	$75.9	$28.5	$24.7	$31.1	$20.8
Astronomy	6	6	29.7	27.4	26.5	24.7	.8	.6	2.4	2.1
Chemistry	10	10	49.1	43.3	22.1	19.5	13.7	12.4	8.7	8.1
Physics	13	13	66.1	55.7	30.6	31.6	14.0	11.7	20.1	10.6
Environmental Sciences	17	16	84.4	71.0	64.3	60.3	9.6	7.7	8.7	1.2
Atmospheric Sciences	5	6	27.5	24.8	25.0	24.1	.4	.5	1.7	------
Earth Sciences	5	4	23.5	16.9	9.4	8.8	7.7	6.3	5.5	1.2
Oceanography	7	7	33.5	29.3	29.9	27.3	1.5	.9	1.5	------
Mathematical Sciences	11	11	53.9	47.4	12.7	12.7	27.8	24.8	7.6	3.5
Life Sciences	17	15	85.8	66.7	44.1	40.6	19.7	17.6	19.4	5.9
Social Sciences	7	9	37.0	36.9	15.7	15.7	13.6	13.5	5.1	5.0
Engineering	9	10	44.6	45.0	20.5	20.1	15.8	15.1	6.5	7.8
All Other [1]	11	9	54.6	39.2	------	------	9.7	3.1	4.7	2.4
Total	100	100	505.2	432.6	236.5	225.3	124.8	106.5	83.2	46.5

	Computing activities		Sea grant program		Planning and policy studies		Science information activities		International science activities		Program development and management	
Fiscal Year	1968	1969	1968	1969	1968	1969	1968	1969	1968	1969	1968	1969
Physical Sciences	$.2	$.7	(*)	$.2	------	------	$5.7	$3.9	$.1	$.2	------	------
Astronomy	------	------	------	------	------	------	(*)	(*)	(*)	(*)	------	------
Chemistry	.2	.4	(*)	.2	------	------	4.4	2.6	(*)	.2	------	------
Physics	------	.3	------	(*)	------	------	1.3	1.3	(*)	(*)	------	------
Environmental Sciences	(*)	(*)	$.4	1.1	------	------	1.1	.5	.2	.1	------	------
Atmospheric Sciences	------	------	------	------	------	------	.2	(*)	.2	(*)	------	------
Earth Sciences	(*)	------	(*)	.3	------	------	.7	.3	(*)	(*)	------	------
Oceanography	------	(*)	.3	.8	------	------	.2	.3	(*)	(*)	------	------
Mathematical Sciences	5.2	6.1	------	------	------	------	.5	.2	(*)	(*)	------	------
Life Sciences	------	------	1.8	2.0	------	------	.4	.3	.3	.2	------	------
Social Sciences	.5	.5	.3	.7	$1.0	$.5	.7	.9	(*)	(*)	------	------
Engineering	------	.3	1.2	1.2	------	------	.5	.4	(*)	.1	------	------
All Other [1]	16.0	9.2	1.3	.8	1.4	1.9	5.5	4.4	.6	.9	$15.4	$16.5
Total	22.0	17.0	5.0	6.0	2.4	2.4	14.4	10.7	1.4	1.8	15.4	16.5

* Less than $100,000.

[1] All other includes those obligations in support of programs which cut across disciplines and, therefore, are not attributed to any single discipline.

NOTE.—Detail may not add to totals because of rounding.

an institutionwide basis in order to minimize overall adverse institutional effects. No limitation was imposed on institutions which had annual expenditures under $50,000. The remaining institutions with NSF grants were assigned ceilings, each of which had been carefully developed. It should be noted that later in the fiscal year both President Johnson and President Nixon raised the National Science Foundation expenditure ceiling somewhat in recognition of the hardship which the previous ceiling was placing on the Nation's colleges and universities. However, it is anticipated that in fiscal year 1970 the National Science Foundation will again be subject to some expenditure limitation.

Significant Program Changes

New Programs

Pre-Service Teacher Education Program.—A new program was introduced during fiscal year 1969, by the Division of Undergraduate Education in Science, to assist universities and colleges in improving curricula at the undergraduate level for the preparation of those who plan to become elementary or high school science teachers. The program encourages institutions to develop a closer working relationship between their science departments and education departments in providing training that will offer undergraduate students increased knowledge of subject matter in science and mathematics, greater skill and experience in developing and testing course materials, and early direct involvement in teaching.

State and Local Intergovernmental Science Policy Planning Program.—During fiscal year 1969 the Foundation started a new program to make awards to help science policy development and planning at the State and local levels of government. The prime objectives of the program are to: (1) advance the understanding of public issues and problems having scientific and technological content at the State and local levels of government; (2) promote better planning and application of scientific and technological approaches to public problems; (3) improve communication between persons concerned with science and technology at the Federal, State, and local levels of government; and (4) secure information on State and local scientific and technical resources.

International Programs.—Three new international cooperative programs were started during fiscal year 1969. A United States-Australian agreement for scientific and technical cooperation; a United States-Republic of China (Taiwan) cooperative science program; and a United States-Romanian cooperative science program were initiated by international agreement and discusions on implementation are currently underway. Activities will include the exchange of scientists and collaboration in research programs.

Other Program Changes

Expansion of College Science Improvement Program.—During fiscal year 1969 the Foundation expanded its College Science Improvement Program (COSIP) to include 2-year colleges offering college level courses in science. COSIP, which had been designed to assist in the development of the science programs of institutions with potential for improving their science capabilities and instructional programs, had been restricted to 4-year institutions with limited graduate programs. Now regional groupings of 2-year colleges are eligible to participate with a neighboring college or university to accelerate faculty development and related course content improvement. This program marks the first Foundation effort specifically designed to benefit 2-year colleges.

In addition, the College Science Improvement Program now permits eligible 4-year institutions to form ad hoc or formal groups of institutions for cooperative science projects. This allows these 4-year colleges to engage in undertakings better accomplished by associations of institutions than by individual schools.

Institutional Grants for Science.—The Institutional Grants for Science Program provides annual grants to colleges and universities for use at their discretion for the purpose of maintaining and strengthening their science programs. In the past the amount of each institutional award has been determined, with the use of a graduated arithmetical formula, on the basis of the total amount of applicable research and research-training grants each institution received from the National Science Foundation during the previous fiscal year. In fiscal year 1969 the Foundation announced its intention to expand the base used in computing these formula grants to include awards made by other Federal departments and agencies, with the exception of research grants made by the National Institute of Mental Health and other components of the U.S. Public Health Service. The extension to a broader Federal base will increase significantly, from 500 to 675, the number of institutions eligible for such support.

Program Accomplishments

Nobel Awards for Physiology or Medicine

Two Nobel laureates were aided in the research which led to their awards. Robert W. Holley of the Salk Institute and Har Gobind Khorana of the University of Wisconsin, both NSF grantees, shared the 1968 Nobel Prize for Physiology or Medicine with Marshall Warren Nirenberg of the National Heart Institute for their work in interpreting the genetic code and its function in protein synthesis.

The three scientists worked independently in their investigations but all contributed to a common understanding of the genetic code and its function in the making of proteins. Dr. Holley's research was conducted at Cornell University, and he and his team are credited with being the first to determine the primary structure of transfer ribonucleic acid (tRNA), the carriers of amino acids used in building up protein chains. Dr. Khorana and his associates at the University of Wisconsin developed chemical techniques that permit the assembly of specific DNA (deoxyribonucleic acid) molecular structures, and confirmed that the genetic code is read in a linear and consecutive manner and that it is a nonoverlapping triplet code. For his work Dr. Khorana was also a joint recipient with Dr. Nirenberg of Columbia University's 1968 Louisa Gross Horwitz Prize for outstanding research in biochemistry.

Through a greater understanding of the DNA-RNA complex it is hoped that new controls over disease and genetic defects can be developed. For example, because viruses contain DNA, knowledge of these nucleic acids is valuable in attempting to overcome virus diseases.

This marks the second consecutive year in which work supported by the Foundation led to the Nobel Prize in Physiology or Medicine. George Wald of Harvard University who was awarded this prize in late 1967 for his contributions to research in vision had received research support by the Foundation for his studies over a period of several years.

Discovery of Gravity Waves

University of Maryland scientists claim to have made the first detection and measurement of gravity waves from developing or collapsing stars in the Milky Way. This discovery, which supports the Theory of Relativity of Albert Einstein, essentially means that gravitational energy is transmitted through waves similar to light or radio signals. Through this research man is now able to detect and measure these gravity waves. Further work in this area can lead to a far greater understanding of the earth and the universe and could lead to the availability of a new source of energy. According to project director Joseph Weber there is on the order of 100 times more gravitational energy than nuclear energy in the universe.

Interstellar Formaldehyde Discovered

Organic molecules in interstellar space have been discovered for the first time. D. Buhl and L. E. Snyder of the National Radio Astronomy Observatory (NRAO), B. Zuckerman of the University of Maryland, and Patrick Palmer of the University of Chicago comprised a team which detected interstellar formaldehyde by use of the 140-foot radio telescope at the NRAO observing site in Green Bank, W. Va. Formaldehyde is the first polyatomic organic molecule to be discovered in the interstellar medium. Ammonia and water were also detected this year. These finds are expected to yield important information about the history of nuclear reactions within the galaxy.

Support for School of Social Sciences at Institute for Advanced Study, Princeton

The establishment of a school of social sciences at the Institute for Advanced Study in Princeton, N.J., is being aided by a National Science Foundation grant toward the construction of a social sciences building. The new school will join the Institute's schools of mathematics, natural sciences, and historical studies in the fostering of scholarly activity at the highest level. The grant represents another step in the Foundation's program to provide additional resources for activities in the social sciences.

Manganese Deposit Found

A multimillion-dollar deposit of manganese on the floor of Green Bay—an inlet located along the northwestern shore of Lake Michigan—was discovered by a University of Wisconsin oceanographer, J. Robert Moore. The deposit lies in relatively shallow water and should be recoverable by readily devised undersea mining methods. The research was supported in part by the National Science Foundation.

The manganese-bearing pellets were found in routine bottom sampling and lie off Green Bay's western shoreline. These pellets constitute the first significant deposits which have been found in potentially commercial quantities beneath the surface of a body of fresh water. Most of the world's manganese deposits lie outside the United States.

Deep Sea Drilling Project

The Deep Sea Drilling Project (DSDP), conducted from the ship *Glomar Challenger*, has produced important results, some of great potential economic significance. A major surprise was the discovery of oil, gas, sulfur, and other minerals commonly associated with land salt domes in deep water in the Gulf of Mexico—the first time that oil has been discovered in the deep ocean. The site was the Sigsbee Knolls, discovered in 1954, which are now known to be domes produced by the upward thrust of salt. Later DSDP discoveries have strongly substantiated the theory of seafloor spreading and given much information about the geological history of the ocean basins—data that are useful both for science and for potential economic exploitation of the ocean. As a sidelight, deep sea drilling technology has been advanced; the longest drill string ever suspended from an ocean vessel—more than 19,000 feet long—was successfully used. This project is carried on through a contract with the Foundation by the Scripps Institution of Oceanography, with participation by scientists from many universities and institutes and from industry.

Special Activities

Report on Role of Research and Development in Major Innovations

In a report entitled "Technology in Retrospect and Critical Events in Science" (TRACES), the IIT Research Institute delineated the research and development processes that lead to technological innovation. The report presented tracings, that is historical charts, of the key research and development events which led to five specific technological innovations with major economic and sociological impacts. The five innovations studied included: (1) The oral contraceptive pill; (2) matrix isolation—a technique for "stopping" chemical reactions and observing the reaction species, with significant application in the chemical industry; (3) magnetic ferrites—materials widely used in computer memory devices, telecommunications, and small electric motors; (4) the video tape recorder; and (5) the electron microscope—a device to produce images enlarged to more than 100,000 times their actual size. Each of these innovations was reviewed to establish its scientific origins. The tracings showed that about 70 percent of the research contributing to an innovation was nonmission-oriented, i.e., undertaken for the purpose of improving scientific understanding, and nine-tenths of this nonmission research had been accomplished before the innovation itself was ever conceived. About 20 percent of the events leading to the innovations were oriented toward some end product and about 10 percent were connected with development and innovation. The results of the analyses thus revealed the broad base of research generally necessary for the eventual development of significant technological innovations and the significant role of non-mission-related research activity.

Special Commission on the Social Sciences

In 1968, in response to the increased interest in the social sciences in both the legislative and executive branches of the Federal Government, the National Science Board established a Special Commission on the Social Sciences charged with recommending how the social sciences could best contribute to the solution of critical problems of society. This commission, which elected as its chairman Orville G. Brim, Jr., president of the Russell Sage Foundation, issued its final report at the start of fiscal year 1970.

Entitled "Knowledge into Action: Improving the Nation's Use of the Social Sciences," the report stresses that Government as well as society at large should make increasing use of the social sciences. The document points out that many present day decisions which take economic factors and costs into account should also be made on the basis of social costs and returns.

With regard to specific recommendations for implementing this broad goal the report recommends:

- Appropriation in fiscal year 1970 to the National Science Foundation of $10 million for the establishment of social problem research institutes;
- Increased representation by social scientists on major Federal policymaking groups such as the President's Science Advisory Committee, the Office of Science and Technology, and the Council of Economic Advisers;
- Improved dissemination of social science knowledge to the public;
- The strengthening of social science activities by professional schools, business and labor, and community organizations.

Organizational Changes

Office of the Director

The 6-year appointment of Dr. Leland J. Haworth as Director of the National Science Foundation expired on June 30, 1969. Upon his departure from the Foundation, Dr. Haworth, whose career included terms as a Commissioner of the Atomic Energy Commission; President of Associated Universities, Inc.; and Director of Brookhaven National Laboratory, became assistant to the president, Associated Universities, Inc.

The President nominated Dr. William D. McElroy, chairman of the biology department at Johns Hopkins University and Director of the university's McCollum-Pratt Institute to succeed Dr. Haworth. Dr. McElroy received Senate confirmation on July 11, 1969, and took the oath of office as Director on July 14, 1969.

In the brief interim period between Dr. Haworth's departure and Dr. McElroy's appointment, Dr. Louis Levin, Executive Associate Director of the Foundation, served as Acting Director. Dr. Levin, whose appointment as Executive Associate Director was announced early in fiscal year 1969, succeeded Dr. John T. Wilson, who left the Foundation to join the University of Chicago as vice president and dean of faculties.

National Science Board Changes

Some changes in National Science Board membership and organization took effect in fiscal year 1969. Eight 6-year appointments to the National Science Board were made by the President at the close of fiscal year 1968, six new appointments and two reappointments. These appointments were listed in detail in the last annual report of the Foundation. A complete list of National Science Board members can be found in appendix A.

In addition, as also described in the previous report, elections were held at the end of fiscal year 1968 for Board officers. Dr. Philip Handler was reelected chairman and Dr. E. R. Piore was elected vice chairman for terms expiring in May 1970.

National Science Board Organizational Changes

Changes were also made during the year in the Board's committee structure. The Standing Committee on Science Development Awards and Standing Committees I, II, and III, each responsible for the surveillance of specific Foundation program activities, were abolished and the following new standing committees were established:

Programs Committee which is concerned with current and proposed Foundation programs (except for institutional programs);

Institutional Committee which provides oversight, reviews policy issues relating to the administration of Foundation institutional programs, and assesses the impact on institutions resulting from the manner in which Foundation programs are administered;

Long-Range Planning Committee which concentrates on the long-range problems of science in the United States and the role to be played by the Foundation in acting upon these problems;

Proposal Review Committees (Research Review Committee and Education Review Committee) which, in specified areas of Foundation activity, are responsible for carrying out project reviews based on which appropriate action is recommended to the Board or questions of policy are raised;

Budget Committee which reviews and advises on budgetary and fiscal matters.

Staff Changes

Several key personnel changes were announced during the year:

Appointments

Dr. Arley T. Bever, Deputy Planning Director.

Dr. Charles A. Whitmer, Division Director for Pre-College Education in Science.

Resignations

Dr. Milton E. Rose, Head, Office of Computing Activities, resigned to accept the chairmanship of the department of mathematics and statistics at Colorado State University.

In total, 953 full-time personnel were employed by the National Science Foundation at the end of fiscal year 1969 as compared to 972 in fiscal year 1968.

Research Support Activities

Providing the scientist with the resources to carry out his creative work is a primary function of the Foundation. To carry out this responsibility, the NSF supports scientific research primarily through grants to colleges and universities for projects proposed by the scientist who would carry out the research. Research activities covered in this chapter, are divided into four [1] major areas:

- Research grants to institutions for scientific investigations by individual scientists or groups of scientists.
- Grants to academic institutions for the acquisition of specialized research equipment and facilities.
- Support of cooperative National (and International) Research Programs.
- Support of National Research Centers, established and operated for the Foundation by associations of universities.

Research Project Grants

In fiscal year 1969, the Foundation awarded 4,088 grants for research projects amounting to a total of $176.0 million, a slight increase over the figure for fiscal year 1968. Of all the actions taken by the Foundation on research project proposals in fiscal year 1969, 51 percent were awards. Table 3 gives the distribution, by number and amount, of awards according to fields of science for the fiscal years 1967, 1968, and 1969. Grants were awarded to 423 institutions, including 324 colleges and universities, in all 50 States, the District of Columbia, Puerto Rico, and the Canal Zone. More than 90 percent of the funds went to academic institutions. Of these, 233 received two or more research grants, and 118 received at least $200,000.

In engineering, the program of Research Initiation Grants initiated in fiscal year 1966 for young engineering faculty members beginning independent investigations has been continued. During the fiscal year, the Foundation received 587 proposals for Research Initiation Grants (a decrease of about 15 percent over the previous year) requesting $8.7 million. A total of 136 grants were awarded in the amount of $2.0 million.

Specialized Research Equipment and Facilities

Many of the scientific tools used by scientists are so large and complex that they cannot be funded from grants awarded for individual research projects. Moreover, the complex and sophisticated character of much current research makes it more economical to provide common-use items for utilization by groups or numbers of independent investigators. The Foundation has initiated programs of support for specialized research facilities and equipment in most of the fields for which research grants are awarded. A summary of grants awarded for this purpose over the past 3 years is given in table 4.

National Research Programs

National Research Programs are specifically identified as major research efforts undertaken because of a national need to accomplish a designated task in a particular field or group of fields. Some programs include aspects which border on applied science; others are characterized by work in a specific geographical area, and some involve international cooperation and coordination. In some instances the Foundation has been given specific responsibility for such programs by the President, or by the Congress, or by agreement within the executive branch of Government. Table 5 summarizes totals for grants and contracts for National Research Programs over the past 3 years.

[1] Research undertaken in connection with the National Sea Grant Program and computing activities in research are discussed in separate chapters.

Table 3
Scientific Research Projects
Fiscal Years 1967, 1968, 1969
(Dollars in millions)

	Fiscal year 1967		Fiscal year 1968		Fiscal year 1969	
	Number	Amount	Number	Amount	Number	Amount
Astronomy:						
Optical		$4.55		$4.06		$3.85
Radio		1.28		2.14		2.96
Subtotal	117	5.84	119	6.19	125	6.82
Atmospheric Sciences:						
Aeronomy		1.83		1.89		1.65
Meteorology		3.80		3.94		4.32
Solar-Terrestrial		1.41		1.74		2.25
Subtotal	92	7.03	103	7.57	116	8.21
Biology:						
Cellular Biology		10.33		9.41		8.69
Environmental and Systematic Biology		7.44		6.89		6.88
Molecular Biology		10.75		10.14		9.59
Physiological Processes		7.85		10.31		9.36
Psychobiology		4.96		4.09		3.78
Subtotal	1,062	41.33	1,130	40.83	1,173	38.31
Chemistry:						
Chemical Analysis		1.07		1.07		1.48
Chemical Dynamics		5.80		3.73		4.16
Chemical Thermodynamics		1.17		1.60		1.56
Quantum Chemistry		3.12		3.38		3.54
Structural Chemistry		3.80		3.73		3.22
Synthetic Chemistry		2.25		4.26		3.90
Subtotal	416	17.21	454	17.77	484	17.85
Earth Sciences:						
Geology		1.27		1.56		1.31
Geochemistry		3.18		2.97		3.31
Geophysics		3.49		3.28		3.30
Subtotal	221	7.94	214	7.81	200	7.92
Engineering:						
Engineering Chemistry		2.69		2.84		2.73
Engineering Energetics		3.08		3.11		29.4
Engineering Materials		2.89		3.44		3.23
Engineering Mechanics		5.97		5.93		6.39
Engineering Systems		3.46		3.44		3.00
Special Engineering Programs		1.15		.63		.98
Subtotal	495	19.24	506	19.40	491	19.27
Mathematics:						
Algebra and Topology		4.50		4.44		4.39
Analysis, Foundations, and Geometry		4.50		4.32		4.37
Applied Math and Statistics		4.04		3.94		3.94
Subtotal	396	13.05	405	12.70	462	12.70
Oceanography:						
Biological Oceanography		6.85		6.05		6.03
Physical Oceanography		2.97		1.94		2.16
Geological Oceanography		1.94		2.91		2.55
Support, Ship Operations		6.38		6.88		8.64
Subtotal	276	18.14	239	17.78	280	19.38
Physics:						
Atomic and Molecular Physics		2.37		2.33		2.64
Elementary Particle Physics		8.28		6.48		11.53
Nuclear Physics		4.97		9.07		8.01
Solid State and Low Temp Physics		4.50		4.40		4.61
Theoretical Physics		3.55		3.63		3.73
Subtotal	265	23.67	236	25.90	283	30.35
Social Sciences:						
Anthropology		3.46		3.50		3.42
Economics		3.17		3.58		4.29
Geography		.43		.59		.19
Sociology and Social Psychology		4.04		3.73		3.29
Political Science		.72		.76		1.28
History and Philosophy of Science		.72		.73		.87
Special Projects		1.87		1.76		1.90
Subtotal	425	14.42	426	14.67	474	15.24
Total	3,765	167.87	3,832	170.61	4,088	176.02

Table 4
Specialized Research Equipment and Facilities
Fiscal Years 1967, 1968, and 1969
(Dollars in millions)

	Fiscal year 1967		Fiscal year 1968		Fiscal year 1969	
	Number	Amount	Number	Amount	Number	Amount
Astronomy	12	$1.860	4	$0.662	5	$0.324
Atmospheric Sciences	19	.954	11	.788	8	.298
Biological and Medical Sciences	25	1.668	30	1.709	34	.880
Chemistry	88	3.121	113	4.296	57	1.700
Engineering	44	.943	43	1.073	26	.880
Oceanography	11	2.017	9	4.711	1	1.397
Physics	19	5.797	19	4.697	25	1.300
Social Sciences	10	.309	3	1.006	2	.438
Total	228	16.671	232	18.942	158	7.216

Table 5
National Research Programs
Fiscal Years 1967, 1968, and 1969
(Dollars in millions)

	Fiscal year 1967		Fiscal year 1968		Fiscal year 1969	
	Number	Amount	Number	Amount	Number	Amount
U.S. Antarctic Research	143	$7.58	149	$7.64	145	$6.86
Arctic Ocean Research	1	.13	0	0	0	0
Weather Modification	41	2.91	32	2.77	24	2.43
Deep Crustal Studies of the Earth (MOHOLE)	1	.06	0	0	0	0
International Year of the Quiet Sun	18	.71	0	0	0	0
International Biological Program	12	.50	1	.70	16	1.22
Ocean Sediment Coring Program [1]	0	0	4	4.17	5	2.43
Global Atmospheric Research	0	0	1	.20	9	.54
Total	216	11.89	187	15.48	199	13.48

[1] Continuing program begun in fiscal year 1966, no funds added in 1967.

National Research Centers

The four National Research Centers established and funded by the Foundation are Government-owned facilities designed to fill special research needs that cannot be met by existing institutions. The facility is operated in each case by a corporation formed by a group of universities under the general supervision of the Foundation. A limited staff of scientists and support personnel is maintained at the two optical observatories—Kitt Peak National Observatory, Tucson, Ariz., and the Cerro Tololo Inter-American Observatory in Chile—and at the National Radio Astronomy Observatory, Green Bank, W. Va. Most of the available telescope time at these facilities is assigned to visiting astronomers and graduate students from the general academic community.

At the National Center for Atmospheric Research (NCAR), near Boulder, Colo., a sizable staff of scientists from a number of disciplines conducts basic research in the atmospheric sciences and exercises leadership in broad, cooperative projects of major national significance. There is considerable participation by academic scientists in these extensive cooperative programs and in the use of NCAR specialized equipment in connection with independent research projects.

Table 6 shows the level of funding for the National Research Centers during fiscal years 1967, 1968, and 1969.

Table 6

National Research Centers—Fiscal Years 1967, 1968, and 1969

	Fiscal year 1967			Fiscal year 1968			Fiscal year 1969		
	Capital obligations	Research operations and support services	Total	Capital obligations	Research operations ard support services	Total	Capital obligations	Research operations and support services	Total
Cerro Tololo Inter-American Observatory	$1, 020, 000	$693, 000	$1, 713, 000	$1, 502, 000	$823, 000	$2, 325, 000	$3, 449, 000	$1, 101, 000	$4, 500, 000
Kitt Peak National Observatory	2, 058, 400	3, 446, 600	5, 505, 000	8, 331, 176	4, 144, 192	12, 475, 368	1, 137, 700	4, 561, 809	5, 699, 510
National Radio Astronomy Observatory	1, 392, 538	3, 592, 462	4, 985, 000	874, 300	3, 989, 700	4, 864, 000	483, 212	6, 795, 001	7, 278, 214
National Center for Atmospheric Research	3, 060, 656	9, 240, 000	12, 300, 656	2, 041, 100	9, 758, 612	11, 799, 712	425, 000	10, 611, 736	11, 036, 737
Total	7, 531, 594	16, 972, 062	24, 503, 656	12, 748, 576	18, 715, 504	31, 464, 080	5, 494, 912	23, 069, 547	28, 564, 461

MATHEMATICAL AND PHYSICAL SCIENCES

Recognizing the critical importance of the mathematical and physical sciences to the advancement of all science, the Foundation has devoted about a third of its total scientific research project support to physics, chemistry, mathematics, and astronomy. In fiscal year 1969, approximately 1,300 grants were awarded at a level of $67 million in these areas.

Although distinctions among the traditional divisions of the mathematical and physical sciences can be made in such matters as cost and equipment requirements, there is a continuing erosion of the boundaries which divide the substantive content of these sciences. As an example, among the following articles which highlight mathematical and physical scientific research support by the Foundation, two experiments are described, one by a physicist and the other by a chemist, in which optical lasers are used to resolve problems in quantum chemistry.

Chemistry

The major portion of grants for chemical research in fiscal year 1969 were used to support, at essentially the same dollar level as in the two preceding years, projects representative of the broad range of chemical research, including analytic, synthetic, and physical chemistry, and instrumentation development for chemical technology.

The Foundation continues to be concerned with the research opportunities afforded to young men who are just beginning a teaching career in chemistry. To maintain the creativity of these young teachers, it is imperative that they be able to begin a program of research immediately upon accepting their position. Accordingly, approximately 20 percent of the grants provided during fiscal year 1969 were for the support of new investigators.

During fiscal year 1969, the Foundation awarded 484 grants for research in chemistry with a dollar value just under $18 million.

Laser Excitation of Molecules

Laser excitation of molecules permits the chemist to study in a gas sample only those molecules which are in a completely specified energy state. This is tantamount to realization of the chemist's dream of a "Maxwell's Demon"—a hypothetical submicroscopic imp who would sit inside a gas sample and separate the gas molecules according to their energy levels, making the sample hot on one side and cold on the other.

Intense, highly monochromatic lasers are now being used as light sources in photochemistry, and in studies of energy transfer. Quantum mechanical theory predicts that a molecule's motion may have only certain discrete rotational and vibrational frequencies. The laser beam, because of its single sharply defined wavelength, can be used selectively to excite the molecule, causing a transition from one particular vibrational-rotational level of the ground state to one particular vibrational-rotational level of the excited state. By choosing the plane of vibration of the laser beam, the orientation of the excited state molecule may be determined as well.

Once the molecule absorbs the laser radiation and makes a transition to an excited state, it may lose its energy of excitation through three pathways: (1) Reactive collisions which form new compounds; (2) inelastic collisions in which the excitation energy is transferred to new vibrational-rotational levels of the excited state; and (3) spontaneous radiative decay by which the excited molecule acts as a small radio antenna and radiates away its excess energy. In the last process the spectrum of the radiation emitted by the molecule is not a continuum, but consists of sharp lines of different wavelengths corresponding to those various ground state vibrational-rotational levels to which it can make transitions. (See illustration.) These

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lines, known as a molecular fluorescence series, fingerprint the energy levels involved and serve to identify in detail those processes which have affected the excited state molecule before it radiates. For this reason, laser-induced molecular fluorescence is an exceptionally sensitive means of investigating both the dynamics of the internal molecular motions and the collision processes the excited state molecules undergo.

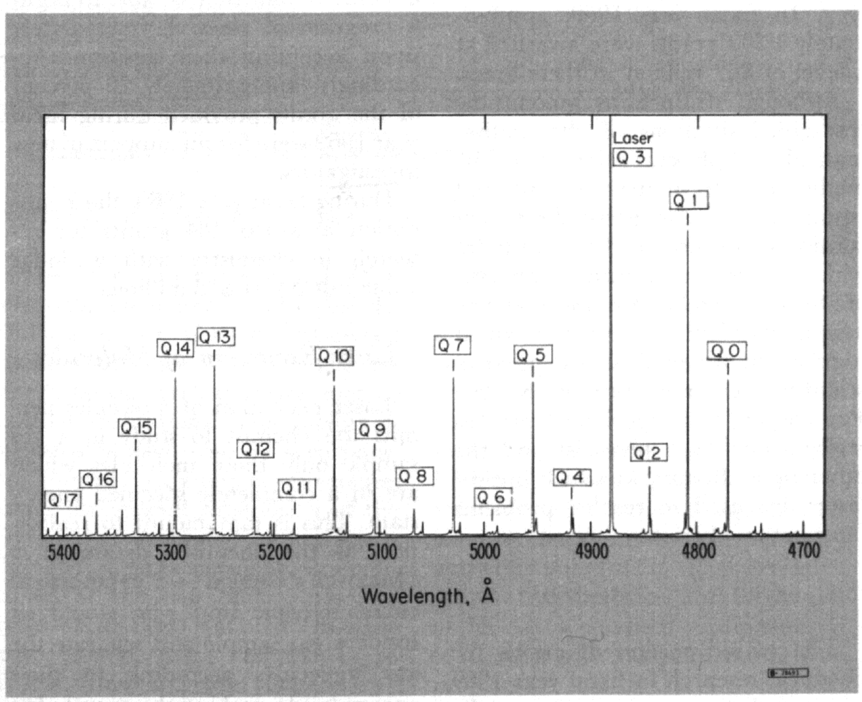
Richard N. Zare of the University of Colorado has been studying laser excitation of molecules in order to explore the potentialities of this new technique. In December 1967, he and his collaborators announced the successful observation of fluorescence from the dipotassium molecule using the red light beam from a helium-neon laser as a source of excitation. Since then, the list of molecules his group has studied has grown to include diiodide, disodium, dilithium, nitrogen dioxide, and s-tetrazine. Many of these compounds occur only in very minute concentrations, and observation of molecular fluorescense from these molecules using laser excitation demonstrates how sensitive the technique is for detecting and monitoring the presence of trace compounds. This has many important practical applications in analytical work, such as the possible development of a "laser radar" capable of measuring the impurity levels of contaminant gases in the atmosphere and tracking their positions and motions.

From a spectroscopic study of laser-excited molecular fluorescence, Dr. Zare has been able to determine the fundamental rotational and vibrational frequencies of the different molecular quantum states and to deduce, in some cases, the dissociation energy of the molecule, i.e., the energy required to rupture the chemical bond between two nuclei. Such information has allowed him to construct accurate graphs of potential energy for these molecules over a larger range of distances between atomic nuclei than has been hitherto possible. Potential energy is the energy which a system—a molecule in this case—possesses by virtue of its position or configuration (just as a suspended weight or a stretched spring has potential energy). The shapes of such potential curves play an important role in the models chemists construct to describe collision processes.

Dr. Zare has also used the laser-excitation technique to gain new insights into other properties of excited-state molecules. Information about the electromagnetic charge distribution, radiative lifetime, fine and hyperfine structure of molecules was previously measurable only when they were in the ground state, through the use of such techniques as microwave and molecular beam methods. However, Dr. Zare has shown that the excited states can be studied with comparable accuracy by subjecting laser-excited molecules to electric, magnetic and radiofrequency fields and measuring the effect these fields have on the angular distribution of the emitted light. The first results of the investigations on such molecules as nitrogen oxide and hydroxyl are showing that the internal motions of excited-state molecules are far more complex than was previously assumed. It has also proved possible to excite selectively only one isotopic form of a molecule in the presence of others. This may lead to a photochemical procedure for synthesizing compounds with predetermined isotopes incorporated into specific sites which would be invaluable in analyzing complex reactions such as those in living organisms.

Microscopic Motions in Solutions

Scientists have known for many years, and have been able to prove in-indirectly, that molecules in solutions are constantly in motion. These mo-



Fluorescence series for the disodium molecule, excited by an argon gas laser at a wavelength of 4880 Ångstrom units. The sharp spikes on the spectrum, indicating different quantum levels of energy (Q), serve to identify the molecule and its possible alternative energy states. (After R. N. Zare) tions include moving from one place to another, called translational diffusion, and tumbling, rolling or spinning, called rotational diffusion. In addition, large flexible molecules, such as those which make up living organisms, can spontaneously change their shapes. These microscopic motions are classed as thermal motion since they are affected by changes in temperature. They are not yet very well understood, since until recently it has been impossible to observe or measure them directly.

Robert Pecora of the Chemistry Department at Stanford University has theorized that a beam of light directed at a solution will be scattered and its frequency shifted in a specific manner by interactions with the moving molecules. If the frequency shift, intensities, and the scattering angles could be measured accurately, the motions themselves could be analyzed from the theory. In addition to his work on microscopic motions, Dr. Pecora has also developed a theory whereby the rate at which certain reactions occur can be measured using similar techniques.

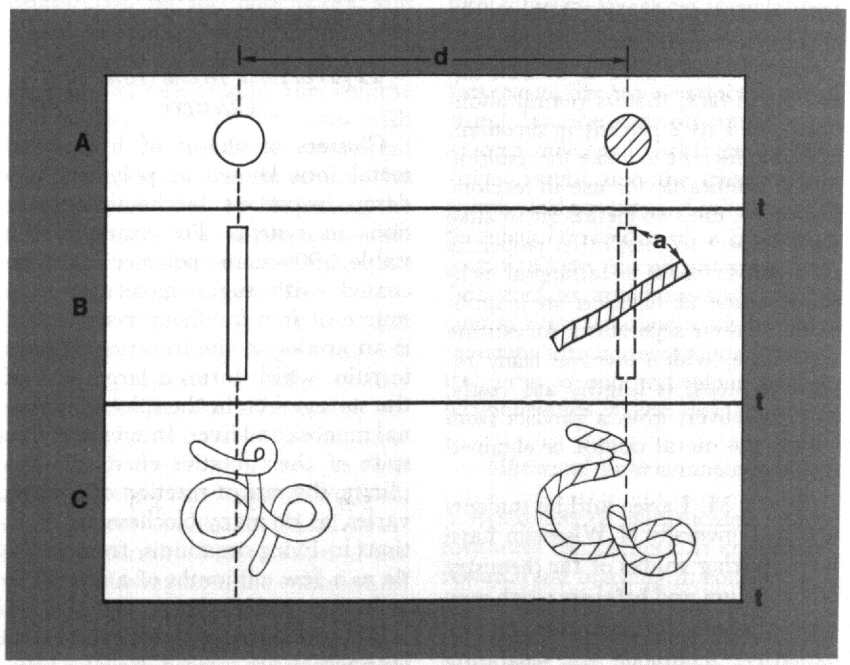
It should be emphasized that the changes in the frequency of the incident beam related to scattering from solutions of molecules are so small—on the order of one part per hundred billion—that they could not be detected before the invention of the laser which provides high-intensity light of a sharply defined frequency.

Experiments of the type first suggested by Dr. Pecora in 1962 were performed in 1964 by H. Z. Cummins, Norman Knable, and Y. Yeh at Columbia University. In their classical experiment, they worked with suspensions of microscopically small polystyrene latex spheres, which would exhibit frequency shifts in the scattered light due only to translational diffusion. Dr. Cummins and his coworkers directed a narrow ray of light from a monochromatic gas laser at the solution, and measured the intensity and frequency distribution of the scattered light at various angles relative to the transmitted ray. Their results confirmed that a characteristic rate of diffusion could be obtained from the new theory and experiments.

Theory so far has concentrated on relating models of the microscopic thermal motion involved to the frequency distribution of the scattered light. This distribution may be calculated for many kinds of systems, for example, liquids composed of small, nonspherical molecules. Dr. Pecora and his coworkers have in the past few years concentrated on theories applicable to dilute solutions of large molecules, which are difficult to study by other techniques. Surprisingly, for such systems the frequency distribution of the scattered light is relatively simple.

For more complicated situations, it has been shown that in addition to the translational diffusion rate, the rate of molecular rotation and, sometimes, the rate of spontaneous shape changes of large flexible molecules may be obtained. During the past few years, two light scattering experiments have been performed which succinctly measure rotational diffusion rates. Dr. Cummins, T. J. Herbert, Francis D. Carlson, A. Wada, and others have worked with rod-shaped tobacco mosaic viruses in water solutions. No one has yet attempted to use light scattering to observe the spontaneous shape changes predicted by Dr. Pecora's theory for flexible large molecules.

In addition to the ability to detect extremely small frequency shifts and thereby measure molecular motions, the remarkable sensitivity of the light scattering technique gives other advantages such as the fact that it can be used with very small amounts of material. Moreover, it does not destroy or change the sample in any significant way, as do some of the older techniques. For this reason, delicate biological materials which are in scarce supply can now be more readily studied.



(a.) Spherical molecule has moved distance *d* in time *t*. (b.) Rod-shaped molecule has moved distance *d* and rotated through angle *a* in time *t*. (c.) Flexible molecule has moved distance *d* and spontaneously changed shape in time *t*.

Separation of Zirconium and Hafnium

One of the cornerstones of modern chemistry was the discovery that the physical and chemical properties of the elements reoccur in a regular pattern, causing them to fall into family groupings all of whose members have analogous properties. An important example of the way in which this phenomenon can be troublesome rather than useful is the similarity in the characteristics of the metals zirconium and hafnium.

With the current rapid increase in the use of nuclear reactors as a source of commercial electric power, zirconium has become a valuable resource as a material for their construction. Zirconium's value in this application is due to its low capacity for the capture of thermal or low energy neutrons which must be captured by the fissionable fuel in order to maintain a chain reaction. Unfortunately, hafnium, which occurs in the natural state with zirconium, differs from it in physical properties almost exclusively with respect to this key ability, i.e., it is an extremely good neutron absorber. It is so good a neutron absorber, in fact, that its normal abundance of 1 to 2 percent in zirconium ores is sufficient to make the resulting metal unsuitable for use in reactors. However, the two metals are so alike with respect to most other properties that conventional metallurgical techniques such as flotation are inapplicable to their separation. An existing technique, which involves many repetitive steps, is lengthy and costly, and moreover, gives a product from which the metal cannot be obtained directly.

Edwin M. Larsen and his students at the University of Wisconsin have been making studies of the chemistry of zirconium and hafnium which may clear the way for a simpler and less expensive technique for separating them. Professor Larsen's attention has been directed toward the reduced states (generally speaking, the opposite of the oxidized states in which they naturally occur) of the metals, in which there are known to be more significant differences in their properties. This work has led to the interesting discovery that zirconium tetrachloride, dissolved in aluminum chloride, is reduced at a relatively low temperature (260° C.) by zirconium metal to yield crystalline, nonvaporizable zirconium trichloride. On the other hand, hafnium tetrachloride does not react at all under these conditions, and the vaporizable unreduced hafnium tetrachloride and aluminum trichloride can be separated from the zirconium trichloride by sublimation—the direct transition from solid to gas. In a typical reaction, zirconium tetrachloride containing 1.4 percent hafnium is reduced to the trichloride with a residual hafnium concentration of 0.074 percent, or a 2,000-percent increase in purity. The reaction system has the further advantage of relatively low temperature and a pure crystalline product suitable for direct incorporation into normal metallurgical techniques.

Hydrolyzed Metal Ions and Clusters

Clusters of chains of hydrolyzed metal ions known as polymers undergo important biochemical reactions in systems. For example, the stable, 900-atom polymer of iron coated with sugar molecules is a source of iron for living systems and is an analog to the iron-rich protein ferritin, which forms a large part of the storage iron in the spleen, intestinal mucosa and liver. Interestingly, in spite of their relative chemical simplicity, the rate of reaction of clusters varies, as do many biochemical reactions in living organisms, from as little as a few millionths of a second to as long as several days.

The chemistry of hydrolyzed metal ions, which are formed in water solutions at intermediate levels of acidity, has until recently attracted little direct attention. It is known that, under the conditions described, most metal ions will form soluble clusters or polymers with the hydroxide ion (OH^-). For a given metal, the clusters seem to occur in a limited number of preferred forms or species, which profoundly affect the availability and reactivity of both the metal and the hydroxide ions. For example, iron III exists as a stable dimer, or 2-atom cluster, although its other, biologically more important form is the 900-atom polymer.

Dale W. Margerum and his coworkers at Purdue University are studying the reaction mechanisms and energies of reactions involving metal hydroxide clusters in order to more fully understand this puzzling variation in reactivity. The starting point for their investigations was the rate of reaction of acid with the hydroxide groups. The usual rate of such a reaction, which involves the combination of hydrogen ion (H^+) with hydroxide ion (OH^-) to form a water molecule, is extremely rapid. In reactions involving metal ions, however, the reaction rates are highly variable.

Dr. Margerum's group found, from an investigation of the cluster containing nickel hydroxide units, that the stable cluster is not directly attacked by acid. It turns out instead that there is a less ordered, looser form of the cluster, although of identical chemical composition, which does react with the acid. This is significant for the purpose of understanding and controlling the rate of reactions of this kind, since the reaction velocity can be limited by the rate of conversion of the tightly grouped cluster to its more open or distorted form. In turn, the rate of this conversion can be controlled by normal techniques of chemical manipulation.

Dr. Margerum's studies of the iron-III polymer, in collaboration with Paul Saltman at the University of California at San Diego and Thomas Spiro at Princeton, show that these polymers are modified as they stand in solution. In this process, the rate at which the polymer reacts is decreased tenfold without substantial changes in the molecular weight of the polymer. This behavior strongly suggests that here, too, structural changes in the polymer leading to a more tightly clustered form are behind the reduced reactivity.

These studies have provided valuable insight into the mechanisms of reactions analogous to those occurring in living organisms, and contribute to progress in the synthesis and control of reactions in the biological counterparts of the simple ion clusters.

Pore Structure Analysis

All materials which we ordinarily encounter are porous, and have porous surfaces like a sponge, but on a microscopic scale. This structure is crucial to virtually all our uses of materials. It determines a host of material properties, including permeability (the ability of gases and liquids to "seep through" apparently solid objects), strength, surface friction, and most importantly, chemical reactivity, such as the rapidity with which metals exposed to atmospheric pollution corrode or tarnish.

A striking example of a solid in which pores play a decisive role is concrete. When portland cement reacts with water, a hard, porous paste is obtained, which binds the grains of sand and pieces of crushed stone into a coherent, rock-like mass. The size and distribution of the pores in the hardened paste determine the concrete's density, rigidity, and strength. For instance, freezing of water can occur only in larger pores because in the very small pores the nuclei cannot grow into ice crystals. Expansion upon freezing in large pores produces local stresses which can cause cracking. Because porosity in a surface increases the surface area, pores also play an important role in absorbents and catalysts in many chemical and physical reactions.

An understanding of the properties of pores including their distribution, size, and shape is hampered by the fact that the majority of pores are so tiny that even with the most sophisticated of electron microscopes they cannot be examined directly, and surface areas and volumes of pores must be determined by less direct means.

Stephen Brunauer of Clarkson College has recently made a major contribution to the field through the use of a "modelless" method of analysis of porous solids. The contribution is called the modelless method because the analysis starts without assuming a model for the shape of the pore. Prior methods have assumed that all pore walls have the same shape, although it seems more likely that pores in most solids have irregular shapes. Dr. Brunauer's method of analysis yields three key pore dimensions as properties of the empty space within the pore. This space, known as the core, is that part of the empty space in a pore which remains when a film is adsorbed on the pore walls, and which is capable of filling up with gas.

Dr. Brunauer's analytic technique depends on determining the volume and surface area of the cores with subsequent mathematical treatment of experimental data. He secured his experimental data by observing the amount of gas that a porous sample will absorb or release when subjected to a range of pressures while at a constant low temperature. Under such conditions, the larger pores absorb at higher pressures while the smaller pores, including the micropores, absorb gas at lower pressures. From these data, both the volume and surface area of the core are calculated, whereas previous mathematical methods only permitted calculation of the volume. Having both the volume and the surface area, a third figure, characteristic of the distances across the pores can then be calculated. With reliable dimensions for all three parameters of the core, one cannot go too far wrong in calculating from them the parameters of the pore itself.

Previously used techniques of pore structure analysis have not been able to take into account the effects of "micropores"—the smallest kind of pores, with radii measured in hundred-billionths of an inch—because they do not always exhibit the same kind of properties as larger pores. Dr. Brunauer has developed a method of analysis for these pores as well, which, taken together with his modelless technique, permits for the first time, a complete pore structure analysis. His micropore analysis method uses data obtained at low pressures and temperatures which are subsequently treated mathematically accordingly to theories contributed by J. H. de Boer at the University of Delft.

Almost the entirety of the surface of an object is composed of pores, and the degree and nature of the porosity of a surface is central to many important properties aside from purely physical ones. Because the atoms on the surface of an object are less tightly packed in among their fellows than those in the body of the objects, they are more chemically reactive. For this reason, the more surface area an object has, the more chemically reactive it will be. In addition to providing insight into the physical attributes and reactions of substances, a thorough knowledge of a material's pore structure will allow better prediction of its reactivity and greater control over its behavior in chemical reactions, which is of immense potential value to any industrial process which depends on chemical synthesis.

Chemical Instrumentation

Availability of sophisticated instrumentation for chemists is crucial for research and teaching in colleges and universities. This has become a critical concern for departments of chemistry since the acquisition, maintenance, and replacement of instruments is an expensive task.

During the past year, the Foundation received 244 requests totalling $11 million for support of chemical instrumentation in colleges and universities.

The Foundation was able to support 57 of these requests by contributing $1.7 million toward the purchase of $3.3 million worth of instrumentation. Over the past 6 years the Foundation has been able to provide $14.4 million toward this program, with universities, primarily from their own resources, providing an additional $7 million as institutional contributions. These significant institutional contributions are evidence that the institutions of higher learning recognize the necessity of complex instrumentation in chemistry.

Physics

The Foundation is currently providing approximately 20 to 25 percent of the direct Federal support for physics research at colleges and universities. This percentage of the total has been increasing in recent years, partially as a reflection of the increasingly rapid reduction in support of physics by other Federal agencies.

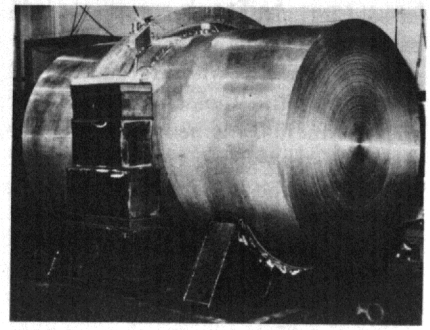
The subject matter of the projects supported by the Foundation is extremely diverse in style—ranging from the large scale, highly concentrated expensive experiments of high energy physics to the smaller scale, individual labors of theoretical physicists. For this reason, the size of an individual grant in physics can vary across an extremely broad range. The total dollar amount of such grants in fiscal year 1969 amounted to about $30 million for 284 grants.

Gravity Waves

Of the four basic interactions of nature: strong and weak nuclear interactions, electromagnetic, and gravitational, only the gravitational force is intuitively familiar. But a detailed understanding of gravity has been extremely elusive even though Newton's "Universal Theory of Gravitation" and Albert Einstein's "General Theory of Relativity" have been two of the seminal theories in the historical development of modern science. This is mainly because, paradoxically, gravity is the weakest force in nature, even though it dominates the large-scale structure of the universe.

One effect of gravity predicted by Einstein's theory but which remained unobserved is the existence of gravitational radiation, or gravity waves. The theory predicts that such waves would be generated by oscillating bodies in a manner analogous to the generation of electromagnetic radiation, such as radio waves, by oscillating electric charges. Because these waves would be exceedingly weak, their detection would require unprecedented feats of instrumentation. For several years the Foundation has supported an effort by Joseph Weber at the University of Maryland to develop instruments that could detect such gravitational radiation. This quest now seems to have borne fruit.

Dr. Weber's antenna for detecting gravitational waves consists of a 1½-ton aluminum cylinder carefully suspended by a steel wire on acoustic filters (see figure). Piezoelectric crystals that convert mechanical motion into electrical signals are bonded to the surface of the cylinder so that vibrations of the cylinder can be detected and analyzed electronically. The basic hypothesis is that if a gravity wave passes through the cylinder, a very slight mechanical distortion will be produced which will produce an electrical signal from the crystals which can be amplified and recorded on a graph. The response of the cylinder can be calculated quite precisely using Einstein's theory. The distortion expected is so slight, however, that the signal could readily be obscured by random electrical fluctuations in the circuitry and other sources of noise if special precautions were not taken. Moreover, distortions due to other natural causes, such as cosmic rays or earthquakes, or local sources, such as



This half-ton aluminum cylinder serves as an "antenna" for the detection of gravity waves. (University of Maryland photo) trucks on neighboring highways or construction also could produce signals. Consequently, an elaborate set of seismic detectors and special sorting and filtering procedures were needed to rule out spurious signals. The need to rule out such signals led to an unprecedented degree of development of detection technology. In 1967, even with most noise eliminated, Dr. Weber still recorded occasional signals.

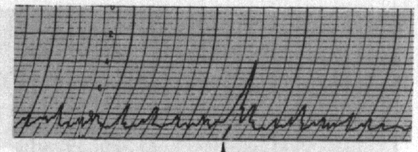
In an effort to ensure that some nearby object was not accidentally responsible for the measured signals, Dr. Weber constructed an additional cylinder, separated from the first by thousands of yards and considered only the coincidences (instances in which the detectors produced signals simultaneously). Even with such precautions, recognizable signals were detected.

Finally, in order to clinch the case, an additional cylinder was set up at Argonne National Laboratory, over 600 miles away from the cylinders in Maryland. Gravitational waves travel, according to Einstein's theory, at the speed of light. Thus, coincidences between these two thoroughly isolated detectors could be due to gravitational radiation but not due to seismic disturbances, which travel at the velocity of sound. When the chart records produced by these machines were compared, there still remained clearly recognizable coincidences recorded over an 81-day period which could not be attributed to any other source. Detailed statistical analysis indicated that random accidental occurrences of this sort were virtually impossible, indicating the first detection of gravitational radiation.

The confirmation and the continuing analysis of the observed effects may well lead to the development of a whole new field of science. At present, no one knows the source or sources of the radiation and many of its properties have yet to be examined. Detection, alone, is so difficult a task that many years will undoubtedly be required for these phenomena to be fully understood and routinely studied. Even if Weber's events should turn out not to be gravitational radiation, they still would represent an intriguing new phenomenon demanding a scientific explanation. If they are gravitational radiation, as is now widely believed, the basic discovery is in many ways as fundamental as the analogous discovery of electromagnetic radiation by Heinrich Hertz in the 1880's. Weber's work ultimately may lead to unique insights into the properties of matter and the structure of the universe.

Self-Induced Transparency

A new effect has been observed by Erwin L. Hahn and Samuel L. McCall at the University of California, Berkeley, which shows that a short burst of light from a laser can pass a significant part of its energy through a thickness of material of nongranular composition such as crystals which would block out a similar burst of light with the same power from an ordinary lamp source. The light waves from a laser may be pictured as traveling through space in the form of evenly timed electric vibrations. These vibrations are spoken of as being coherent, in contrast to the incoherent, randomly phased vibrations from an ordinary lamp. When ordinary incoherent light of a specific color or wavelength is absorbed by a material, the light pulse gives up its vibration energy to the atoms as it penetrates into the medium for a short distance. Since this energy can never return to the light beam, the material is then defined as being opaque to the light. However, if coherent laser light is applied in a very short time burst with an intensity which is sufficiently great to overcome atomic friction, the electrons of the atoms of the material are forced, momentarily, to absorb the light energy, but will then return the light energy to the laser beam in the same direction it was originally



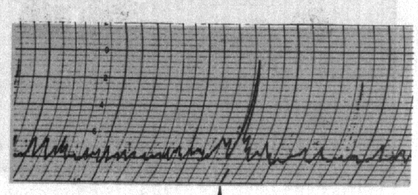
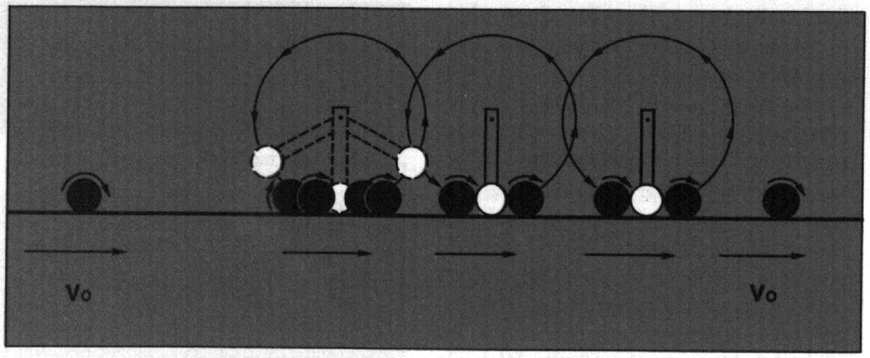


Chart records showing simultaneous observation of gravitational radiation signals by detectors separated by 600 miles. (University of Maryland photo)



Pendulum analog of self-induced transparency. Pendulum (white ball) is struck from left by light pulse (rolling dark ball). Energy given to pendulum causes it to rotate a full circle and strike rolling dark ball from behind. Rolling ball then strikes next pendulum and process is repeated. (After Hahn and McCall)

traveling. This happens because the electrons are set into motion synchronized with the coherent light vibrations.

A crude analogy is illustrated in the following figure where a rolling ball is aimed with a certain initial velocity into a row of pendulums. Each pendulum consists of a fixed ball hanging on a rigid rod suspended from a pivot. The rolling ball represents the light pulse and the pendulums represent the absorbing material. Before impact the pendulums are hanging down at rest, arranged in a straight line one after another. If the rolling ball strikes the fixed ball of the first pendulum head-on with sufficient impact (meaning the light burst is now entering the material); the rolling ball momentarily gives up a good portion of its energy to the first pendulum and slows down. The pendulum will then swing upward and around, and "spank" the rolling ball on its backside. This second impact restores the energy lost during the previous impact, to the rolling ball and revives the ball's motion in the direction of original travel. This process can repeat itself with pendulums further down the line, and the ball "passes through" the succession of pendulums as does the light burst through the material in the actual experiment. Obviously, if the ball does not have sufficient impact velocity or energy to start with, the first pendulum will not "loop the loop," and the ball will lose energy and eventually stop rolling.

In the actual experiment the laser light pulse is absorbed over a short distance in the material if the light burst is not sufficiently powerful. At present, this novel transparency effect is understood to apply only to optically responsive ions in nonconducting crystals, such as the chromium ions in the ruby, which give it its color, and not to metals. The same effect should occur for bursts of radio waves, microwaves, or sound waves which are usually absorbed in matter. The phenomenon is expected to be useful in studying atomic and electronic motion which occurs over extremely short time intervals. Moreover, while the pulse passes through matter, it is slowed down considerably below the speed of light. This slowing down or delay property constitutes a new form of control over laser light which may have applications in communication and computer technology.

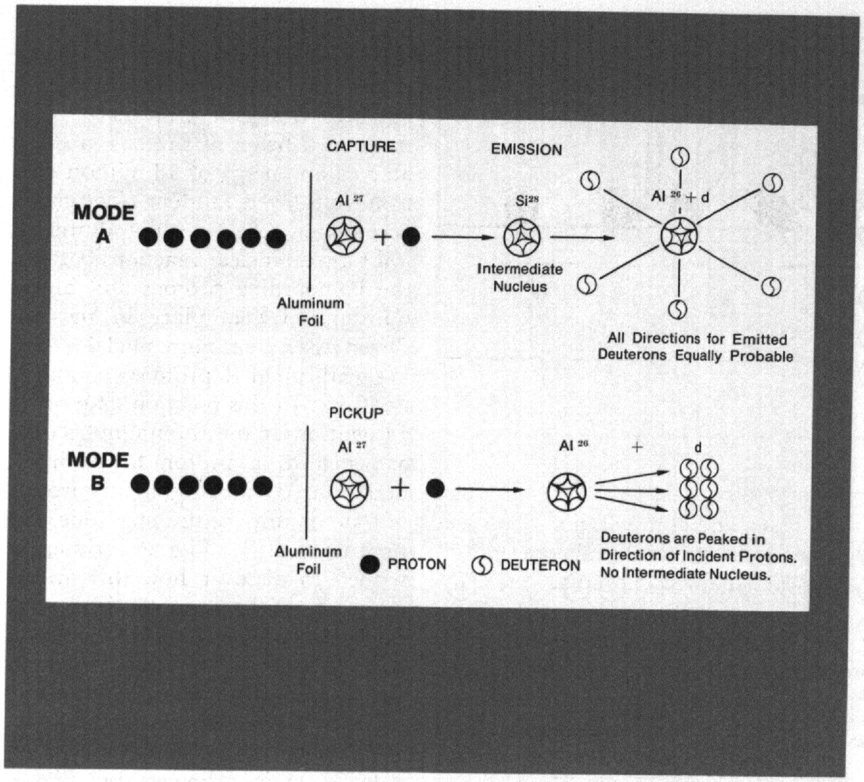
Nuclear Reactions

Research into nuclear reaction mechanisms involves study of collisions between atomic nuclei in an effort to understand the dynamics of their interactions. These collisions often produce new nuclei, some of which do not exist in nature.

Philip R. Bevington and others, with Foundation support, have been examining nuclear reaction mechanisms at Stanford University. They directed a beam of protons, accelerated to an energy of 18 million electron volts by a tandem electrostatic accelerator, onto a thin aluminum foil target. Nuclear reactions between the bombarding protons and aluminum nuclei take place in the foil. Ordinarily, aluminum nuclei (Al^{27}) are made up of 13 protons (p) and 14 neutrons. In this reaction, one of the 14 neutrons in the aluminum becomes attached to a proton producing a deuteron (d) plus the lighter isotope of aluminum containing one less neutron (Al^{26}). The experimenters wished to discover how this attachment of the neutron to the proton takes place. Does the incident proton striking the foil become absorbed into the aluminum nucleus, producing a nucleus of the element silicon (Si^{28}), which then emits the deuteron, i.e., $p + Al^{27} \rightarrow Si^{28}$ followed by $Si^{28} \rightarrow d + Al^{26}$, or does the proton pick up a neutron from the Al^{27} nucleus as it passes by, forming the deuteron directly?

Theory predicts that in the first case, deuterons will be emitted with equal probability in all directions from the target nucleus, while in the second case the deuterons should come out with a characteristic pattern in the same general direction as the proton beam. The detection apparatus determined from the deuteron count that rather than being uniformly distributed in all directions, the deuterons were concentrated in the direction of the incident beam. This result is consistent with the hypothesis that the reaction proceeds by a direct pickup of the neutron from the Al^{27} nucleus, rather than by the formation of an intermediate Si^{28} nucleus.

A recent nuclear structure experiment by W. Parker Alford and his group at the University of Rochester has provided interesting information



Alternate reaction modes for a proton, deuteron reaction. In upper model, a proton from the incident beam at left is captured by an aluminum nucleus in the foil target, forming a silicon nucleus which decays, emitting a deuteron, which can emerge in any direction. In lower model, the proton picks up a neutron in passing, forming the deuteron directly, which then emerges in substantially the same direction in which the proton entered.

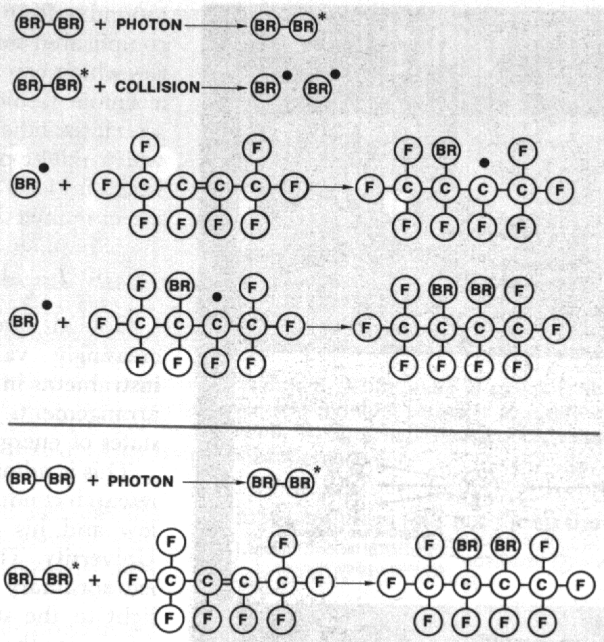
about nuclei of the element bismuth (Bi^{209}). A beam of helium-three nuclei (He^3) which consists of two protons and a neutron from the Rochester electrostatic accelerator was directed onto a lead target (Pb^{208}). Protons were stripped off the He^3 nuclei, producing the reaction $He^3 + Pb^{208} \rightarrow d + Bi^{209}$.

The emerging deuterons were sorted according to their energies in a magnetic spectrograph. The deuterons were found to be bunched in discrete energy groups due to the formation of corresponding discrete excited states in the resulting Bi^{209} nuclei. Excited states are transient forms of the nucleus which occur when the nucleus contains more internal energy than it does in its normal or ground state. An excited state typically lasts for less than a millionth of a second before giving up its excess energy in the form of gamma rays (electromagnetic radiation). Measurement of the energy and other properties of the gamma rays which result from the decay of excited states, and identification of the particles emitted in the process of forming the excited states (deuterons in the above example) provide an understanding of the internal constitution of nuclei, especially how the protons and neutrons which make up a nucleus are distributed and how they move within the nucleus. In the case of Alford's experiment, the emitted deuterons revealed the energies and intensities of the excited states of Bi^{209}. These states were found to have a particularly simple character which can be loosely described as corresponding to a proton revolving around a Pb^{208} core. The fact that a complicated nucleus exhibits properties which can be interpreted in such a simple fashion has stimulated the search for other nuclear energy levels which might possess these characteristics and lead to a closer understanding of many other nuclei.

Laser Light in Photochemistry

Optical lasers are becoming increasingly valuable as laboratory instruments in the study of structural arrangements of molecules and their states of energetic excitation.

This is admirably illustrated in the research conducted by Arthur Schawlow and his associates at Stanford University. They have exploited the extraordinary spectral purity of laser light in the study of photochemical processes; that is, chemical processes in which part of the energy necessary for the reaction is provided in the form of light. The first reaction studied has been that of bromine with fully halogenated butene. Butene is an unsaturated chain of 4 carbon atoms linked to other elements. It is said to be unsaturated because 2 of the carbon atoms share a double bond, i.e., they are tied to each other rather than to another element. Under proper conditions, it can take up 2 atoms of bromine to form a saturated compound (halogenated butane). Bromine, on the other hand, customarily exists as a molecule consisting of 2 bromine atoms. The initial object of the research was to determine whether the bromine molecule must first be dissociated into 2 free bromine atoms which subsequently react one at a time with the butene, or whether properly excited bromine molecules can react directly with the butene, supplying both of the needed bromine atoms at once. If the latter situation obtains, then the exact state of excitation of the bromine molecule immediately before reacting might be expected to determine the rate at which the chemical reaction proceeds.



Possible mechanisms for reaction of bromine and halogenated butene. In top figure, excited-state bromine molecule dissociates and its atoms react individually with butene. In lower figure, excited-state bromine molecule reacts directly with butene. * denotes excited-state molecule; · indicates electron available for bond formation; *Br*=bromine atom; *C*=carbon atom; *F*=fluorine atom.

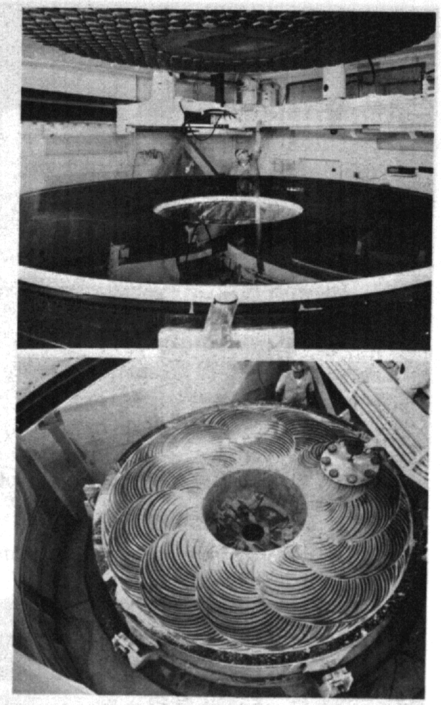
These alternative possibilities are indicated respectively in the following figures. In both cases, the bromine molecule is brought to a predetermined state of excitation very near to the dissociation threshold by the absorption of a photon of definite energy emitted by the laser.

It was possible to bring the bromine molecules to various known specific states of excitation just short of actual dissociation by irradiating them with high-intensity laser light at wave lengths in the vicinity of 6940Å, the exact state of excitation depending on slight variations of the laser wavelength. Moreover, because of the spectral purity of the laser radiation, it was possible to excite selectively one or the other of two bromine isotopes present in the experiment.

Dr. Schawlow's group irradiated the bromine molecules in a quartz cell together with the halogenated butene, and observed the dependence of reaction rate upon irradiation wavelength, that is, upon the state to which the molecules were excited. Also, they examined the isotopic composition of the reaction products in relation to the choice of bromine isotope excited by the laser. Results to date indicate that the bromine molecule must dissociate before reacting. This is an interesting result in itself but not nearly as important as the development and demonstration of a technique for initiating chemical reactions selectively from known specific excited states of molecules. This should ultimately lead to improved analysis of many important chemical processes including photosynthesis and other biochemical processes.

Astronomy

The Foundation is the principal Federal agency for the support of ground-based astronomy. Through research project support, research facility and equipment programs, and through the national observatories, the Foundation is at present providing about 47 percent of the total Federal support of research in astronomy. Significant contributions previously made by other Federal agencies are decreasing and, consequently, a greater number of requests are being received by the Foundation to provide support for research projects of proven quality. Although this reduction is expected in both optical and radio astronomy, it is more acute in the latter field. During fiscal year 1969, the Foundation awarded 125 grants at a level of just under $7 million.

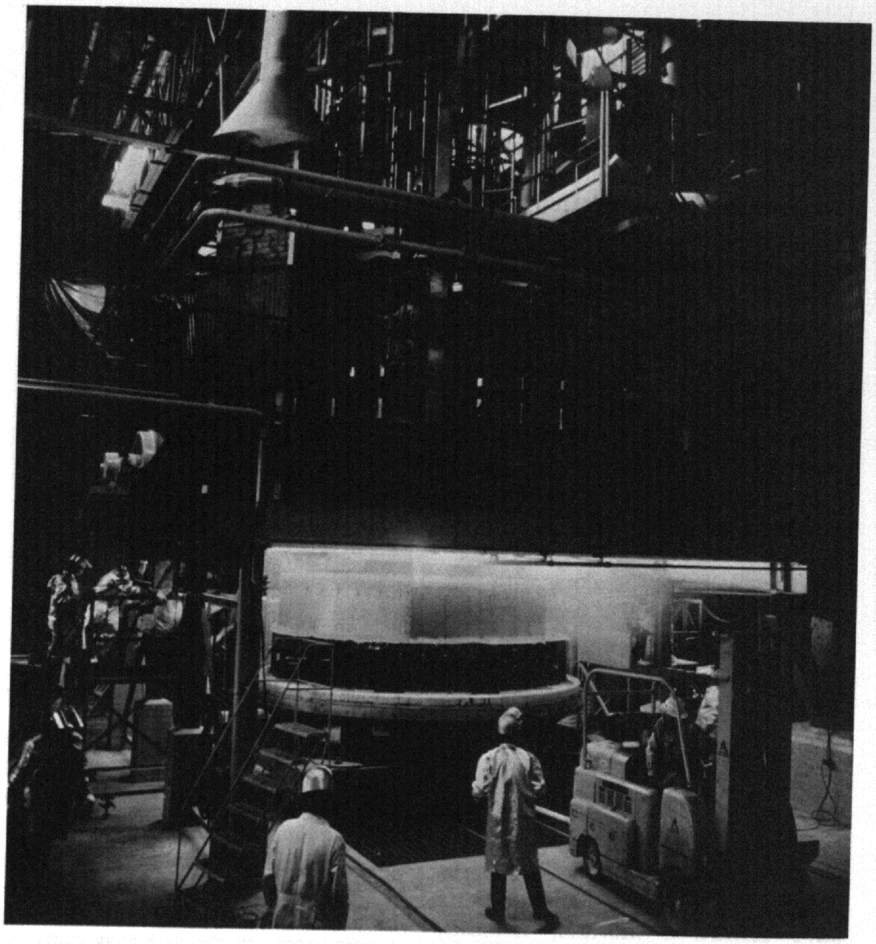


The 158-inch G.E. quartz mirror blank on its grinding machine. *Above:* The largest tool, 138 inches in diameter, used mainly for polishing to obtain a figure of revolution free from astigmatism. *Below:* A smaller tool, 30 inches in diameter, is shown during its epicyclic motion of removing glass with garnet powder as the abrasive. The work is being done in the optical shop at the Tucson headquarters, Kitt Peak National Observatory. (KPNO photo)

Kitt Peak National Observatory

Facilities

Kitt Peak National Observatory (KPNO), near Tucson, Ariz., was established in 1958 for the purpose of



The largest single piece of glass in the free world was cast by Owens-Illinois, Inc., in Toledo, Ohio, with the pouring of a 158-inch mirror blank for the new Cerro Tololo Inter-American Observatory in Chile. The "Cer-Vit" material used for the 25-ton mirror blank does not change shape or dimensions even when subjected to extreme temperature changes. With other types of mirror materials, thermal changes can cause warping of the mirror surface and subsequent blurring of astronomical objects and the loss of valuable viewing time while waiting for the mirror to adapt to the changes. (Owens-Illinois, Inc., photo)

strengthening basic research and education in astronomy in the United States. As a national scientific facility, KPNO is operated for the National Science Foundation by the nonprofit corporation, Association of Universities for Research in Astronomy, Inc. (AURA).

Research is organized into three principal fields—stellar, solar, and planetary sciences astronomy. In addition, engineering design and construction of instrumentation for telescopes and rocket experiments comprise a significant portion of the observatory's activities.

In a major capital construction program, unique for a single observatory, excellent progress was made in fiscal year 1969 on the two 150-inch telescope projects. Both are the responsibility of KPNO, although one will be located in Chile at the Cerro Tololo Inter-American Observatory (CTIO). The building and dome construction for the 150-inch Kitt Peak telescope is on schedule for completion by the end of 1969; the 158-inch primary mirror is being ground and polished in the observatory optical shop in Tucson, and the mechanical mounting is in an advanced state of component fabrication in California, Washington, and Japan. For the 150-inch Cerro Tololo telescope, the building is on schedule for completion in 1970, and the mounting is being fabricated concurrently with that for Kitt Peak. In June 1969, 25 tons of molten glass were poured into a mold at Toledo, Ohio, to become a 158-inch disc of zero-expansion glass which will become the mirror for the Cerro Tololo telescope. Present plans call for completion of the two telescopes—the world's second largest—in late 1971 and 1972 for the Northern and Southern Hemispheres, respectively.

Stellar Astronomy

A total of 119 visiting astronomers and graduate students used the 84-, 50-, two 36-, and two 16-inch stellar telescopes for approximately 60 percent of the available scheduled time during fiscal year 1969. For the average assignment of telescope time, the duration was 4.7 nights, the average number of participants per assignment was 1.3, and the useful observing time was 62 percent that allotted. The visiting observers represented 40 universities and research organizations in the United States and six from foreign countries.

Staff and visitors alike have participated in applying new observing techniques on Kitt Peak. A pressure-scanning Fabry-Pérot interferometer was put into operation as a Kitt Peak instrument, and groups from universities in Wisconsin, New York (Cornell), and Maryland used similar instruments brought to the observatory during the year. Image tubes have been applied to an increasing number of observational programs. Thus, at the 84-inch telescope, use of the image tube spectrograph for the first time has exceeded the use of the conventional spectrograph at the Cassegrain focus (one of the several observing positions available for management of incoming light). It is noteworthy that one group of investigators obtained more spectrograms of galaxies for radial velocity measurements in 6 nights than were reported in the first 15 years following the discovery of red shifts in the spectra of galaxies.

A new three-stage image tube has been applied to spectroscopy of faint sources. As one of the users of this new sytsem, W. A. Hiltner, Yerkes Observatory, University of Chicago, obtained a series of more than 100 spectrograms of the X-ray source Scorpio (Sco XR–1) during a 6-night run at Kitt Peak while the object was simultaneously being photometrically monitored by Delo E. Mook of the University of Michigan.

Following the discovery of the optical variations of the pulsar in the Crab nebula by astronomers of the Steward Observatory, University of Arizona, C. R. Lynds and D. E. Trumbo, with others at Kitt Peak, have obtained a number of time-resolved spectroscopic and photometric observations. The spectra of the main and mid pulse appear to be continuous, for neither emission nor absorption features are recognizable in these records.

The 50-inch telescope, formerly the remotely controlled telescope, was scheduled regularly for vistor use as a manually operated instrument beginning in April 1969. Light-weight replacement optics of new, distortion-free glass-ceramic material have been ordered, and the telescope will be reautomated at some time in the future when program priorities and funding will allow the changeover.

Solar Astronomy

The visible surface of the sun is called the photosphere, and the atmosphere immediately above it is termed the chromosphere. The McMath Solar Telescope with its large light-gathering power (60-inch aperture) and its big image (34-inch diameter) is a particularly suitable instrument for the detailed study of these layers of the sun, which send us over 99 percent of the energy in the solar spectrum. Violent convective motions continually occur in the photosphere and bring to the surface some of the heat from below. On occasion, powerful magnetic fields burst through the surface creating sunspots; also, from time to time chromospheric flares occur, which last 10 minutes to an hour.

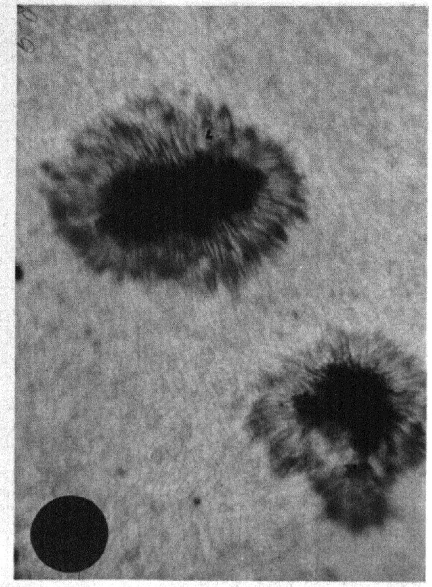
During fiscal year 1969, 14 American astronomers, two graduate students, two visitors from Norway, and one each from Switzerland, Australia, Sweden, and France used the McMath Solar Telescope along with the resident staff of solar astronomers. Their fields of study were broadly of three kinds: (1) The sun's chemical composition; (2) the sun's magnetic phenomena; and (3) the motions of gases in the photosphere and chromosphere.

Of the 92 elements making up the earth, only 63 are presently proven as present without doubt in the sun. To this list the newest observations have confirmed thorium, terbium, and erbium, and have added holmium as a new one. The large infrared spectrometer just approaching completion will be able to explore the red region of the sunspot spectrum for such chemical compounds as carbon monoxide, steam, hydrochloric acid, etc., which are normally decomposed at the higher temperatures of the photosphere.

A 40-channel magnetograph, employing 80 fiber optic systems, 80 amplifiers and 80 photocells has been under construction for a year and is expected to be in operation the summer of 1969. This instrument will allow detailed full-disc magnetograms to be recorded in about one-half hour, and will make possible the study of the changing solar magnetic fields that produce sunspots and flares.

The sun rotates once in about 25 days at the equator, and in about 30 days at the poles, hence not as a solid body but as a gaseous mass stirred deeply by internal motions. Solar staff astronomers have started a new long-range program of spectroscopic determination of the sun's rotation, with the aim of finding a clue to the nature of the peculiar rotation of the sun. In addition to these large-scale currents, the surface of the sun is covered with clouds of hot gases that are about 500 miles in diameter, and which ascend from deep in the photosphere to the top of the chromosphere at speeds of 1 mile per second. An understanding of this violent boiling on the sun's surface has been the study objective of a number of visiting scientists.

The McMath Solar Telescope continues to be used as a powerful telescope-spectrograph-computer combination useful in the study of the brighter stars and the major planets. Visitors and staff have made observations to determine the Martian carbon dioxide abundance, and to detect by its variations the topographic features of the planet.



Sunspots photographed at the McMath Solar Telescope. The black spot represents the earth's size. (KPNO photo)

Planetary Sciences

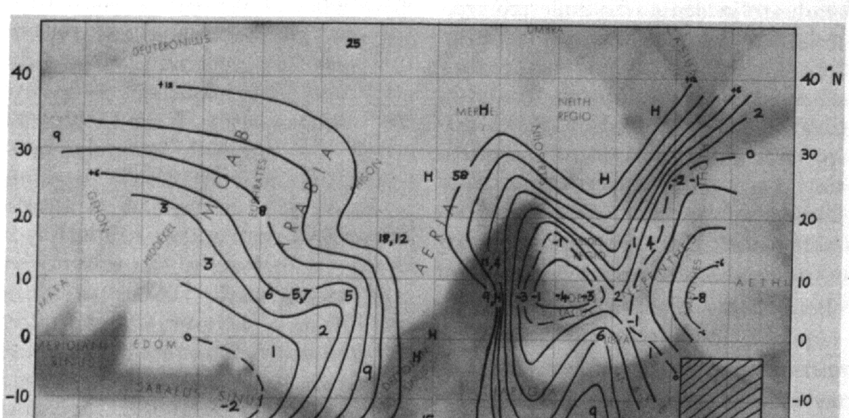
The Planetary Sciences Division at Kitt Peak National Observatory conducts basic research in astronomy with particular attention to observational data obtained outside the earth's atmosphere through the use of sounding rockets. Investigations are conducted by staff and visiting scientists, especially in the radiation of celestial objects in wavelength regions that are closed off to ground-based astronomy by the earth's atmosphere and ionosphere. A significant portion of the current effort is concentrated on the atmospheres of the planets Mars, Venus, and Jupiter.

Sounding Rocket Program and Ground-Based Observations.—During fiscal year 1969 two Aerobee sounding rockets were launched at the White Sands Missile Range, N. Mex., and each was successful in returning scientific and engineering data.

The first rocket, launched on October 23, 1968, was an engineering test flight of the new Aerobee 170, furnished by NASA, coupled with a KPNO investigation of the ultraviolet spectra of stars in the northern Orion region by means of an instrumented payload including a scanning spectrophotometer. The Aerobee 170 is capable of carrying the payload to an altitude more than 500 kilometers, higher than the earlier Aerobee 150, and provides 87 seconds more observing time above 100 kilometers. The spectrophotometer covered the ultraviolet spectral range of 1,050 Å to 2,150 Å. Good ultraviolet spectra were obtained on 17 stars, in spite of the fact that the sky background count was higher than expected.

The second rocket, an Aerobee 150, was launched on June 12, 1969. The purpose of this flight was to observe the ultraviolet spectrum of Mars in the range from 1,700 Å to 3,500 Å. This was the third successful flight in three launches of the newly developed Separable Payload Orientation System developed by the Ball Brothers Research Corp., Boulder, Colo., with the assistance of KPNO. The scientific payload consisted of a 13.4-inch Cassegrain telescope system with quartz optics, and a spectrometer using a Paschen-Runge mount with a 40-cm. focal length grating. The spectrum was recorded in two segments, and large-scale solar features are easily identified, but the signal level was low, and a satisfactory spectrum can only be obtained by summation of the data.

In order to check early radar indications that large topographic features exist on Mars, staff members developed a three-channel multislit spectrophotometer for the purpose of measuring the distribution of the partial pressure of CO_2 as a function of position on the planet. Using this instrument in conjunction with the McMath Solar Telescope on Kitt Peak, they have been successful in obtaining observations which, when interpreted as local height variations in the surface, confirm the Mariner IV radar results and provide more extensive maps of these and other topographic features.



Contour map of part of the Martian surface obtained with the McMath Solar Telescope. The abundances of carbon dioxide, measured at many points, were converted to partial pressures. On the assumption that lower pressures correspond to higher elevations, the pressures were interpreted as height differences, with contours drawn every two kilometers. Points marked H are so high that no CO_2 atmosphere could be detected over them (KPNO photo).

Theoretical Programs

In a published critique of models for interpretation of certain emissions observed by Mariner V, D. M. Hunten and M. B. McElroy concluded that the simplest model is one that requires the deuterium/hydrogen ratio to be about 100 times larger on Venus than on Earth. In the upper atmosphere, as a consequence of fast hydrogen escape, the abundance of deuterium atoms would be larger than that of hydrogen. Thus, much of the emission observed by Mariner V would be a result of resonance scattering of sunlight by deuterium rather than by hydrogen atoms. If correct, this model offers important insights into evolutionary processes in Venus' atmosphere. In particular, it implies that a large fraction of the initial hydrogen budget has escaped over the lifetime of the planet.

Work continued during the year

on the interaction of the solar wind with planetary atmospheres. In an initial paper that discussed Mars, it was concluded that the Martian ionosphere is drastically modified by the solar wind, which results in a significant loss of gas from the planetary atmosphere. On the average, however, the planet tends to gain hydrogen by accretion from the solar wind.

Work also continued on the problem of interpreting absorption lines formed in hazy planetary atmospheres. A model devised by J. W. Chamberlain will be applied to new observations of Venus in an attempt to elucidate the scattering properties of that planet's atmosphere.

In the past year, KPNO scientists have broadened their interests to include the outer planets. Several research papers have been written on diverse topics ranging from the scattering properties of Neptune's atmosphere to the hydrogen abundance on Jupiter.

Cerro Tololo Inter-American Observatory

In order to provide astronomers with an unusually favorable window to the southern skies, the Association of Universities for Research in Astronomy, Inc., (AURA), has established and operates, under a contract with the National Science Foundation, the Cerro Tololo Inter-American Observatory in the Republic of Chile.

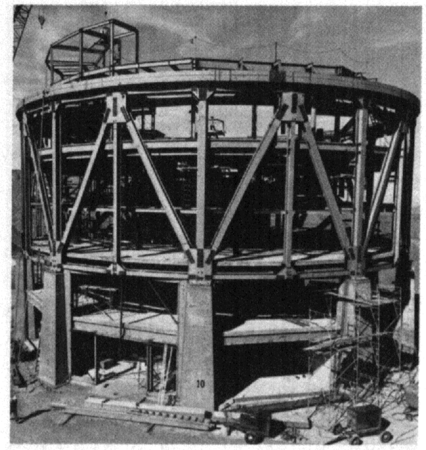
At this observatory site, 40 miles southeast of the city of La Serena at 30° south latitude, excellent atmospheric conditions have been found for astronomical observations. These result from a most fortunate set of geographic factors. Prevailing offshore winds blowing across the cold Humbolt current form a pronounced, lower level inversion layer that dampens atmospheric convection. Above the inversion layer, astronomical seeing is superb. Cerro Tololo, with an altitude of 7,200 feet, rises above the inversion layer on the western approaches of the Andean cordillera. As a result of these favorable conditions, the region shows promise of becoming an astronomical community of worldwide importance. A consortium of six European nations has established the European Southern Observatory some 60 miles from La Serena, and the Carnegie Institution of Washington plans to establish a major telescope installation in the vicinity.

In fiscal year 1969, construction proceeded on the building which will house the 150-inch telescope, and completion is scheduled for March 1970. The 158-inch blank for the primary mirror was poured in the United States in June 1969.

In other construction, under an agreement between AURA and the Lowell Observatory, a 24-inch reflector was erected on Cerro Tololo. This telescope was immediately pressed into service in April by the Lowell Observatory staff for photography of the planet Mars.

During fiscal year 1969, a total of 47 astronomers and graduate students carried out observations on Cerro Tololo. These included 33 visitors from the United States, four of whom were graduate students who collected material for doctoral dissertations; nine from Latin America, principally from Chile and Argentina; and five from Canada and Western Europe, including one graduate student. In addition, four astronomy students from Chile and one from Argentina accompanied their professors during visits to the observatory to acquaint themselves with observational techniques. Observing time assigned to all visitors was 69 percent of the total available. The remainder of the time was used by the resident staff, by Kitt Peak National Observatory staff, and for maintenance work.

Five telescopes were operational throughout the entire fiscal year; four are Cassegrain reflectors with apertures of 60, 36, and 16 inches (two telescopes). The fifth telescope has Schmidt-type optics and a 24-inch



Close-up view, toward the south, of the building for the 150-inch telescope on Cerro Tololo on June 24, 1969. The steel structure, floors, and interior walls are approaching completion, with work on the rotating dome about to begin. (CTIO photo) aperture, and is operated on loan from the University of Michigan. Two-thirds of its observing time is available to observatory visitors and staff.

A wide variety of observational programs was undertaken by the visitors and resident staff. The objects studied ranged from the planet Venus to the nearer galaxies and distant quasars. Studies of Milky Way or galactic objects included X-ray sources, old novae, peculiar variable stars, spiral-arm tracers in the Carina-Centaurus region of the Milky Way, planetary nebulae, globular and open star clusters. In the Magellanic Clouds, new photometric sequences, spectral types, and radial velocities were determined for the brighter stellar populations in these two nearest galaxies. The photometric variability of various southern quasars was also investigated.

A highlight of the programs was a concentrated observational effort on the planet Mars, which had a favorable approach in May and June 1969. Photometric, spectrographic, and photographic observations with filters selecting wavelength regions from the ultraviolet to the far infrared were undertaken by astronomers from the University of Arizona, California Institute of Technology, Cornell University, Lowell Observatory, and Massachusetts Institute of Technology. These observations were aimed at determining the nature of the Martian surface by studying its reflectivity and its photometric properties at various phase angles. The polar cap was observed in an effort to find its composition. Surprisingly, the preliminary reductions of the latter observations indicate that, during the 1969 Martian approach, the observable polar cap consisted of clouds.

National Radio Astronomy Observatory

Facilities

The National Radio Astronomy Observatory (NRAO) is managed by Associated Universities, Inc., under contract with the National Science Foundation. Now in its 13th year of operation as a national center for basic research in radio astronomy, the observatory has two observing sites, Green Bank, W. Va., and Tucson, Ariz. Most of the staff scientists, the main library, and computer are located at a third site in Charlottesville, Va. Support staff at Green Bank includes engineers who plan and maintain new receivers for the telescopes, telescope operating personnel, and a complement of administrative and maintenance specialists. At Green Bank the major radio telescopes are the 300-foot meridian transit telescope, the 140-foot fully steerable centimeter-wavelength telescope, and an interferometer consisting of three 85-foot telescopes. At Tucson, a 36-foot millimeter wavelength telescope is located at Kitt Peak National Observatory. With more than 25 receivers available for use on the 30-, 140-, and 300-foot telescopes, the observatory has the capacity to satisfy most staff and visitor requests for telescope time over a wide range of frequencies extending from below 100 MHz (million cycles per second) to 300 GHz (billion cycles per second). Visitor-users of NRAO telescopes are assigned at least 60 percent of the telescope time available. Visiting scientists and graduate students conduct observing programs either independently or in conjunction with staff members. In some cases, NRAO now supports part of the travel costs for distant visitor-users of the telescopes.

During the past fiscal year the new 413-channel autocorrelation receiver became fully operational on the 140-foot telescope. With it a group of staff and visitors discovered both the C^{12} and C^{13} forms of interstellar formaldehyde (H_2CO), which is thought to indicate that interstellar chemical evolution is at a more complex level than anticipated. Two tunable receivers became available that permit observers quickly to tune to any frequency between 1 and 4 GHz. These receivers enable observers to undertake molecular line searches in that frequency interval. On-line computers became fully operational at the 140- and 300-foot telescopes, removing the necessity to wait for full data processing at the IBM 360/50 system in Charlottesville before learning the preliminary results of an observing program. At the 300-foot telescope, a four-feed arrangement at the telescope focus quadrupled the rate at which data can be obtained for radio source surveys.

The 42-foot portable telescope was operated successfully at a remote site, 25 miles from Green Bank. This telescope can be operated remotely as an interferometer in conjunction with one of the 85-foot telescopes. Its operation has demonstrated the feasibility of achieving 1″ arc resolution at 11-cm. wavelength, one of the design goals of the Very Large Array (VLA) Project which proposes the use of a number of telescopes to observe radio sources much fainter than now possible. Very long baseline (VLB) interferometry continued during the year with the NRAO acting as a clearing house for various groups throughout the nation who want to use the new 3- and 6-cm. portable VLB receivers that became operational during the year. New terminals and a fast computer-processor are under construction and will markedly increase the rates at which data can be taken and analyzed. On the 140-foot telescope, a new clip-on receiver became available which operates at 2- and 6-cm. wavelength and that can be installed in less than 2 hours to take advantage of clear weather. This receiver system has been scheduled on a weather contingency basis and the success experienced with this type of scheduling has shown that a telescope located in Green Bank can make high frequency, weather-dependent observations for at least 20 percent of its total observing time.

Visitors, Students, and Staff

During calendar year 1968, 94 visitors observed with NRAO radio telescopes, an increase of 12 percent over 1967. Twenty-eight different institutions were represented by these visitors.

Students from five nearby cooperating colleges spend alternate terms at the NRAO where they assist staff scientists and engineers in their research. The NRAO summer student program accepts about 30 undergraduate and graduate students between May and September each year. The students attend a series of lectures on radio astronomy and assist in the NRAO research program.

At the end of fiscal year 1969, the NRAO staff included 12 scientists on the permanent staff, 13 on temporary appointments, and 24 structural, mechanical, and electronic engineers. The total permanent NRAO staff was 224.

Antenna and Telescope Design Projects

The design work on the Very Large Array (VLA) was completed in January 1969 and a report was published, "A Proposal for a Very Large Array Radio Telescope, Volume III," covering all work since the publication in January 1967 of volumes I and II. The VLA project proposes an array of 27 radio astronomy antennas on a field approximately 30 miles on a side. The antennas will be mounted on railroad tracks so that their positions can be moved. The positions are chosen so that when the signals are added together, the combined instrument will make "pictures" in radio wavelengths having a resolution of detail equal to that provided by a 200-inch optical telescope. With the publication of this report, the work on the VLA has been brought to a point where detailed design, prototype, and construction would be the next logical steps. Pending authorization for the VLA or some modified version of it, no further design work is planned.

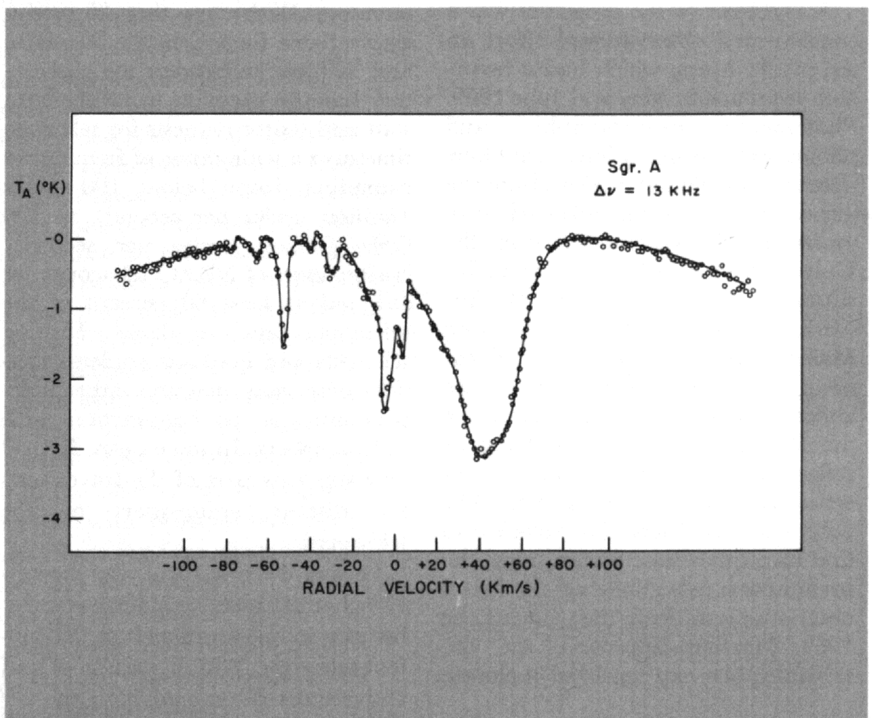
A conceptual design for a 300-foot fully steerable homologous telescope has been completed. The expected surface accuracy is 0.7 millimeter during night and 1.0 millimeter during the day. A full report, *A 300-Foot High Precision Radio Telescope,* was published in June 1969.

NRAO Research Projects

Formaldehyde Discovered

In early March 1969, interstellar formaldehyde ($H_2C^{12}O^{16}$) was discovered in absorption with the 140-foot radio telescope at 4,830 MHz in 15 galactic sources by D. Buhl and L. E. Snyder of the National Radio Astronomy Observatory, B. Zuckerman of the University of Maryland, and Patrick Palmer of the University of Chicago. Formaldehyde is the first polyatomic molecule ever detected in the interstellar medium and its widespread distribution is expected to provide important information about the chemical processes of our galaxy.

Late in March, the same group found formaldehyde absorption in several more sources, including four dark nebulae where the background source appears to be the isotropic 2.8° K. microwave background radiation. This implies that the nebulae are very cool with microwave excitation temperatures less than 1.8° K. for the H_2CO energy levels involved. In June, a second organic polyatomic molecule, $H_2C^{13}O^{16}$ (an isotopic form of formaldehyde), was detected in absorption at 4,593 MHz against the



Radio absorption spectrum indicating the presence of interstellar formaldehyde. The 140-foot antenna was pointed in the direction of the center of the Milky Way system (Sgr A). The formaldehyde signal is shown as the three major dips occurring at velocities in the line of sight, of +40, −5 and −53 kilometers per second. Each of these 3 absorption lines represents the effect of a different cloud of formaldehyde along the line of sight. (NRAO photo) galactic center by the same team of radio astronomers. The two forms of formaldehyde are expected to yield new information about the history of nuclear reactions toward the center of our galaxy.

The discoveries of radio spectral lines from formaldehyde, ammonia, and water vapor, all of which occurred in fiscal year 1969, have stimulated searches for other radio spectral lines at frequencies from 100 MHz to 150 GHz, further increasing demands on telescope time.

CRAB NEBULA PULSAR DISCOVERED

The Crab Nebula, the remnant of a supernova explosion in A.D. 1054, is one of the most fascinating celestial objects. It was the first cosmic radio source to be identified with a galactic object, the first identified X-ray source, and the first celestial object in which optical synchrotron emission was detected. Although the Crab Nebula had been intensively investigated prior to 1968–69, the source of its radiation remained a mystery. In November 1968 during a survey designed to detect new pulsars with the 300-foot radio telescope, D. H. Staelin and E. C. Reifenstein discovered two pulsating sources NP 0527 and 0532, the latter located at the center of the Crab Nebula. This discovery proved to be the key that led to a much more complete understanding of the astrophysical processes that cause the continuing optical, radio, and X-ray emission from the Nebula. Observers at the Arecibo Ionospheric Observatory showed that the period of the pulsar, only 33 milliseconds, was the shortest period yet found for a pulsar.

At the close of the fiscal year, T. Gold found that pulsar emission was sufficient to explain the intensity of cosmic rays in the Milky Way system. Further studies have shown that pulsars are probably neutron stars of exceedingly high density and are the stellar end products of supernova explosions that occur near the end of the lifetimes of stars whose masses slightly exceed the mass of the sun.

University Research, Facilities, and Equipment

University Research

NEW SPECTRAL LINE DISCOVERY

The past year has been a most important one for the discovery of new lines in the radio frequency spectrum. In addition to the spectral line of interstellar formaldehyde discovered at NRAO, additional unexpected spectral lines were discovered at the Hat Creek Observatory of University of California by the team of C. H. Townes, D. M. Rank, A. C. Cheung, W. J. Welch, and D. D. Thornton. In an investigation partially supported by NSF, this group detected interstellar ammonia, NH_3. This emission line at 23.7 GHz (1.27 cm.) was observed in a number of clouds in the direction of the galactic center. The measurements implied a temperature of the clouds, in which the line originated, to vary from 25° K. to 125° K. The presence of ammonia in the higher temperature cloud suggested that water vapor emission at 22.3 GHz (1.35 cm.) might also be observable. This phenomenon was found by the University of California group not only in the direction of the galactic center, but in the Orion Nebula and other sources such as the Aquila Cloud, W49. The group has also observed the 65α ionized hydrogen emission line at 24 GHz (1.2 cm.). All in all, the number of observable spectral lines detected by radio telescopes has dramatically increased from the single observable 1,420 MHz (21 cm.) hydrogen line of a decade ago.

Our view of the interstellar medium is in the process of evolving a picture of chemical composition much more complex than had been envisioned. The existence of ammonia, water vapor, and formaldehyde imply that even more complex atoms may be observable and that the searching of the heavens with radio telescopes is even more rewarding to man's understanding of the universe than the leading proponents of these instruments would have imagined only a few short years ago.

PULSARS AND NEUTRON STARS

During the year there was continued excitement about the pulsars. These remarkable celestial objects, first reported last year by British radio astronomers, are characterized by a pulsed radio signal from a very small area of the sky; the pulse periods are within the range of 0.02 second to nearly 4 seconds. The pulses vary in intensity but occur with great regularity. Observations this year have revealed a very minute lengthening of the periods for all of the pulsars which have been sufficiently well observed. Approximately 30 pulsars have now been discovered, compared with a total of 9 known as the year began. Radio astronomers in many countries have been active in the search.

The hypothesis that the pulsar phenomenon results from a collapsed star—a neutron star—in rapid rotation with a period of rotation equal to that of the pulse period, has gained many proponents, especially since the discovery of the shorter periods. The minute slowing of the pulse repetition rate is interpreted as a slowing of the rotation of the neutron star.

Such neutron stars had been hypothesized earlier as a possible result of the collapse of stellar material into a highly condensed state, perhaps initiated in the catastrophic implosion called a supernova. Here an unstable star collapses upon itself, at the same time blowing away much of its surface material to the surrounding space. The resulting neutron star would contain much of the material of the original star but packed into a sphere 10 miles or less in diameter. The rotation of the original star would be greatly increased as the collapse toward the final neutron star occurred.

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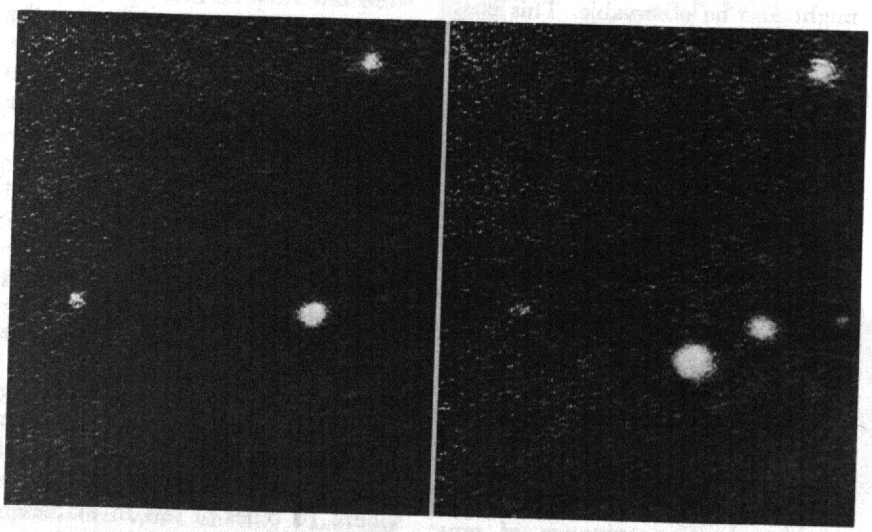
There is not yet agreement on the details of the production of the pulsed radiation. In one version it is supposed that some of the material which is escaping from the surface is constrained by the intense magnetic field to rotate with the neutron star; and emission from this material is in a beam which, as it sweeps around the sky, is directed toward the earth once during each rotation of the star.

Of the two pulsars discovered at NRAO in November 1968, the short period pulsar NPO532 provided especially significant information when three astronomers, W. J. Cocke, M. J. Disney, and D. J. Taylor, using the 36-inch telescope at the Steward Observatory of the University of Arizona on January 16, 1969, detected pulsations in the optical part of the spectrum from the central region of the Crab Nebula, with a pulse period apparently identical to that of the fast radio pulsar. Within a few days after this discovery, observers at the Kitt Peak National Observatory, the University of Rochester, the University of Texas, and the Lick Observatory of the University of California had confirmed the optical pulsations and found further that the pulsar position coincided with that of a faint star near the center of the nebula which was known to have an unusual, essentially featureless spectrum. The group at the Lick Observatory, E. J. Wampler, J. D. Scargle, and J. S. Miller, were able to demonstrate photographically an image of this star when the recording of the photons coincided with the pulse, and absence of an optical image when the recording was shifted out of phase with the pulses. The work at Lick was jointly supported by the Foundation and NASA. Several observers found a secondary pulse of light occurring somewhat less than half way between the main pulses, in agreement with the radio results.

Less than 2 months after the Crab Nebula pulsar was detected in the optical region of the spectrum, a group at the E. O. Hulburt Center for Space Research of the Naval Research Laboratory observed an X-ray source in the direction of that nebula. The scientists, G. Fritz, R. C. Henry, J. F. Meekins, T. A. Chubb, and H. Friedman, found the pulsar to be the same as that of the optical source. Dr. Henry's work at the Hulburt Center was supported by the National Science Foundation. They reported that "the pulsar X-ray power is about 200 times the optical power and about 20,000 times the radio power." This is in line with the theory of a rapidly rotating young neutron star which would be expected to radiate most strongly in the shorter wavelengths. As the rotation slowed through conversion of some of the rotational energy to energy of radiation by the pulsar process, one would expect the radiation maximum to shift to longer wavelengths with an eventual concentration in the radio portion of the spectrum, as appears to be the case for the longer period pulsars. At the end of the year, the Crab Nebula pulsar is the only one which has been detected in the optical and X-ray ranges of the spectrum.

One may now perhaps speak of the two lifetimes of a massive star. After the star is born by contraction out of a cloud of gas and dust, it begins to shine as this contraction heats the material by compression. When the central temperature of the new star rises to several million degrees, energy is released deep in the interior by the process of nuclear fusion in which hydrogen atoms impacting at high speeds combine to form helium. The star eventually adjusts its size and surface temperature until the energy radiated out into space from the surface just equals the energy produced in the fusion of hydrogen into helium in the interior. Since this is a slow process, the star will shine in this way for a very long time—its first lifetime.

With the depletion of the hydrogen fuel deep within the star, it again becomes unstable; the interior may collapse and the outer layers expand, a stage that is followed in some cases for the more massive stars by a complete collapse to a much smaller size, with an accompanying explosion at its sur-



During 1969, the first visual observation of a pulsar was made. The large star at about 6 o'clock in the photograph to the right, not visible in the photograph to the left, has been visually observed to blink on and off 33 times per second, in exact agreement with radio pulsations from the same source. The pulsar is in the Crab Nebula. (Lick Observatory photo) face to divest itself of superfluous material. We occasionally detect such a catastrophe as a supernova event.

If a compact neutron star results from the event, the star has entered its second lifetime. The gravitational energy lost in the implosion now appears in great part as rotational energy, in an amount rather similar to the budget of energy it produced by nuclear fusion in its first lifetime. Thus in the eventual slowing of its rotation the neutron star has roughly the same amount of energy to dispose of in this second lifetime as was used up during its first life as a visible star. It is believed by some scientists that particles of relativistic speeds (near that of light) may be emitted from such neutron stars, and serve as the principal source of cosmic rays. In any event, detection of the pulsars, first in the radio portion of the spectrum and now in the optical and X-ray ranges, has tended to confirm the existence of such neutron stars and furnished exciting new vistas into the life of a star.

University Facilities and Equipment

In fiscal year 1969, a number of significant new items of astronomical equipment procured with support from NSF came into operation. The 130-foot radio telescope at the Owens Valley Radio Observatory of the California Institute of Technology was formally dedicated in October 1968. A new 92-inch optical telescope at the Kitt Peak station of the Steward Observatory of the Universtiy of Arizona was completed and became operational in June 1969. Two other major instruments which became operational during the year—the 88-inch telescope at the University of Hawaii and the 107-inch telescope at the University of Texas—are housed in observatory buildings partially funded by NSF.

Mathematics

Much of the rapid expansion of research in mathematics supported by the Foundation over the last 10 or 12 years has been as applied mathmatics, i.e., the development of mathematical theory for use in the better understanding of real phenomena, both physical and social. This is, of course, to be expected in a time when the physical, biological and social sciences, which depend heavily on mathematics, are themselves growing rapidly. Although the rate of growth in support of the field of pure mathematics has not been as great, new mathematical tools of unparalleled power and generality have been developed.

The major source of the growing demand for support is the rapidly increasing number of high quality young research mathematicians on university and college faculties, matching a similar striking growth in the number of students. A contributing factor in the increasing demand for Foundation support has been a concurrent decline in the support of mathematical research by other Federal agencies. The Foundation supported about 460 research projects in mathematics during fiscal year 1969 at a level of almost $13 million. This represents about a 13-percent growth in the number of grants over fiscal year 1968, although at a slightly lower overall cost.

Biomedical Applications of Scattering Theory

One of the most important physiological indicators in the practice of clinical medicine is the oxygen saturation of blood. This is defined quantitatively as the ratio p of oxidized hemoglobin to total hemoglobin. Until recently the method whereby p was measured consisted in extracting a sample of blood from the body, forming a solution of hemoglobin by releasing it from the red blood cells (hemolyzing the blood) either by crushing the cells mechanically or by chemical extraction. Light of a given wavelength is then directed through the hemoglobin solution and its absorption measured. The intensity of transmitted light T (or, equivalently, the absorption) is related to p through a rather simple equation called the Lambert-Beer law, and once T is measured, the Lambert-Beer law gives p. This is essentially a refined version of the easily made observation that the color of arterial blood is bright red (high p) while that of venous blood is dark red (low p).

Sampling the blood is not convenient, however, in cases where it is desirable to know the oxygen saturation rapidly or continuously. Such cases occur in surgery, space flights, experiments, etc., and as a result, in situ optical instruments have been developed and calibrated by comparison with data on hemolyzed blood. Among such instruments, one uses transmission of light through the flesh of the ear, another the reflection of light from the forehead, and a third is a fibre-optical catheter which is inserted directly into a blood vessel.

The use of absorption measurements from instruments of this sort for the determination of oxygen saturation is more complicated than the method described above because in whole blood the hemoglobin is packaged in the red blood cells rather than in the hemoglobin solution. To be specific, if one uses the Lambert-Beer law on optical data, results from seven to 20 times that measured for the hemolyzed case are obtained. Physically, what happens is not merely absorption of the light beam (as in Lambert-Beer), but scattering to other directions than that of the beam as well as scattering into the beam.

Some years ago Victor Twersky of the University of Illinois became interested in electromagnetic scattering by random distributions of bodies and through this became interested in oximetry, or measurement of blood oxygen content. He has extended his early work, obtaining explicit results for oxygen saturation of the blood in the case in which the red blood cells are assumed to be spheroids (flattened spheres), similarly aligned. Since the optical measurements are made on flowing blood, and since the concentration and alignment effects on the red blood cells caused by the shape of the blood vessels and the flow are not fully understood, his results may also be of interest in the study of these phenomena. Twersky has developed a mathematical expression for the transmitted intensity which accounts not only for the absorption, but also for the scattering and the backscattering of the spheroidlike cells. It is believed that his work may suggest new measurement procedures and diagnostic instruments. The results are also of interest for analogous studies seeking the absorption spectrum of other molecules in other kinds of biological cells and may also be useful for optical (or acoustic) monitoring of various fluid transport processes.

Major Developments in Topology

During fiscal year 1969, three of the oldest and hardest problems in geometry have been solved, two of them with surprising results.

Topology, the branch of mathematics involved, is that aspect of geometry which deals with those properties of surfaces which do not depend on size or shape—for example, the property of being all in one piece (technically known as connectedness), or the property of being knotted. A major emphasis of topology is on the study of surfaces with more than three dimensions. While it may be impossible to visualize an object which could exist only in six-dimensional space, such an object can be conceived intellectually and described mathematically.

A key property of surfaces is that they fall into families of analogues. There are, for instance, five- and six-dimensional surfaces with mathematical properties similar to the familiar three-dimensional doughnut or innertube. In general, surfaces of more than three dimensions are known as manifolds. An elaborate algebraic apparatus has been developed to treat properties of these objects and to define them precisely. Despite their esoteric nature, manifolds are found to be helpful in describing physical systems in which time is thought of as the fourth dimension, or in which the existence of many particles makes it useful to think of each particle as adding three more dimensions to the system.

The three problems which have been recently settled are known as the annulus conjecture, the triangulation problem, and the Hauptvermutung. The annulus conjecture, which concerns the mathematical description of the region between two spheres, or their higher dimensional analogues, one of which is entirely contained within the other, has been a problem for mathematicians for many years. A trained mathematician could intuitively predict the truth of this conjecture, but a proof remained elusive without the use of various additional hypotheses. The more roundabout proof, in turn, made the proof of a number of other theorems more difficult. The new solution has now cleared up these problems. The research in question was done independently by the young Englishman, C. T. C. Wall, at the University of Liverpool, and Julius L. Shaneson and Wo-Chung Hsiang at the University of Chicago, both using the results of still another young man, Robion Kirby, at the University of California at Los Angeles. The Foundation supported the work at American institutions.

The results concerning the other two problems are striking, since they are negative and show that even the experienced mathematical intuition, which could predict the correct outcome of the annulus conjecture, cannot be trusted very far, unless it points the way toward a subsequent careful proof. In brief, there are a variety of ways to specify a manifold precisely in mathematical terms. One of the simplest in concept, although cumbersome in practice, consists of triangulating, or describing how the manifold is built up from very simple bits and pieces, such as points, line segments, triangles and their higher dimensional analogues, which are called simplexes. The triangulation problem arises from the conjecture that a manifold described in some other careful way could always be broken down into simplexes which would all fit neatly together where they meet. It seemed so obvious that this conjecture was true that it came as a considerable surprise when Robion Kirby and Lawrence Siebenmann constructed a six-dimensional manifold which showed it was false. Some manifolds cannot be triangulated.

Mathematical intuition with regard to this problem had been led astray, despite a number of contributions which led to its eventual disproof, by the facts that most manifolds can be triangulated and all one-, two-, and three-dimensional manifolds have been proved triangulable. Thus although intuition is correct in most cases, Siebenmann and Kirby's example proves that the conjecture is not an absolute rule. A further but positive aspect to their results lies in a basic understanding of how nontriangulability can be predicted. Associated with each manifold is an infinite sequence of algebraic objects known as cohomology groups. It turns out that only one of these cohomology groups affects triangulation. If this group has a certain elementary character, regardless of that of the others, the manifold can be triangulated.

The Hauptvermutung conjecture is of a similar nature. In this it was proposed that a manifold which can be triangulated cannot be triangulated in two essentially different ways, i.e., that the simplexes of each triangulation could be broken down still further to arrive at some common set of basic building blocks. This too turned out to be false: there is a five-dimensional manifold which has two quite different triangulations.

The obstruction to the truth of both the triangulation problem and the Hauptvermutung turned out to be the same, namely, a certain algebraic object known as a homotopy group (whose nature determines among other things, the nature of the cohomology groups above). While these can be quite complicated objects in general, by the fall of 1968 it had been established that both conjectures were true if this particular homotopy group consisted of exactly one element and were false otherwise. In February 1969, Kirby and Siebenmann proved that the homotopy group in question had exactly two elements. Thus these famous conjectures came to "within an inch" of being true, but are both actually false.

BIOLOGICAL AND MEDICAL SCIENCES

The Foundation supports basic research covering the entire spectrum of the life sciences. Investigation of biological processes at the molecular level has produced results of outstanding importance which have received world recognition. There now exists a rapidly growing concern for understanding and conserving our environment. Ecology, the specialty which contributes most importantly to environmental studies, requires large-scale support because of the complexity of the phenomena it includes. A major undertaking of particular ecological significance is the International Biological Program (IBP). The IBP is an international endeavor designed to study the productivity of land, freshwater, and marine environment of the world, related problems of maintenance and change of these environments, and the question of human adaptability to them.

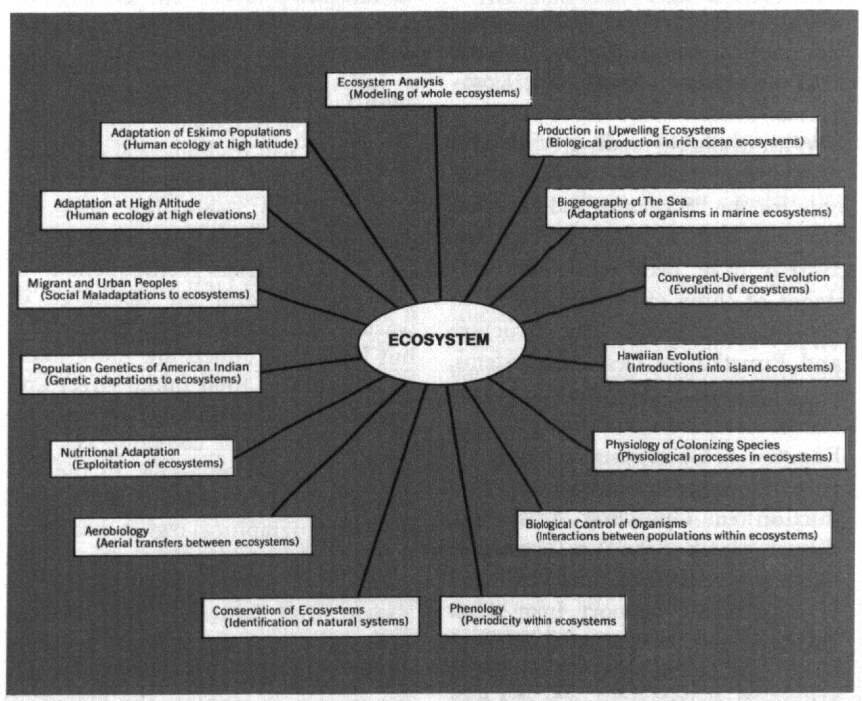
A decrease of about 3 percent in available funds during 1969 has inhibited any significant shift in research support priorities. Existing commitments largely preclude undertaking new programs in response to new scientific and social needs. Certainly public concern warrants significant increases in the research effort devoted to those biological fields that will contribute toward easing current national problems.

During fiscal year 1969, the Foundation awarded nearly $40 million to support about 1,200 research projects in the biological and medical sciences.

International Biological Program

The International Biological Program (IBP) is a response on the part of biologists to mounting concern throughout the world for some major problems confronting mankind today—increasing population, food shortages, and environmental deterioration. As national programs and research proposals have been developed, it has become apparent that IBP is primarily an ecological program, including human ecology. The proposed Integrated Research Projects of the U.S./IBP are presented in this context in the accompanying figure. The U.S. participation involves both integrated team research projects and individual research efforts which are directed toward two primary goals: Understanding (1) the structure and function of ecosystems; and (2) man's adaptability to his environment.

The scale of these IBP programs is larger than that of conventional biological research. If only for this reason, the effectiveness of any proposed approach is more than normally uncertain. The U.S./IBP is not intended to solve the monumental challenges of environmental quality and management of the biosphere, but aims rather to develop an effective ap-

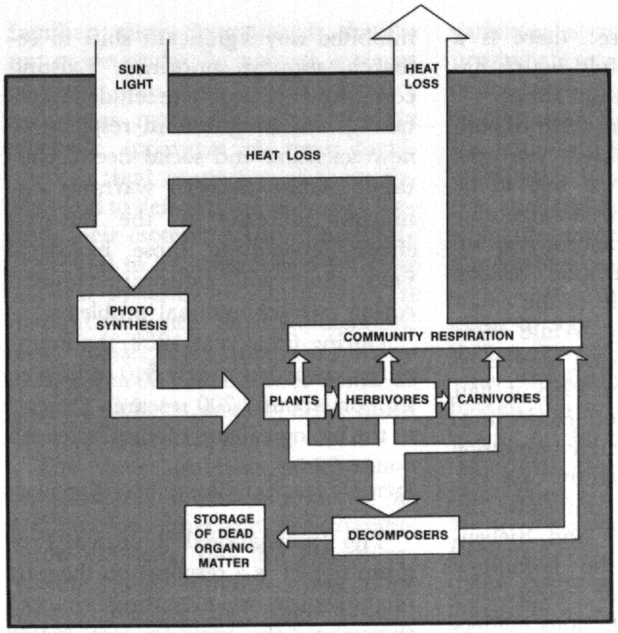


Ecosystem analysis is the basis of the approaches of programs within the International Biological Program, as indicated by the variety of investigations identified.

proach to their study and ultimately a scientific basis for coping with them. Such a scientific platform requires the technology and knowledge of many disciplines, the coordinated efforts of many scientists, the experimental manipulation of large environmental-biological systems, the study of interactions and stresses in such systems, and the synthesis of large amounts of information into workable and predictive models.

During the past year the development and review of Integrated Research Programs have continued and strengthened under the U.S./IBP Committees of the National Academy of Sciences. Effectiveness has been increased by realignment of these into Executive, Program Coordinating, and International Coordinating Committees. In order to facilitate handling of proposals and to provide more effective management for grants, a new Program for Ecosystem Analysis has been established within the National Science Foundation. Coordination with other Federal agencies continues to be effected through an Interagency Coordinating Committee.

With available funding, substantial development has been possible so far only for the "Structure and Function of Grassland Ecosystems." Smaller awards have been made for early stages of three other components of Ecosystems Analysis—the Structure and Function of Desert Ecosystems, Structure and Function of Deciduous Forest Ecosystems, and Structure and Function of Coniferous Forest Ecosystems. Work has been initiated on Production in Upwelling Ecosystems, Biogeography of the Sea, Convergent and Divergent Evolution, and Aerobiology, while support from other Federal agencies has permitted some work on Adaptation of Eskimo Populations, Population Genetics of American Indians, Migrant and Urban Peoples, and Nutritional Adaptation.



The diagram shows how energy from the sun, the ultimate source of energy for any ecological system, flows through a simple system. Note the decreasing amount of energy available at each higher level in the food chain, as the greater part of the energy received at each step is dissipated in community respiration. The true facts are even more dramatic than depicted here: for example, less than 2 percent of the sunlight is captured in the first place, 98 percent being lost as heat to the atmosphere.

Ecology and Environmental Management

The problem of environmental quality in its broadest sense has become a focus of national interest, and since man will undoubtedly continue to exploit and modify his environment on an increasing scale, a rational basis is needed for his activities. The physical consequences of strip mining and the discharge of wastes into rivers are quite obvious, but biological effects are more likely to be subtle in their initial effect and sometimes dramatically unpredictable in their final consequences. An ecosystem, encompassing all the life forms within a reasonably circumscribed geographical region, has properties which depend upon the interactions between organisms in the system and between each of the organisms and its physical environment. The crucial problem confronting man is to estimate the biological consequences of manipulation of an ecosystem by present or projected activities.

There are at least two complementary ways of looking at ecological problems. One can focus on the level of organization being studied: individual, species populations, mixed species populations, or communities and ecosystems. On the other hand, one can consider functional relationships: productivity, cycles of essential elements, energy flow, and physiological adaptations.

An important component of ecosystems analysis is photosynthetic efficiency, i.e., the evaluation of primary productivity and its relation to solar energy. Daniel Botkin of Yale University, for example, has been attempting to measure the efficiency of net primary production based on interception of radiant energy under field conditions. Interception, the difference between radiant energy above and below vegetation, was measured with a solarimeter. The size of this small, specialized instrument makes it possible to measure energy below the vegetation with a minimum disturbance of vegetative cover. Production in a 1-year-old field in New Jersey was evaluated in terms of the energy equivalence of the plant growth. Above-ground growth was measured for each species by a series of short-term harvests, and total root production was also measured by short-term harvests. The net production was 10 percent of the solar energy intercepted by plants during the growing period, but this represented only 3.5 percent of the energy available above the vegetation during the same period. Since the growing period extends over only part of the year, plant production was equivalent to only 1.8 percent of the energy available annually.

Understanding the effects of radiant energy presents problems other than photosynthetic efficiency. Since the photosynthetic efficiency is a function of wavelength, and since the spectral distribution of light reaching the plant is affected by the particulate or other matter in the atmosphere, a proper measurement of environmental effects upon productivity will have to include information upon spectral distribution as well as total radiant energy. Radiation effects of still another kind include damage by ultraviolet radiation and its reversal by visible light. Martyn Caldwell of Utah State University has been investigating the importance of this factor by subjecting alpine plants to precisely defined combinations of ultraviolet and visible radiation. Tissue destruction caused by ultraviolet alone was evident in some individuals; while under normal conditions of high intensity ultraviolet but with visible light also present to produce photoreactivations, such severe tissue destruction does not normally occur.

The research examples described above are limited to the effects of light on elements of selected ecosystems. Clearly, the magnitude of the task involved in developing a fully descriptive and predictive model of a complex ecosystem is enormous, and will require our best scientific efforts joined with the latest technological tools.

Macromolecules

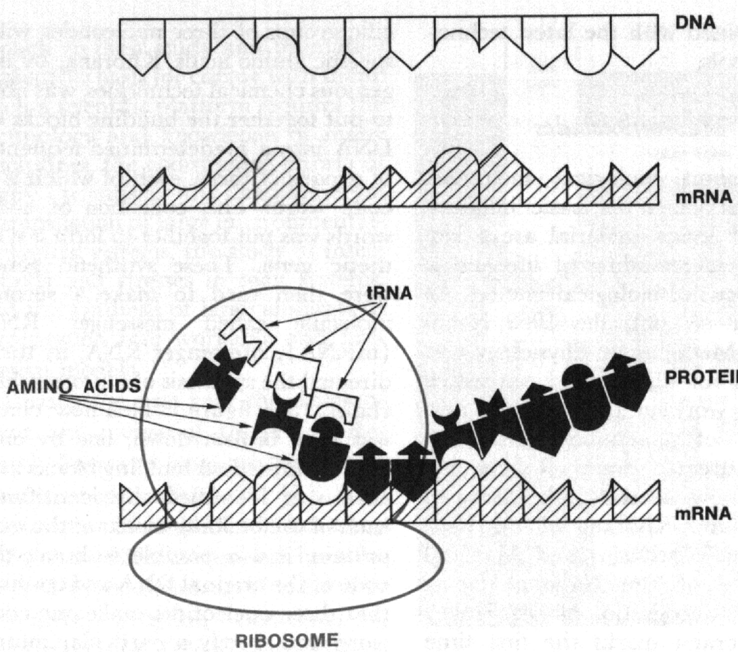
The giant biological molecules which make up the basic building blocks of living material are a key to our understanding of life and a major focus of biological interest. As a matter of fact, the 1968 Nobel prize in Medicine or Physiology was awarded for the second successive year for work in the structure and function of macromolecules. The 1968 laureates were Robert W. Holley, now at the Salk Institute; Har Gobind Khorana of the University of Wisconsin; and Marshall Nirenberg of the National Heart Institute. Recognition of Drs. Holley and Khorana marks the first time that grantees of the Foundation have received the Nobel prize for work carried on during the period of support by the Foundation.

During a little more than the first half of this century, the concept of the gene as the unit of biological inheritance has emerged, and it has been identified chemically as deoxyribonucleic acid (DNA). Also, a mechanism has been formulated for the duplication of DNA during cell division, and its function in producing a particular polypeptide chain (a string of amino acids which make up a protein) has been identified. The question of how the DNA encodes the information for the construction of a polypeptide chain which contains a specific number of different amino acids in a specific order was largely illuminated by the work of Dr. Nirenberg. He was able to produce convincing evidence that a unit of three of the DNA building blocks, known as nucleotides, constitutes a chemical "code word" which ultimately determines that a particular amino acid will be introduced into the proper position in the polypeptide chain.

Dr. Khorana validated the nature of the DNA code and identified specific groups of three nucleotides with specific amino acids. Khorana, by ingenious chemical techniques, was able to put together the building blocks of DNA into a predetermined sequence of groups of three, each of which is a code word. This collection of code words was put together to form a synthetic gene. These synthetic genes were then used to make a second molecule called messenger RNA (mRNA). Messenger RNA, in turn, directed the synthesis of a protein-like chain. (See figure.) This new chain was then broken down, one by one, into its individual building blocks and each was identified. By identifying each of the building blocks of the new protein, it was possible to break the code of the original DNA and confirm that three nucleotides make one code word and specify a particular amino acid. Khorana and his students have also been able to establish the direction in which information on the mRNA is read, that punctuation between code words is unnecessary, and that code words cannot overlap.

Accepting that a code word of three nucleotides in DNA generates a complementary code word of three nucleotides in mRNA, and that each code word in mRNA dictates the introduction of a particular amino acid at a particular point in the growing protein chain, how is a particular amino acid positioned properly in the chain? The middleman in this process has been identified as another kind of nucleic acid, transfer RNA (tRNA). There are different species of tRNA, each of which can recognize only one amino acid and a proper code word on mRNA.

Dr. Holley determined the primary structure of tRNA. Work initiated in 1960 led to the isolation of a pure tRNA and, in 1965, to the determination of the complete nucleotide sequence of a tRNA. Subsequently, his attention has been directed to the way in which the tRNA molecule is folded, and he has proposed a cloverleaf model which seems consistent with present knowledge of the structure



The replication of mRNA is accomplished, as shown in the upper diagram, through the use of code words (depicted here as geometric shapes) composed of three organic molecules known as nucleotides. The reaction takes place within the nucleus of the cell. The mRNA leaves the nucleus and, as shown in the lower diagram, directs the synthesis of a protein within a cellular structure known as a ribosome. This is accomplished by tRNA molecules bringing specific amino acids to the active sites on mRNA. The recognition of the code is believed to reside in hydrogen bonds formed in the reaction.

and function of this macromolecule.

The implications of these continuing developments in understanding the molecular basis of genetics and protein biosynthesis are so far-reaching that they probably are not fully appreciated despite wide exposure in the news media. Khorana's synthesis of DNA represents the creation in the laboratory of genetic material. Although it would be an extremely complicated extension, it points the way to the synthesis of a modified or entirely new set of genetic information. Methods can now be conceived by which this genetic material could be introduced into a cell, or perhaps used to replace the genetic material normally present in a given cell to produce an entirely new organism. With this possibility for changing the programming of a cell and with increased understanding of protein synthesis as represented by the work of these Nobel laureates, we are presented with the possibility of modifying biological systems.

Species

The first step in the scientific understanding of a naturally occurring phenomenon is classification, the sorting of data into groups and classes. In the biological sciences, the specialty of taxonomy fills this role and provides much insight into the degrees of relatedness and evolutionary adaptation of living organisms. Among many important applications of this knowledge is its use as an analytic tool in the study of the organization of ecological systems.

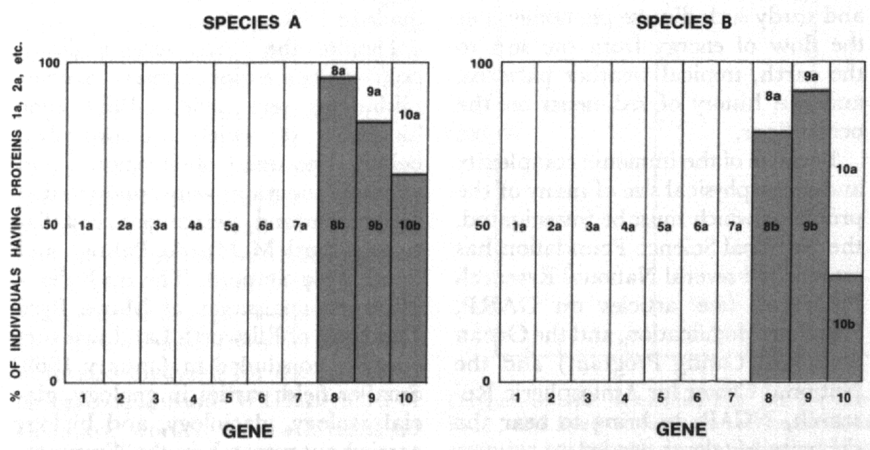
The concept of a species in man's scheme of classifying things has tended to take on the aura of a biological reality even though it has not yet been possible to provide a definition of a species which is acceptable to all biologists. Taxonomy is usually based on gross differences in form, reflecting the fact that as different species separate from a form of common origin and evolve, their genetic constitutions are independently modified by the forces of evolution. After the passage of a sufficient number of generations and the development of differences in a sufficient number of genetic characters, there will eventually be enough differences in form to provide for a recognizably different species—that is, a group of organisms within which there may be free exchange of genetic material, and which is separated from other species by the lack of such exchange.

Complicating the view that the species is a discrete or bounded entity has been the recognition that there is considerable genetic variability within a species, and difficulties often arise in deciding whether one is dealing with a new species or merely a variant within a recognized species. Attempting to assess the genetic relatedness of groups of individuals by observing gross differences in form is difficult and unsatisfactory because the characters which are used are generally remote consequences of the effects of genes. In recent years, however, it has become possible to measure genetic variability within and between species in a much more direct way, by the study of specific gene products, the proteins. Among the tools developed by protein chemists, gel electrophoresis provides a rather simple method for detecting differences between proteins which can often be identified as due to differences between particular genes.

For several years, Richard C. Lewontin at the University of Chicago has been applying gel electrophoresis to the study of genetic diversity in species of the fruit fly, *Drosophila*, an organism which has been extensively studied by classical genetic methods. He has now extended this work to include the protein variants arising from 26 genetic loci, and the results have been some somewhat unexpected. In the first place, the extent of genetic variability within a species has proved to be greater than expected, involving something over 30 percent of the genes which were sampled at random by this method. A second surprise has been the constancy of occurrence of certain genetic variants within the species over a very wide geographical range in North America. It had been expected that different environmental conditions might exert a selective pressure which would result in a different frequency of occurrence of some of the genetic variants at the extremes of geographic distribution, but this was not found to be the case. A further surprise has been the failure to find any genetic site which is uniquely different between closely related species. The differences between species of *Drosophila* have been with respect to the relative frequencies of occurrence of the proteins which are a reflection of the variable genes rather than in the appearance of new proteins in one species but not in another.

Another aspect of the species concept has been the hypothesis that two species cannot occupy the same ecological niche. Robert R. Sokal now at the State University of New York, Stony Brook and Koichi Fuji of the University of Kansas have recently examined ecological characters of populations of bean weevils from a variety of geographical areas by numerical clustering techniques. Parameters such as developmental time, number of eggs laid, population density, and the like may be regarded as ecologic in the sense that there are biological or physiological qualities required to fill a particular environmental niche. The extent to which estimates of a group of these parameters for populations cluster about similar values should give an indication of the extent to which the populations represent the same or different species. The resulting ecological classifications corresponded with the expectations on taxonomic evidence.

Finally, it may be noted that man is not the only taxonomist. Parasites are usually rather specific with respect to their host species. This is, of course, consistent with the ecological view that each species will have its own niche—in this particular case, its own host. There are not only particular kinds of mites which live in the feathers of birds and others which infest bees, but particular species of feather mites select particular species of birds. Warren T. Atyeo of the University of Georgia, and Irwin Newell and Paul Hurd of the University of California, Berkeley, are investigating these relationships for feather mite and bee mites, respectively, partly with a view to using these parasitic or symbiotic organisms as an aid in the classification of the hosts.



Hypothetical distribution of proteins 1a, 1b, 1c, etc., arising from genes 1, 2, 3, etc. Proteins produced by 7 of the 10 genes are the same in all individuals of species A. Proteins of genes 8, 9, and 10 may be of the a or b type, indicating two kinds of genes 8, 9, and 10. In closely related species B, only those proteins are found which also occur in A, but the relative proportions of 8a and 8b, etc., are different.

Chemical Communication

Chemical communication between individual humans has fallen into disuse except for the employment of artificial scents. Modern society obviously calls for deodorants rather than odorants. However, we still depend upon chemical communication between cells (for example, in the action of hormones) to regulate our internal balance. In the case of other forms of life, chemical communications play a very important role, two examples of which may be mentioned among many supported by the Foundation.

There are at least two periods in the life cycle of the cellular slime mold when movement toward chemical attractants is observed. The first reaction, one of orientation to a food source, occurs during the active feeding period of the vegetative amoebae; and the second reaction, leading to aggregation, occurs when the amoebae stream together to form a multicellular organism which then undergoes changes in form and the development of specialized cell-types, organismal structures, and differentiation. After a search for many years, John T. Bonner at Princeton University has found that the chemical attractant of the aggregation phase, in at least one species of slime mold, is an organic chemical compound known as acrasin (or cyclic AMP). This discovery was of special interest because heretofore cyclic AMP had been implicated in the action of several hormones in higher animals but had not been known to influence chemical communication in relatively primitive kinds of organisms like slime molds. Judging from the way in which cyclic AMP is involved in hormone action in higher animals, it is likely that the story in slime molds is also complicated and other substances are involved in producing a shift from conditions of feeding to aggregation.

Another area where chemical communication is of major importance is within the insect world. Edward O. Wilson and his associates at Harvard University have conducted studies of the organization of insect societies over a period of some years. The primary emphasis of their research has been upon the role of chemical signals, or pheromones, in communication among insects. Most of the work in this field has dealt with those pheromones which are ingested to influence caste and those which are transmitted in a volatile form through the air to attract or alarm, since such substances have been relatively easy to extract and bioassay. Recent work of Dr. Wilson and F. E. Regnier on the alarm-defense system of the ant, *Acanthomyops claviger,* is of interest in illustrating the power of modern chromatographic techniques in such studies and in demonstrating that a simple hydrocarbon such as undecane (a principal ingredient of light mineral oil) may play an important role in signalling and defense. Although undecane is odorless to most organisms, ants have a rather strong olfactory response to it in minute concentrations. Furthermore, they secrete it in one of their glands which suggests its availability for chemical communication.

Within a species, alarm and attractant reactions may be essentially the same, since the alarm response is one of attraction to the site at which the chemical has been released (to help repel an attack, for example). The fact that the secretions contain a mixture of components, however, suggests that modifications may be used to produce more complex responses. For example, certain glands of a subgenus of slavemaker ants are hypertrophied, and contain unusually large quantities of olfactory organic compounds. The possibility is being explored that these organic substances are employed in offense during slave raids or the maintenance of slave colonies.

This program, along with many others in the same field, provides a further example of basic research in which the investigator is not directly concerned with application, and yet the potential for application by others in the control of insects increases with every systematic step taken in an attempt to understand the basis for regulation of social behavior in insects.

ENVIRONMENTAL SCIENCES

The scientific community and the public at large has become increasingly aware in the last few decades that the quality, or even the existence, of human life is dependent upon the quality and nature of its environment. Study of the complex methods by which the various constituent parts of the environment interact, and how the activities of man affect those parts and their roles, are a principal focus of the field of environmental science. To investigate these processes, scientists use the tools of chemistry, physics, biology, mathematics, and astronomy, and study such diverse phenomena as the flow of energy from the sun to the earth, tropical weather patterns, and the history of sediments on the ocean floor.

Because of the immense complexity and sheer physical size of many of the problems which must be investigated, the National Science Foundation has established several National Research Programs (see articles on GARP, Weather Modification, and the Ocean Sediment Coring Program) and the National Center for Atmospheric Research, NCAR, to bring to bear the diversity of talents needed.

The U.S. Antarctic Research Program

In 1969, although the U.S. Antarctic Research Program (USARP) had a number of notable accomplishments, three frustrating events unfortunately impeded general progress in this program. These are mentioned to emphasize the ever-present hazards which can plague polar operations.

In early March after the close of the summer airlift support season at the isolated plateau station, both generators which supply power and part of the heat for the station broke down. Fortunately, the mechanic was able to build one operating generator from the parts of both. Yet this generator worked only haltingly and the sensitive instruments of many of the scientific programs were continually failing. The important micrometeorology program was nearly a complete loss. A second failure occurred when a drill became stuck near the bottom of the deep hole at Byrd Station. Repeated attempts to dislodge it were unsuccessful, and if the drill cannot be dislodged during the 1970 season, the cable will be cut and removed so that electronic, seismic, and other measurements can be carried out in the portion of the hole above the drill. Finally, heavy sea ice frustrated recovery of automatic recording instruments left on the bottom the previous year during the International Weddell Sea Expedition. Another try to recover the instruments will be made in 1970.

Despite the three serious disappointments mentioned, many accomplishments were made in 1969, some highlights of which are described below. The usual observational and scientific programs were conducted at the year-round permanent installations at Byrd, McMurdo, Palmer, and South Pole Stations. The multidiscipline reconnaissance of Marie Byrd Land and of Ellsworth Land was successfully concluded in January 1969. Smaller field parties in geology, glacial geology, glaciology, and biology carried out research in the Transantarctic Mountains, the Queen Maud Mountains, the Antarctic Peninsula, McMurdo Sound, and the dry valleys of Victoria Land.

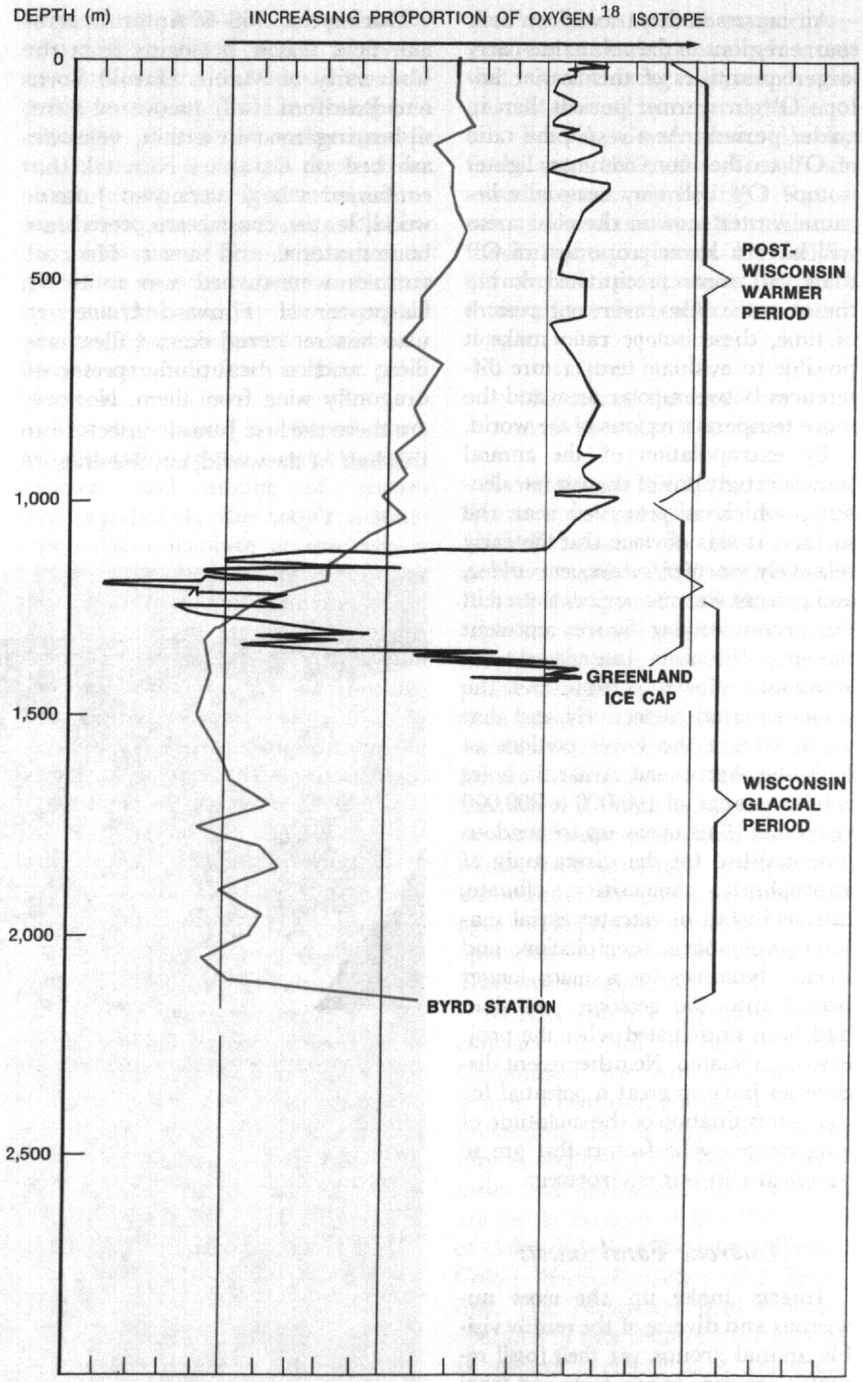
The shipboard programs have been especially successful. When the research vessel USNS *Eltanin* entered the shipyard at Auckland, New Zealand, in August 1969, for routine checkup, she had logged over 256,000 nautical miles in Antarctic waters since February 1962. A submarine ridge that nearly encircles Antarctica has been discovered and partially mapped. This ridge, like the mid-Atlantic and other ocean ridges, is bordered by a bilaterally symmetrical pattern of magnetic anomaly zones believed indicative of ocean spreading. The new U.S. Antarctic research ship *Hero* commenced her first season of work in the waters of the Antarctic Peninsula and southern South America.

U.S. Antarctic Research Projects

Climate Preserved on Ice

Scientists have worked for many years to find out if the glacial periods of the Northern Hemisphere occurred at the same time as those of the Southern Hemisphere. With the development of advanced drilling techniques to recover continuous ice cores at great depths in Greenland and Antarctica, the solution of this problem has become possible. The Antarctic Research Program helped support the development of this unique equipment by the U.S. Army Cold Region Research and Engineering Laboratories that was used to penetrate the Greenland Ice Cap at a point where it is 1,360 meters thick and then to drill completely through the Antarctic Ice Cap at Byrd Station, at a depth of over 2,164 meters.

The cores from both locations were analyzed for oxygen isotopes O^{16} and O^{18}. The ice cores from the Byrd hole were also analyzed for the hydrogen isotope, deuterium. W. Dansgaard of Denmark worked on the Greenland ice core, and Samuel Epstein and Robert Sharp of the California Institute of Technology performed the measurements of the Byrd hole material.



Oxygen-isotope determinations on ice cores from Camp Century, Greenland (black line), and Byrd Station, Antarctica (colored line). Lower concentrations of O^{18}, representing colder periods, are indicated by peaks to the left. The ages of the cores from Byrd Station have not yet been determined, but it is likely that cores from approximately 2,100 meters from Byrd are of the same age as the 1,300-meter samples from Camp Century. (After Dansgaard, Epstein, et al.)

Air masses as they travel from their source regions to the polar areas carry larger quantities of the heavier isotope O^{18} in warmer periods than in colder periods. As a result, the ratio of O^{18} to the more common, lighter isotope O^{16} will vary seasonally because winter snow in the polar areas will have a lower proportion of O^{18} than will snow precipitated during the summer. Also, over long periods of time, these isotope ratios make it possible to evaluate temperature differences between polar areas and the more temperate regions of the world.

By extrapolation of the annual snow stratigraphy of the last few decades, which is preserved near the surface, it was obvious that the early relatively warmer, subsequent colder, and present warmer periods plotted in the accompanying figures represent the pre-Wisconsin interglacial, the Wisconsin glacial periods, and the present period respectively, and that the ice from the lower portions of both the Arctic and Antarctic holes is in the range of 100,000 to 200,000 years old. This opens up tremendous potentialities for the direct study of atmospheric composition, climate, rate of in-fall of extraterrestrial material, volcanism, precipitation, and icecap dynamics for a much longer period into the geologic past than had been anticipated when the project was initiated. No other recent discoveries have so great a potential for the determination of the multitude of long-range cyclic factors that are so significant in our environment.

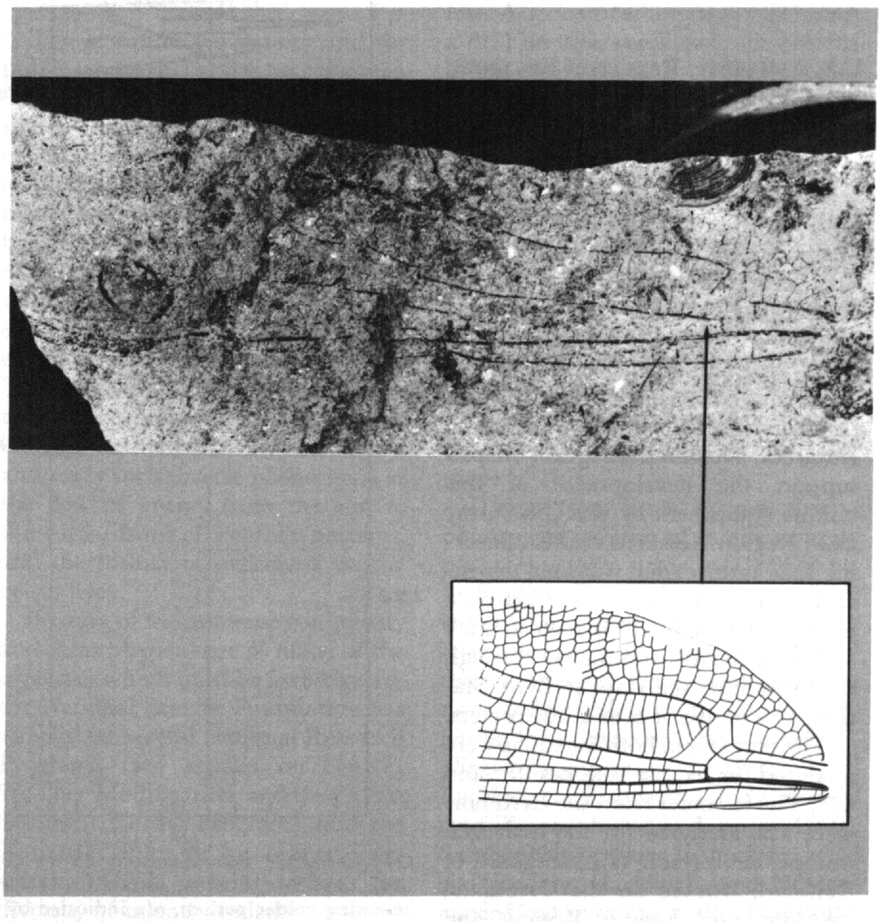
Antarctic Fossil Insects

Insects make up the most numerous and diverse of the readily visible animal groups, yet their fossil remains are rare in any form and from any geologic age. Fossil insects have been particularly scarce from the Southern Hemisphere, and, until this year, none was known south of the equator from rocks of Jurassic Age from about 135 to 180 million years ago.

During the 1968–69 Antarctic summer field season, geologists from the University of Maine, Harold Borns and Bradford Hall, discovered a fossil-bearing zone in a thin, volcanic-ash bed on Carapace Nunatak that contained a large variety of Jurassic wood, leaves, crustaceans, vertebrate bone material, and insects. The rock samples were turned over to F. M. Carpenter of Harvard University, who has recovered damsel flies, may flies, and a beautifully preserved dragonfly wing from them. Not only are these the first Jurassic insects from this half of the world, but the dragonfly represents a new genera and new species from the Suborder Odonata, a dominant group in the Jurassic of Turkistan in the U.S.S.R. and of Germany, but now represented by only one living species from Japan.

The full significance of this discovery will not become known until the deposit can be thoroughly collected by specialists in fossil insects, but it may be comparable, in the scientific light it may shed on geologic history, to the famous Florissant fossil beds of Colorado.

The Carapace fossil beds were formed in the same way as the Floris-



Photograph of the hind wing of a fossil dragonfly from Jurassic lakebeds at Carapace Nunatak, Transantarctic Mountains, Antarctica. The coarse texture of the sediments are the result of the lake beds being formed mainly from coarse volcanic ash.
Below, diagram of the vein pattern of the fossil dragonfly wing shown above. (After Carpenter)

sant beds, by the accumulation of thin layers of fine-grained volcanic ash in a freshwater lake. The rare combination of events that has allowed the preservation of these delicate animals and plants at Carapace Nunatak has preserved important keys to the interpretation of geologic history, not only of Antarctica but of the entire world. Certainly the results of detailed studies on the fossils discovered here will bear directly on the geologic investigation of the ancient southern supercontinent of Gondwanaland, its subsequent breakup, and the drift of the resulting continents.

The White Blood Cell Count

Serial white blood cell counts on a population of eight healthy young men wintering over at the inland Antarctic base known as the Plateau Station during the 1967 year were taken by Lt. A. B. Blackburn (MC), USNR, as one measure of the effect of 9 months total social isolation endured by these men. Done at the suggestion of Drs. Jay T. Shurley and Chester M. Pierce, with the collaboration of Dr. Harold Muchmore, of the Veterans Hospital, Oklahoma City, and University of Oklahoma Medical Center, this study indicated that a phenomenon which is the "mirror image" to the elevation of white cell counts which occurs following exposure to infectious disease organisms took place under the isolated situation in Antarctica. Total white cell counts were seen to drop from an average normal of 8,000 cells per cubic millimeter of peripheral blood, to a mean level of 3,600 cells. These low levels had heretofore been observed in viral infections or in seriously ill persons only.

Absolute leukopenia (decrease in number of white blood cells) has been associated with increasing vulnerability to infection in man. Gnotobiotic (germ-free) animals also exhibit absolute leukopenia, and are markedly vulnerable to severe infection when removed from the germ-free environment and exposed to the microbial populations of everyday life. Extension of the germ-free comparison suggests that the leukopenia observed in isolated polar groups might be due to antigen deprivation which results when the normal microbial mixing associated with social intercourse ceases. This comparison to germ-free animals appears to be further strengthened by the repeated observation of respiratory infections in men returning from isolated polar journeys.

The hypothesis is offered that, after cessation of the normal (usual) renewal and mixing of microbial populations, the body's defense mechanisms involute or undergo a kind of nonuse atrophy, rendering the individual progressively more vulnerable to disease following reexposure to microbes which might have previously been unable to produce illness. If this hypothesis is true, it carries obvious implications for space travelers, or any persons socially isolated for prolonged periods.

Atmospheric Sciences

Fiscal year 1969 marked the end of a decade of support of the atmospheric sciences by the Foundation—a decade in which the rapid growth of atmospheric science activity was paralleled by a growth in the level of Foundation support. In 10 years, the annual production of Ph. D. scientists trained in this field increased tenfold, and, in the 5-year period from 1964 to 1968, the number of universities receiving Foundation support in the atmospheric sciences increased from 31 to 48.

The Foundation programs in this area are subdivided into three fields: aeronomy, the study of the upper atmosphere; meteorology, the study of the lower, weather-producing part of the atmosphere; and solar terrestrial research, the study of the processes by which the earth receives the energy from the sun which powers all atmospheric phenomena. In general, the Foundation research support programs stress basic research in areas that are not being supported adequately or at all by other agencies of the Federal Government. During fiscal year 1969, the Foundation awarded grants supporting 116 projects at a level of about $8 million in the atmospheric sciences. The following articles are examples of work done in these fields with Foundation support.

National Center for Atmospheric Research

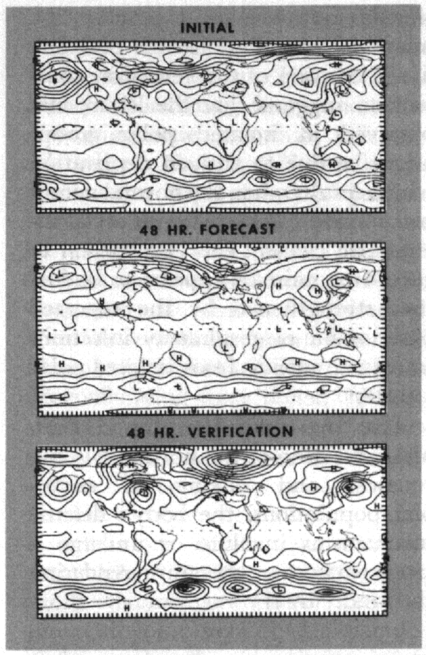
In fiscal year 1969, the National Center for Atmospheric Research (NCAR) marked its 10th year of existence under NSF sponsorship. During that period, NCAR has established a broad research program, emphasizing attacks on fundamental problems by groups of scientists larger than would be typically available in a university; has established facilities for the use of university scientists and has otherwise built a vigorous pattern of scientific interaction and stimulation with university groups; and has joined in the planning and management of projects involving the cooperation of university groups and Government agencies.

NCAR, which is operated under contract with NSF by the University Corporation for Atmospheric Research, a nonprofit consortium of 27 universities, has its principal laboratory at Boulder, Colo. Other laboratories and permanent field stations are on the campus of the University of Colorado, also in Boulder; Climax, Colo.; Marshall, Colo.; and Palestine, Tex. Temporary field sites are operated in this country and abroad as research needs or joint university projects require.

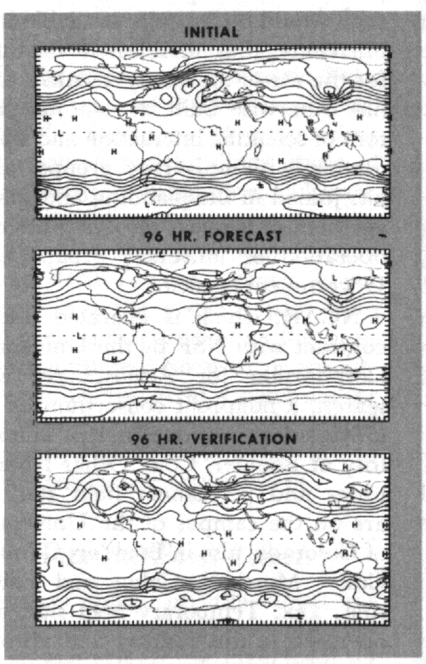
Research on the Atmospheres of the Earth and Sun

Atmospheric Modeling.—At the heart of NCAR's research lies the problem of interpreting atmospheric

A 48 HOUR COMPUTER PRODUCED FORECAST OF SEA LEVEL PRESSURE



A 96 HOUR COMPUTER PRODUCED FORECAST OF PRESSURE AT 6 KM.



To check the ability of the NCAR model's ability to forecast the real atmosphere, experiments are conducted with real data as a starting point. In this example, the model predicted more or less correctly the movements of highs and lows, but underestimated their intensity. (NCAR diagrams)

behavior by numerical modeling of atmospheric processes. The NCAR global atmospheric model which is built upon four equations representing changes in east-west wind, north-south wind, air pressure, and water vapor content is structured on a grid with 5° latitude and longitude spacing, and involves solving equations for 2,522 grid points at each of several levels. During fiscal year 1969, experiments with the NCAR model demonstrated the importance of clouds (and resultant radiation effects) and of mountain ranges in controlling climate. The model is now being tested for its ability to reflect actual climatic conditions as well as the day-to-day march of weather patterns, using real weather data.

Thermal Convection and Mountain Lee Winds.—Studies of thermal convection, especially that involved in severe thunderstorms and hailstorms, have been a prominent part of NCAR research. Theoretical and laboratory studies of cumulus clouds, of flow characteristics in and around storms, and of vertical air motions within clouds (determined by dropsondes falling through the storms from high-flying aircraft and by laboratory simulations) have given new insights into convective circulation. Studies are also being made, in cooperation with a number of other United States and Canadian agencies, of the high-velocity, gusty surface winds known in parts of the world where strong, deep air currents flow over high mountain ranges. In Colorado such winds, frequent wintertime occurrences, sometimes reach velocities in excess of 125 m.p.h. Reconnaissance aircraft and surface instruments have now yielded data which reveal many features of the flow structure of these winds.

Atmospheric Chemistry.—A number of research projects at NCAR have been devoted to determining the nature and distribution of minor constituents of the upper atmosphere. Foremost among these has been the development of a rocket-borne cryogenic air sampler, ENCAR–1, which was flown successfully in September 1968. The sampler opened at 143,000 feet, and gathered the largest sample of high altitude air ever collected—the equivalent of nearly 10,000 cubic feet—by freezing it on low-temperature coils. This unique sample is now being analyzed.

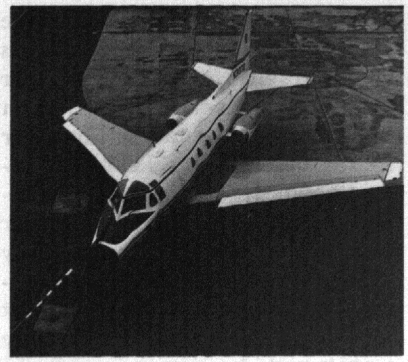
Collections of volcanic fumes during recent eruptions of several volcanoes—Kilauea in Hawaii, Arenal in Costa Rica, and Mayon in the Philippines—have enabled NCAR to continue a program seeking to determine the composition of volcanically derived particles in the atmosphere. Such particles may become significant climatologically during periods of exceptionally active or widespread volcanism. This study is integral to an understanding of the worldwide sources and distribution of solid and liquid atmospheric particles.

Tropopause Folding.—In recent years studies of ozone and radioactivity concentrations have revealed that the boundary between atmospheric layers is not a flat and highly impermeable discontinuity as had long been supposed, but that it often "folds," particularly in the vicinity of the jet stream, so that tongues of stratospheric air extend down into the troposphere. In order to study this exchange, NCAR and Air Force aircraft have sampled both above and below the tropopause in the region of the fold. Stratospheric air, recognizable by its high content of ozone, sulfate, and radioactive aerosol particles, was found at tropospheric levels on the northwest side of the jet stream; tropospheric air, high in silicon and other surface-derived minerals, was found to have entered the stratosphere on the opposite side of the jet stream. Further studies of this interesting phenomenon are planned.

Solar Temperatures.—At the High Altitude Observatory (HAO), studies of the sun's far infrared and far ultraviolet spectra have yielded new information on temperatures near the surface of the sun and in the solar corona. Using specially designed instruments flown in a NASA jet, HAO scientists obtained far infrared spectra which indicate that the lowest temperature of the sun's atmosphere is about 4,300° K. This minimum temperature occurs just above the photosphere, the surface of the solar disc. The far ultraviolet spectrum indicates that the temperature then rises extremely sharply to about 1,000,000° K. at the chromosphere-corona interface, actually reaching a gradient of 10,000° per kilometer, and then increases more slowly to about 2,000,000° K. in the corona.

Solar Magnetic Fields.—It has become increasingly evident that the primary agent which molds the corona into the structure visible at eclipse or by coronagraph is the solar magnetic field. Studies of photographic and photometric records of the 1966 eclipse show that shapes of coronal rays and polar plumes, which are really density enhancements in the solar atmosphere, conform well with the shape of the solar magnetic fields, reflecting the loops and arches of the magnetic field lines. Sunspots, flares, and other prominences also seem to be caused or controlled by magnetic fields, in some cases by relatively small, very strong fields often of opposite polarity from the main field. These fields may be created in the turbulent plasma below the visible surface of the sun, and portions of the plasma may buoy to the surface, at times giving birth to an active region with its own strong magnetic field. The strong field causes a cooling of the plasma and formation of a dark sunspot. Data accumulated at Climax suggest that in active prominences, very strong local magnetic fields control both the flow of solar material and the temperature gradients, and limit such prominences to their characteristic shapes—loops, surges, caps, filaments, and coronal clouds.

Solar Rotation.—Although no satisfactory explanation has been offered for the fact that on the sun the equa-



During 1968 NCAR acquired a Sabreliner twin-jet aircraft especially modified for atmospheric research. The 17-foot boom will support scientific equipment well in front of aircraft turbulence. (NCAR photo) torial regions rotate faster than the polar regions, HAO research has demonstrated that the general solar magnetic field is closely dependent on this differential rotation. Computer studies show that the well-known 11-year cycle of solar activity, or the observed development and drift of polar prominences, can be reproduced by using two different formulas for differential rotation. It is now thought that the differential rotation could be maintained by conversion of the kinetic energy of large-scale convective motions in the sun itself.

Studies of the solar corona, conducted at Boulder and Climax, Colo., and Mauna Loa, Hawaii, have revealed several new features. A sequence of day-to-day measurements obtained from 1964 to 1967 with the k-coronameter at NCAR's Mauna Loa field station indicate that at equatorial latitudes the corona rotates at about the same rate as the solar surface, but at higher latitudes the corona rotates faster than the underlying photosphere, thus in effect smoothing out the differential rotation.

Facilities Operations

The research aviation facility provided research flight support for many NCAR and university programs and made significant strides in aircraft modification and instrument design. During 1968, the facility acquired a de Havilland Buffalo and a North American Rockwell twin-jet Sabreliner, both of which have been modified for research use.

The scientific ballooning facility continued to improve launch techniques, balloon design, and electronic support systems. NCAR staff members met with representatives of the balloon industry and the Government to discuss issues of common concern; an outgrowth of these meetings was the formation of a committee on scientific ballooning standards, to promote use of uniform terminology and to prescribe safety and packaging standards.

The computing facility has developed methods to minimize turnaround time and is therefore able to fulfill many more requests, especially for short-run computing jobs. In addition to general purpose computing for NCAR and the scientific community (an average of 600 jobs per day are run on NCAR's Control Data 6600 computer), the facility devotes an entire shift to large-scale dynamic problems associated with development of the NCAR global atmospheric model. A new software system has made central processor utilization more efficient. The group also works in close liaison with the University of Illinois group which is developing the Illiac IV computer, a parallel-mode machine whose potential is 100 or more times greater than the fastest existing computer. The NCAR general circulation model is being coded for use with that machine when it becomes operational in 1971 or later.

Support activities of the field observing facility were divided nearly equally between NCAR and university programs. The facility assisted in field activities of Florida State University's Barbados Experiment in the summer of 1968, and BOMEX in 1969, and provided major assistance to a number of other programs.

Most of the staff of the global atmospheric measurements program (GAMP) has now moved to the flight station at Christchurch, New Zealand, where globe-circling, constant-level balloons are launched. These inexpensive balloons have remained aloft as much as 441 days, tracking high-level winds as they go. This group works toward improvement of all phases of the GHOST balloon operation.

Educational Activities

NCAR continues to become increasingly involved in activities attracting outstanding students into graduate study in atmospheric science and bringing established scientists to NCAR, where they may participate in research activities. Four UCAR predoctoral fellowships enable recipients to observe and assist in various NCAR programs during the summer and to attend graduate schools of their own choosing during the academic year. Postdoctoral fellowships bring atmospheric scientists from the United States and abroad to NCAR for a year of study and research. NCAR's Advanced Study Program sponsors, each summer, a colloquium on some topic relevant to atmospheric science. In the summer of 1968, the colloquium topic was internal gravity and acoustic waves in the atmosphere; the 1969 topic is solar magnetohydrodynamics. Summer work-study programs at NCAR teach students the use of computers and aircraft as tools for atmospheric research. In another program, several NCAR scientists are now participating as affiliate professors in university research and teaching.

WEATHER MODIFICATION

Under the broad authority of Public Law 90–407, the Foundation supports research at universities and nonprofit institutions on atmospheric mechanisms that could be influenced for weather modification purposes. These involve the study of ice nucleation mechanisms, droplet coagulation and coalescence, cloud electricity, hygroscopic, or water-attracting, nuclei, cloud dynamics, formation of hail and graupel (spongy ice), air mass circulation in severe storms, and many others. In addition, research continues to be sponsored on the social, ecological, economic and legal aspects of weather modification.

Studies on ice nucleation efficiencies of silver iodide generators have been continued at Colorado State University, and it has been found that the results obtained from cold chambers used for determining nucleation efficiency as a function of temperature are very dependent upon the liquid water content of the chamber. With high liquid water contents in the cold chamber, the number of ice crystals formed from a measured quantity of silver iodide is much less dependent upon cold box temperature than formerly believed to be the case. This indicates that the nucleation efficiency tables now being used in the field may be in error by a considerable factor. It was also found that there is a critical concentration of nuclei which cannot be exceeded by any silver iodide generator due to the rapid coagulation of particles in the generator output when concentrations exceed 10^5 particles per cubic centimeter of air. This study demonstrated that increasing the rate of silver iodide being vaporized by the generator does not necessarily mean that more ice-forming nuclei will be produced.

The modification of severe storms such as the hurricane is also being approached from the point of view of a mathematical model under development at New York University. The model was tested on the computer, and simulated the life cycle of a hurricane with a remarkable degree of reality. It now responds sensitively to changes in sea surface temperature, and simulates landfall of the hurricane by drastically reducing the wind speed by 50 percent in 24 hours after the supply of moisture from the ocean is cut off. Besides the fact that the model has succeeded in simulating many aspects of the hurricane, it has demonstrated the importance of the oceanic latent-heat supply to both development and maintenance of the tropical storm.

During the summer of 1968, the New Mexico Institute of Mining and Technology tested a vertical wind tunnel which is capable of injecting a current of 1 milliampere of charged oil smoke particles into the base of a growing convective cloud. The electric field intensities observed downwind from the charger have been very substantial, and appear to be in the order of 500 volts per centimeter. During periods when the mountain was cloud covered and the charger was operated, it was possible to detect singular radar echoes in the treated clouds just downwind of the charger. This suggests that the growth of cloud droplets has been greatly enhanced as a result of the electrical forces. When the charger current was turned off, the radar echoes tended to dissipate. The experiment demonstrated that it is possible to upset the dispersion stability of a finite although rather small atmospheric cloud by electrical forces that are artificially injected.

During fiscal year 1969 the Foundation, with assistance from the NCAR, presented a plan for a national hail research experiment to the Interdepartmental Committee on Atmospheric Research (ICAS) of the Federal Council for Science and Technology. This plan suggested an interdepartmental project of research in northeast Colorado over a 5-year period to study the structure and dynamics of hailstones in order to understand the mechanism of hail formation, and to determine whether the accurate injection of seeding agents in the potential hail-producing clouds might affect the size or amount of hailfall at the ground.

The ICAS recommended that the national hail research experiment be started in 1971 or 1972, and that the Foundation assume the responsibility for arranging the organization and management of the program, and for enlisting the cooperation of all the participating Federal agencies. A field site has been established within the Pawnee National Grasslands which is managed by the Department of Agriculture, and a preliminary observational program has been established by NCAR during the summer of 1969, working jointly with the ESSA Research Laboratories and Colorado State University under NSF sponsorship.

In the field of social aspects of weather modification, the Foundation sponsored a task group on the domestic legal aspects of weather modification at Southern Methodist University to examine the possible need for changes in the present legal framework in order to provide a sound foundation for weather modification in the future. In addition, various alternatives in organizing and administering weather modification operations and programs will be examined and presented in the final report to be published early in 1970.

In summary, the Foundation has continued to encourage and support research in weather modification at universities and nonprofit institutes under the broad provisions of the

An NCAR radar detects developing hailstorms on the prairies of Pawnee National Grassland, north of Raymer, Colo. (NCAR photo)

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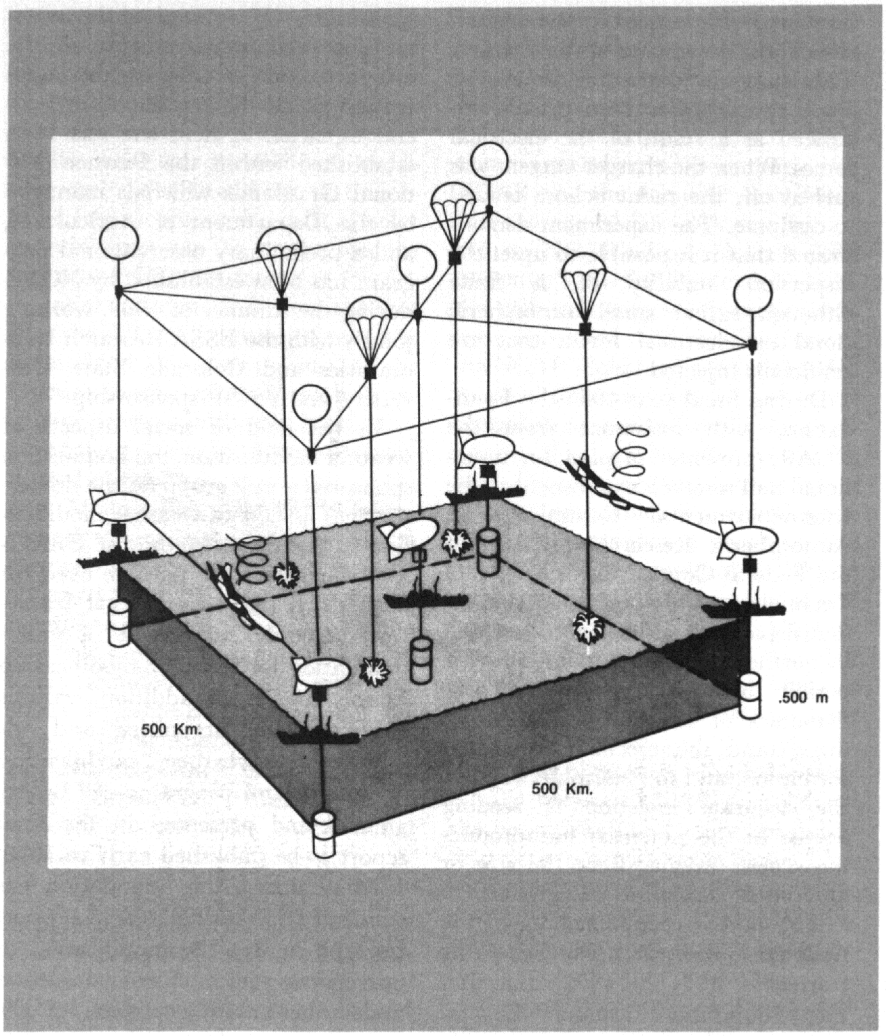


Illustration of the major features of the 11-ship, 17-aircraft experimental array for BOMEX. The 3-month experiment, conducted east of the island of Barbados, studied the transfer of energy from the tropical oceans into the atmosphere.

National Science Foundation Act as amended through August 14, 1968, and will plan to continue this support in the future. At the present time the reporting responsibilities of the Foundation and maintenance of weather modification records under Public Law 85–510 have terminated, and no other Federal agency has been designated to undertake this responsibility. A number of bills have been introduced into Congress to provide this authority, but none had been reported out of committee by the close of fiscal year 1969.

Global Atmospheric Research Program

Progress has continued on several fronts during the past year on the Global Atmospheric Research Program (GARP). GARP has as its objective the attainment of economically useful long-range weather prediction. Recent developments in computer and satellite technology have provided the opportunity for advancing toward this goal, and studies of the theoretical limits of atmospheric predictability have confirmed that significant advances are within reason and reach.

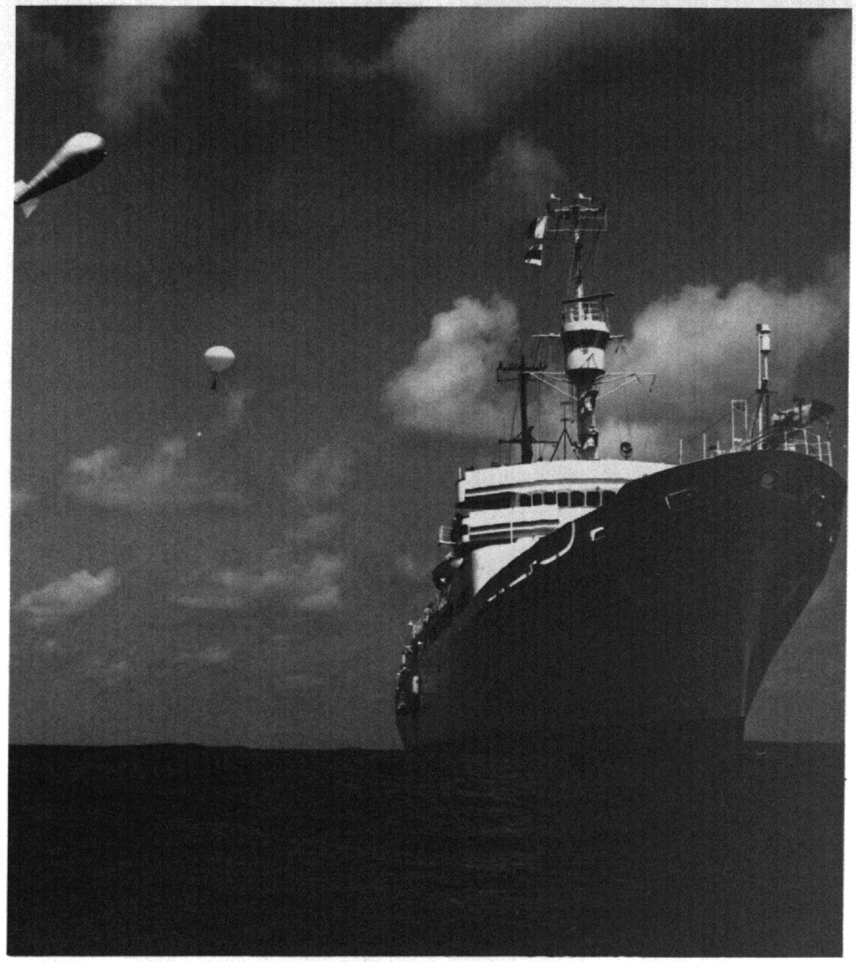
Three requirements have been identified that are essential to meeting the objectives of GARP: (1) The development of a global observing capability; (2) the availability of electronic computers with speeds at least 100 times faster than the speeds of the most powerful computers in use today; and (3) the conduct of regional field programs and computer modeling experiments to improve the physical and mathematical basis of long-range prediction.

Following international acceptance of GARP, the Federal Government requested that the National Academy of Sciences form a committee to plan, coordinate, and guide the U.S. GARP effort. This committee, formed in March 1968 and chaired by Jule G. Charney of the Massachusetts Institute of Technology, prepared a report entitled "Plan for U.S. Participation in the Global Atmospheric Research Program" which has been published and distributed to the scientific community. This report outlines in general terms experiments and programs that should be accomplished by the United States. Recommendations of the report are currently being assessed, and it is anticipated that details of the next several years' work will be completed by early 1970.

During May, June, and July 1969, a field phase of GARP known as the Barbados Oceanographic and Meteorological Experiment (BOMEX) was held in an area east of the island of Barbados, West Indies. The major facilities consisted of 11 ships plus the Navy's research platform FLIP and 17 aircraft. One hundred four principal investigators worked on over 90 separate experiments. The supporting force consisted of more than 1,200 men. All supplies and equipment were flown in by units of the Air National Guard.

BOMEX was designed to explore one of the key processes governing the physical behavior of the atmosphere and the oceans—the transfer of energy from the tropical oceans into the atmosphere. Although this transfer process is complex, BOMEX was designed to investigate the initial stage of the transfer on what is known as air-sea interactions. The following figure shows the experimental array. This part of the investigation lasted for the first 2 months. Preliminary estimates show that during six of the seven experimental periods, 80 to 93 percent of the necessary observational data were collected successfully. The aircraft meaurements were extremely good. This means that when the data are analyzed fully there will be a much better understanding of the subtropical atmosphere and air-sea interaction in that area of the tropics.

The third month of BOMEX emphasized the second stage of the transfer process, the distribution of energy from the lowest layers of the atmosphere into deeper layers by large-scale convective systems. Some



A meteorological balloon released from the deck of the research vessel *Discoverer* carries its instrument package aloft during BOMEX. The tethered balloon in the upper left can fly instrument packages at predetermined heights for extended periods of measurement. (ESSA photo) of these convective systems are 300–500 miles in diameter. By observing the cloud patterns from satellite photographs it was possible to direct aircraft to the areas of interest. Data of interest were collected successfully from several different situations and an analysis of the data will help in understanding how this part of the energy transfer takes place and what is its magnitude.

During fiscal year 1969 GARP funds were used to support seven grants for BOMEX totaling over $250,000. These grants helped support all aspects of BOMEX and were not confined to any one scientific area. The remainder of the GARP funds was used to support more fundamental GARP studies of predictability and the theory of large-scale atmosphere and ocean processes plus an analysis of data from the Line Islands Experiment of 1967. In addition to the regular GARP funds, several grantees received support for their BOMEX studies from meteorology program funds making the grant commitment to BOMEX equal to about $450,000.

BOMEX was supported also by the National Center for Atmospheric Research (NCAR) in several ways. An NCAR scientist was assigned on a part-time basis to the BOMEX project office to help with some of the instrumentation and engineering problems. The NCAR aircraft facility furnished three different aircraft for use during BOMEX and the field observing facility provided technicians and an M–33 radar unit. Finally, several NCAR scientists participated in a number of the experiments and worked in cooperation with universities and Federal agencies particularly during the fourth phase.

NCAR's global atmospheric measurements program (GAMP) is designing new types of instrumentation especially suited for use in oceanic or uninhabited land areas. Notable among the new concepts developed by GAMP is the global horizontal sounding technique (GHOST) superpressure balloon system. One of the GHOST balloons, launched from New Zealand in September 1967, remained aloft for 441 days and completed more than 25 circumnavigations of the Southern Hemisphere. During GARP an operational GHOST system—with thousands of such balloons—will relay weather data via satellite to ground stations.

Meteorology

Because atmospheric processes can be expressed mathematically, it has become possible, by the use of high-speed electronic computers, to simulate the atmosphere by numerical representations. Such models will create realistic weather patterns for a future time. Present experiments indicate that computer models predict fairly well for periods of a few days, but there are many difficulties yet to be overcome, such as taking into account the detailed thermal effects of the earth's land surfaces, the dynamic effects on atmospheric processes of mountains, and the inaccuracy created by feeding incorrect, or too few, observations into the computer. Often it is impossible to obtain weather data from large areas of the globe. It is for this latter reason that the World Weather Program has been initiated.

In addition to the problems mentioned above, much must be learned about the significant energy exchange processes and their interactions. At McGill University in Montreal, Svenn Orvig and E. Vowinckel are investigating the energy balance at the earth's surface and in the atmosphere. The investigators have designed a computer program that permits complete energy budget calculations from normally available synoptic weather observations. The calculations can be done for all terms in the energy budget calculation at a particular station for a number of periods (climatological application) or for many

A constant-level GHOST balloon is launched from Christchurch, New Zealand. Balloons such as this, drifting with the wind, will transmit temperature, pressure, and wind data to satellites for relay to ground stations. (NCAR photo) stations for a particular period (synoptic application).

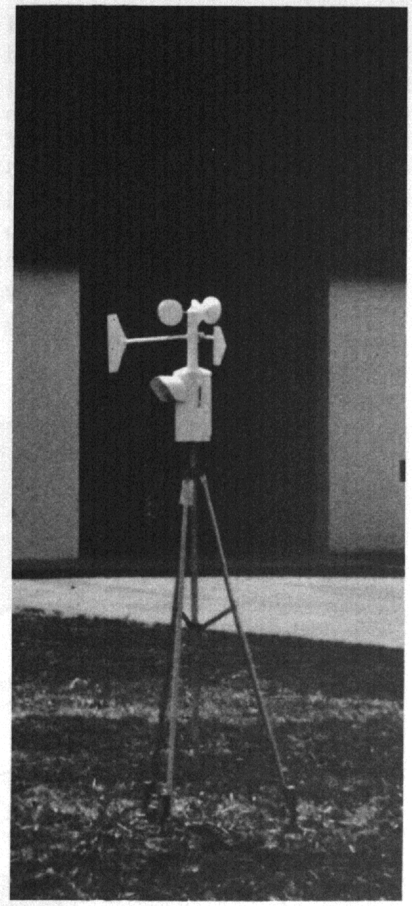
The program allows for four different surface types: water, bare ground, vegetation, and forest. Separate energy budgets are calculated for all of these and combined according to the nature of ground in the area. Seasonal changes are accounted for: winter snow and ice, leaves on the trees in summer, etc. Checks to compare the program with nature have been performed from time to time, such as the comparison of calculated to observed dates of lake ice formation, maximum ice thickness at the end of winter, dates of snow melt, and the amount of river runoff. Such tests have proved to be extremely sensitive, and have proven the accuracy of the computer program.

One of the research efforts under this project "dissected" a strong winter storm in the Atlantic for which actual data were available. The daily values of energy budget elements were computed for 7 days for 37 grid points, at the surface as well as for the higher atmosphere. Solar radiation, terrestrial and atmospheric radiation, turbulent heat transport, evaporation, and heat storage changes in atmosphere and ocean were all evaluated. A detailed picture emerged of the anatomy of the storm as well as the manner in which it redistributed heat within itself. The effect of the ocean on such a storm and vice versa became quite clear.

A similar study of a winter storm over a continental area is nearing completion. It is planned to study the energetics of other storms during a summer season over an ocean and a continent as well as high pressure systems over land and water during various seasons. When these studies are completed, it will be possible to evaluate the effect of the underlying surface on the movement of storms and their intensity. The distribution of energy in the atmosphere as a result of the storms also will be understood better. This knowledge then can be transformed into changes in current numerical models of the atmosphere and hence into better weather forecasts for every day use.

For years nagging questions have arisen about man's effect on his environment. Many of the questions deal with that precious and irreplaceable resource, the atmosphere. A particularly complex one to answer: Is urbanization affecting the climate? and if so, how much? In the past, atmospheric scientists have tried to assess these changes by comparing observations of temperature, wind, air composition, and rainfall taken in cities with those from the nearby rural environment. This yielded estimates of local changes that have been ascribed to the city influence. But some doubts remain in nearly all cases because the precise conditions prior to urbanization have remained unrecorded, and we are forced to substitute a spatial comparison for a temporal one.

An attempt is now in progress to remedy this deficiency in knowledge. The meteorology group at the University of Maryland under the leadership of Helmut E. Landsberg has started a micrometeorological survey of the new town of Columbia in the Baltimore-Washington corridor. At Columbia, 7,000 acres of rolling farm and woodland will be settled in the next decade by nearly 200,000 people. Although planned to minimize some of the most obvious ailments of older communities, some high density sectors are included at Columbia. Hardly avoidable is the replacement of vegetation by impervious surfaces. This causes notable changes in the heat and water balance of the area. The microclimate of the new town, as it grows, is being measured by mobile surveys and observations at fixed locations. A very fortunate circumstance is the existence of three long-record stations in the immediate surroundings, at Woodstock College, at Clarksburg on the University of Maryland's experimental Forage Farm, and at Friendship International Airport.



Micrometerological station in newly urbanized area at Columbia, Md., will help to determine effects of urbanization on local weather conditions. (University of Maryland photo)

One of the first results of the research project is the clear fact that even a single block of buildings or a shopping center and parking lot creates a heat island. An increase of about 1° F. has been noted over the surrounding countryside. The wind field at Columbia is becoming distorted, and it is felt that this change will become more pronounced in coming years. Another effect that shows up even with limited urban developments is the markedly increased runoff from precipitation. The results of paved and roofed-over areas are increased erosion and stream silting. Air pollution is beginning to be indicated at Columbia. Hopefully, as the town develops, technology will keep pace with the needs to conserve the atmospheric resources.

As man destroys natural microclimates, he creates new ones. The study at Columbia is establishing some suitable baselines against which future climatic changes can be measured and criteria can be developed for use in other new towns and in changes of present cities and towns. It is the first time that man has been able to make measurements before a town is built. As such, the quantitative results will help establish the effect of urbanization on the climate.

Aeronomy

Coupling Phenomena in Space

Interdisciplinary cooperation between aeronomers and solar terrestrial physicists has led to the development of unifying concepts which recognize the fact that phenomena in the magnetosphere are strongly reflected in ionospheric disturbances, and the more recently discovered fact that events in the ionosphere affect the magnetosphere as well. The principal coupling mechanisms relating phenomena in these spheres are electric and magnetic fields, electromagnetic and hydromagnetic waves, particle precipitation, and heat conduction.

Herbert Carlson of Cornell's Arecibo Ionospheric Observatory has attributed the presunrise heating of electrons in the upper ionosphere to the photoelectrons ejected from the opposite hemisphere by the ionizing action of sunlight and propagated through the magnetosphere to the ionosphere above Arecibo along magnetic field lines.

Sidney A. Bowhill of the University of Illinois and his students, obtaining data with the MIT Millstone Hill Thomson scatter facility, have detected the arrival of these photoelectrons from the Southern Hemisphere, as predicted by Carlson, and are presently attempting the difficult measurement of their flux and energy spectrum.

In addition to the evidence of particle coupling, other investigators have discovered evidence of coupling by heat conduction. John F. Noxon at Harvard University and John W. Evans at MIT Millstone Hill ionosphere radar coordinated their optical and radio measurements during the rare occurrence of a subvisual, red arc emission of the atmosphere at midlatitude in May 1969. They showed that there was a close quantitative correlation between the emission of the 6,300 Angstrom line of atomic oxygen and the temperature of ionospheric electrons at 300 kilometers altitude. The details of the correlation support the idea that the midlatitude red arc is produced during magnetic storms by electron heat conduction from the magnetosphere to the ionosphere along geomagnetic field lines.

Andrew Nagy, Paul B. Hays, and Raymond G. Roble at the University of Michigan have recently constructed a large aperture Fabry-Perot interferometer to measure the spectral broadening of the 6,300 Angstrom line of atomic oxygen which is a measure of the temperature of the upper atmosphere. Shortly after the instrument became operational, they detected the midlatitude red arc and auroras associated with the large solar storm of October 1968. The measurements indicate that the average temperature of the upper atmosphere in the midlatitude red arc increased from 1,000° C. to 1,500° C. and closely followed the intensity variations of the magnetic disturbance in agreement with Noxon's results. However, the same measurements made in the direction of the aurora (caused by particle precipitation) showed no temperature increase. Such behavior was predicted by theoretical calculations which showed that if energy is deposited in a small region (as in the case of an aurora) it will not cause a large temperature increase, but instead winds will be generated which redistribute the energy globally. On the night of May 14–15, a large storm occurred and was associated with intense auroral activity. As predicted, the temperature of the upper atmosphere showed no appreciable increase, but southerly winds of several hundred miles per hour at 300 kilometers altitude were observed with the interferometer.

While the coupling between the magnetosphere and the ionosphere proceeds in both directions, the coupling between the stratosphere and the ionosphere has been clearly established only in one direction. Anthony J. Ferraro and Hai S. Lee of Pennsylvania State University have clearly shown a sequential correlation between stratospheric warmings and changes in electron density in the ionosphere. Several groups at the University of Illinois, Washington State University, and the University of Washington have shown associations between density variations in the lower atmosphere and disturbances in the ionosphere.

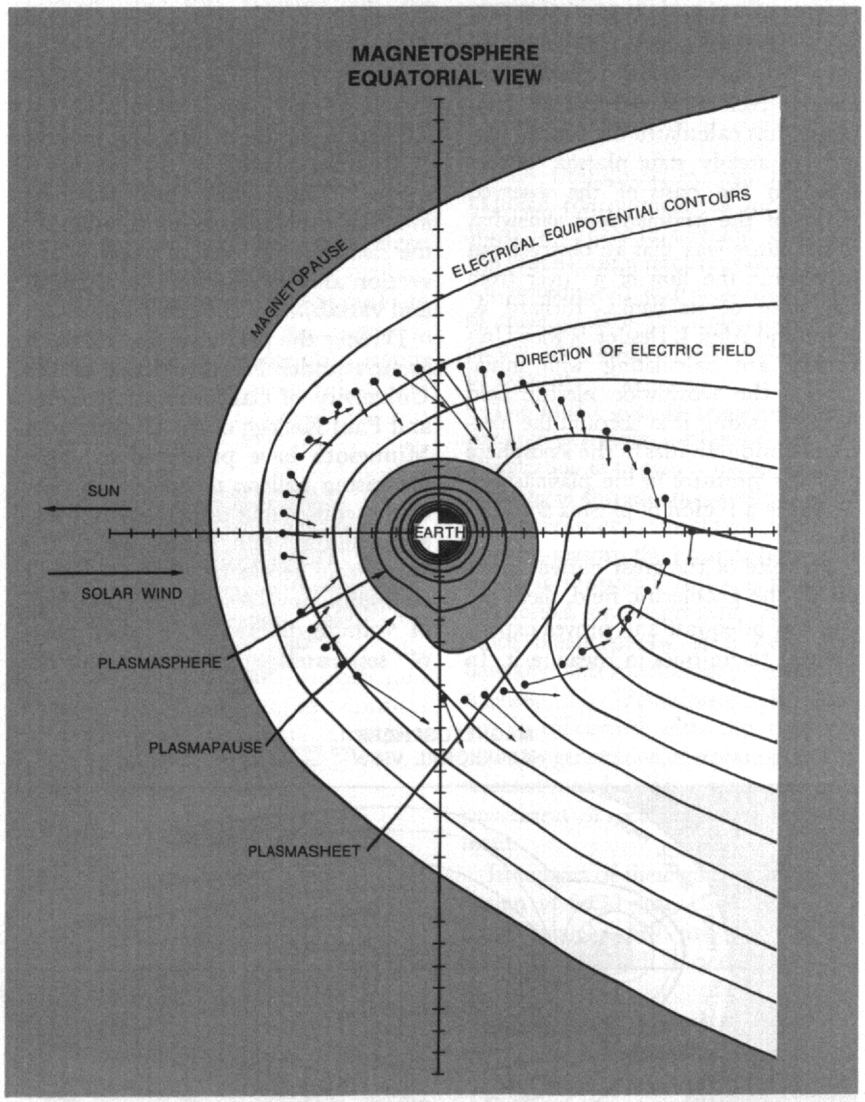
The possibility of the reverse coupling, that is an influence of ionospheric and magnetospheric phenomena on the meteorology of the lower atmosphere, is still one of the most important and most controversial problems of aeronomy. Theoretically, no adequate mechanism has yet been proposed which would support the energetics of such coupling. Further careful interdisciplinary research to explore these problems is underway.

Solar-Terrestrial Research

After a decade of important and spectacular discoveries on the structure of the earth's space environment, the steady-state solar-terrestrial space has become relatively well known; but its fundamental origin, its dynamic behavior particularly under disturbed conditions, and the strong interactions between its many varied phenomena have only just begun to yield to increasingly detailed and quantitative investigations leading to the development of unifying concepts.

Until recently, all geophysical disturbances associated with solar flares were presented in terms of an average disturbance called a magnetic storm which was thought to be the direct result of the interaction between the particle flow from the sun known as the solar wind and the magnetic field of the earth. Syun I. Akasofu at the University of Alaska contested this idea and showed that while general features of the storm were clearly attributable to solar wind interaction, the large temporal structure within the storm was not the result of a corresponding variability in the solar wind. Instead, Dr. Akasofu suggested that these recurrent disturbances are a fundamental mode of behavior of the magnetosphere itself which takes place when energy that has accumulated in the earth's magnetosphere reaches a certain level and is released abruptly in the form of a phenomenon called a magnetospheric substorm. The recurrent period of this dramatic release of energy appears to be 3 to 4 hours, while the magnetic storm itself may last several tens of hours.

After the formulation of the initial concept, different groups studied the various manifestations of the magnetospheric substorm and contributed greatly to the validation of this unifying concept. George Parks and his coworkers at the University of Minnesota and the University of California at Berkeley, and Neil Brice at Cornell University have shown that the puzzling, large-scale distribution of particle populations in the magnetosphere become more understandable when viewed in the context of a magnetospheric storm. Robert A. Helliwell and Donald L. Carpenter have revealed a redistribution of the plasma flow toward and around the earth during a substorm. Also, Warren D. Cummings and Paul J. Coleman of the University of California at Los Angeles have actually observed the magnetic effects of a magnetospheric substorm through simultaneous measurements of the geomagnetic field at the ATS–1 geo-



The magnetosphere and plasmasphere represent 3-dimensional distributions of magnetic and electric lines of force in space around the earth. The surfaces where these fields come to an end are called the magnetopause and the plasmapause.

synchronous satellite and at a location in the Northwest Territories, Canada, which is on the same magnetic field line as the satellite.

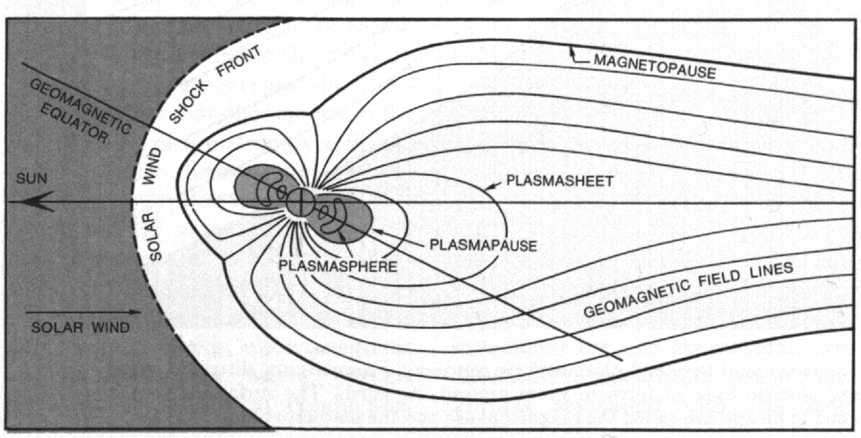
Unlike the concept of the magnetospheric substorm which was almost wholly empirical in its beginnings, the concept of the existence of a large electric field across the magnetosphere was almost, and to a great extent still is, the result of theoretical reasoning. During the past 3 years, the tempo of research on theoretical models of magnetospheric plasma convection (and, by implication, the geoelectric field) has increased considerably and has become more quantitative. Lately, Neil Brice of Cornell University has calculated the general pattern of steady state plasma convection, on the basis of the observed shape of the plasmapause somewhat in the same way that an observer can determine the flow of a river from the state of its banks. Richard A. Wolf and Alex J. Dessler of Rice University are calculating with initial success the worldwide electric field pattern taking into account the electrical conductivities in the ionosphere and the pressure in the plasmasheet, which is a region of plasma accumulation.

In spite of the great current interest in the geoelectric field, there are still few adequate and proven experimental techniques to measure it. In space, the great experimental difficulties associated with the measurements of these very weak fields or slow plasma motions have limited the experimental effort to tests of techniques. So far, ground-based techniques, although they measure the electric field indirectly, have provided the only data to guide the effort of the theoreticians.

Drs. Helliwell and Carpenter of Stanford University have developed a ground-based technique of recording broadband whistler signals, of a type commonly heard on shortwave radio. These signals "fingerprint" the electromagnetic medium through which they pass, and in so doing, provide information on the density and motion of thermal plasma in the magnetosphere. Their work has provided much of the available information on the radial component of plasma convection and hence about the strength and variability of the geoelectric field.

During the past year, the research groups under Forrest Mozer of the University of California at Berkeley and Paul Kellogg of the University of Minnesota have pioneered a highly promising balloon technique, in view of the continuing difficulties of rocket-borne detection, for measuring the large-scale geoelectric field. This new technique involves the measurement of voltage differences between pairs of separated spherical conductors flown on balloons. Preliminary tests of the technique and theoretical calculations indicate that magnetospheric electric fields map down to balloon altitudes without attenuation, and that the weather associated electric fields should not perturb the measurements. The accompanying figures show the results of about 50 hours of balloon electric field data. The good agreement of these results with theory and with the results of Dr. Carpenter offer the promise of a low-cost method of measuring the large-scale electric field of the earth for various degrees of geophysical activity.

MAGNETOSPHERE
MERIDIONAL VIEW



Coordination of the 1970 Solar Eclipse Program

On March 7, 1970, a total eclipse of the sun will occur across the Pacific Ocean, southern Mexico, the Gulf of Mexico, the eastern seaboard of the United States, the maritime provinces of Canada, and finally the North Atlantic Ocean. The eclipse will be seen from 16 to 19 hours, U.T. (universal time)—or 11 to 14 hours eastern standard time—and will produce a maximum totality on the ground of about 3.5 minutes. Solar eclipses offer a splendid opportunity to study not only the solar corona which is the ultimate source of geomagnetic disturbances, but also the magnetospheric and atmospheric processes which are dependent on the presence of particulate and electromagnetic radiations from the sun. Unlike the normal twilight transition in which illumination of the atmosphere recedes gradually, a solar eclipse results in a relatively sudden removal of sunlight from a fully illuminated atmosphere. Consequently, daytime conditions change rapidly to nighttime conditions, and the response of the atmosphere can be studied without the complexity of phenomena occurring during a normal twilight period. Chemical and ionic changes with reaction times of 2 or 3 minutes should be observable.

The proximity of the eclipse path in the United States to large centers of population, universities, astronomical observatories, ionospheric laboratories and major rocket ranges has generated much scientific and popular interest. Already U.S. and foreign scientists have initiated plans for approximately 250 experiments related to the eclipse. These involve optical and radio measurements from stations along the eclipse path, about 50 rocket launchings from Florida, Virginia, and Nova Scotia, and seven research jet aircraft flying along the path of the eclipse.

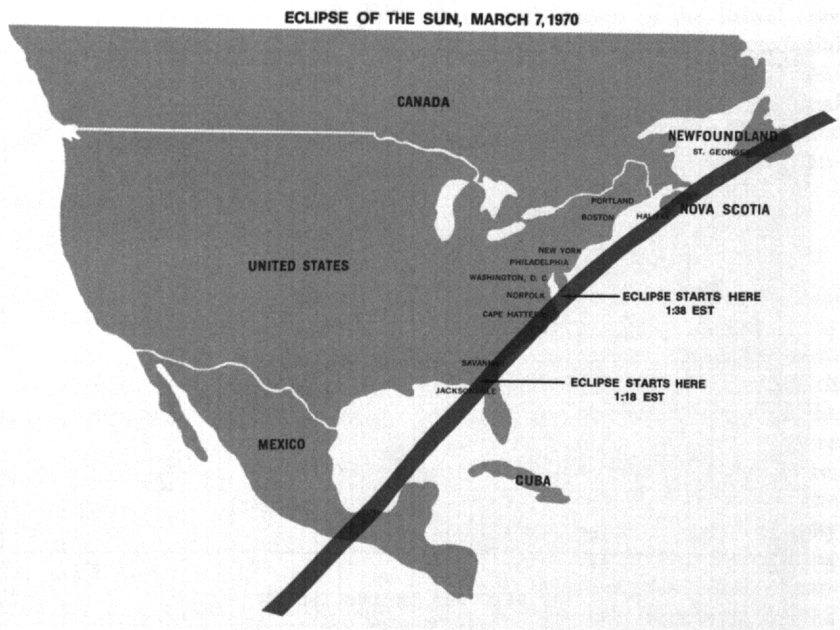
Recognizing the need for coordination of this large scientific undertaking, the Office of Science and Technology of the Executive Office of the President designated the National Science Foundation as the U.S. agency responsible for coordinating Federal activities related to the 1970 eclipse.

A series of "Solar Eclipse '70" bulletins was initiated in July to provide information on the progress of scientific and logistic plans, to present the results of various surveys of the eclipse circumstances, and to provide a forum for discussions of interactions among eclipse experiments.

An inter-agency coordinating panel for the 1970 solar eclipse was organized in October. This panel has been very effective in establishing strong lines of communications and cooperation among the 11 Federal agencies involved in the solar eclipse program.

As fiscal year 1969 ended, it appeared that 30 percent of the planned experiments would be concerned with optical and radio observations of the sun, 60 percent would be concerned with the response of the ionosphere to the sudden removal of solar radiation, and the remaining 10 percent would be directed to meteorological and magnetic phenomena associated with the eclipse.

The meteorological conditions are expected to be most favorable in southern Mexico; therefore, most of the optical experiments and a majority of the foreign expeditions will be based there. The remaining experiments will be conducted in the United States, principally in southeastern Virginia, eastern North Carolina, and Florida. A few experiments, principally the Canadian rocket launches, will take place in Nova Scotia. As a result of these coordinated efforts, the most comprehensive set of solar, ionospheric, and atmospheric measurements ever made during a solar eclipse will be developed. The next opportunity to study a major eclipse in the United States is predicted by astronomers for the year 2186.



Path of the total solar eclipse of March 7, 1970. Between the parallel lines the sun will be totally eclipsed. The sun will appear to be partially eclipsed from any point in the continental United States. Areas closer to the path of totality will see more of the sun obscured.

Oceanography

The United States has made a national commitment to move forward in efforts to develop and use the vast national resources of the sea. An impediment to the achievement of these goals is the imperfect state of our knowledge of the ocean and its contents.

The broad goal of oceanographic research activities supported by the Foundation is to gain a better understanding of the sea and all the objects and phenomena associated with it. For this reason, the Foundation continues to support a full spectrum of meritorious oceanographic research. Since oceanography is a new and basically interdisciplinary area of science, the Foundation is also deeply concerned with the training of a new generation of oceanographic scientists, and with continued improvement of oceanographic equipment.

In support of these goals, the Foundation in fiscal year 1969 obligated approximately $19 million in 280 grants for research in oceanography.

National Ocean Sediment Coring Program

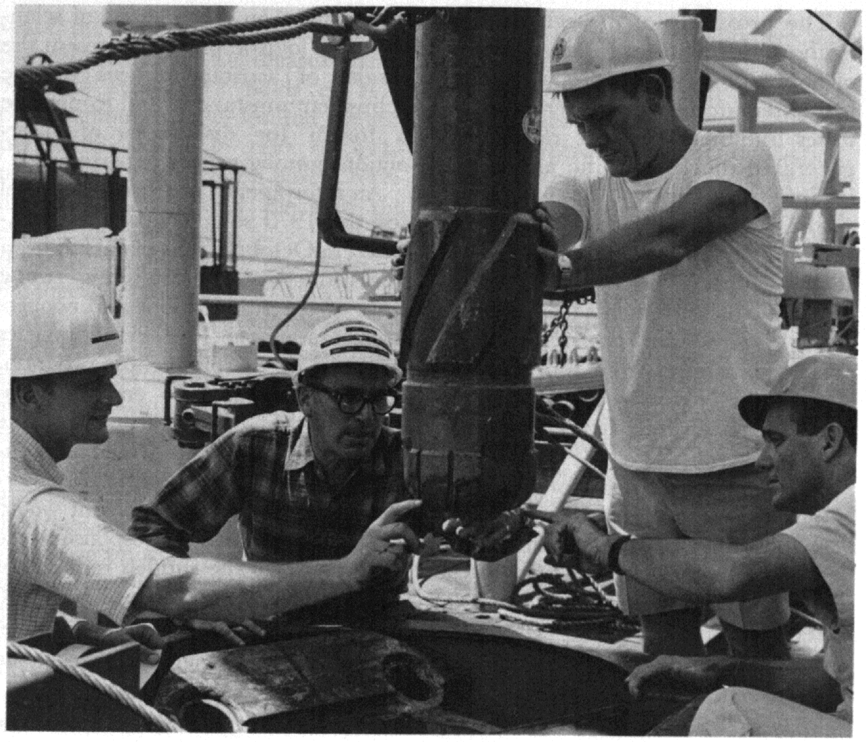
Drilling operations conducted aboard the vessel *Glomar Challenger* were started in mid-August of 1968.

The first several months of drilling and coring in the deep oceans have strongly confirmed the technological feasibility and scientific value of this program, and the finding of petroleum in very deep waters in the Gulf of Mexico within the first few weeks of operation is indicative of the significant economic and industrial implications of the work.

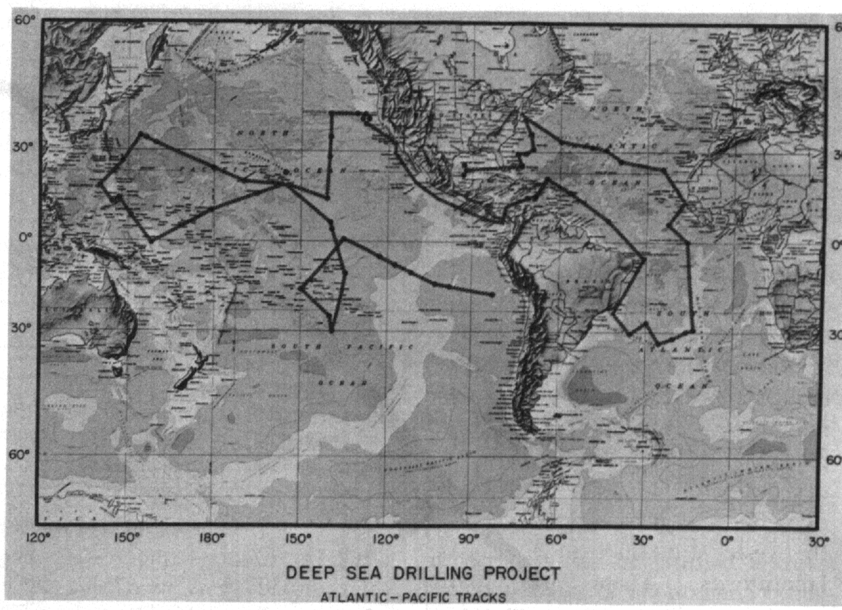
By the end of fiscal year 1969, the drilling vessel had completed the first four 2-month traverses across the North and South Atlantic, with holes drilled also in the Gulf of Mexico and the Caribbean Sea, and had entered the Pacific and completed one and a half of five planned traverses. The results immediately available from a shipboard examination of the cores have already provided additional support to the hypothesis of seafloor spreading, which postulates the continuous formation of submarine crustal rock along the mid-oceanic ridges and its lateral spreading apart of the ocean floor.

In addition to the body of evidence supporting the seafloor spreading hypothesis, other significant discoveries include: the confirmation that the mid-Gulf mounds, in which the surprising finding of oil occurred, are indeed salt domes such as occur on the continental shelves; the recovery of sediments of Jurassic age, older than any previously taken from a deep ocean basin; the finding of much more extensive turbidite (mudflow-like) deposits in most parts of the Atlantic than heretofore thought probable; identification of extensive layers of chert, a flint-like rock, among the deep ocean sediments; evidence of a rate of sedimentation up to 1 foot per 250 years far out into the deep Atlantic from the mouth of the Amazon; and indications that the hilly topography of the northeastern Pacific is a result of extrusive activity prior to the deposition of a thin sediment cover upon the seafloor.

These scientific discoveries result from the technological feat of coring much further into the ocean floor



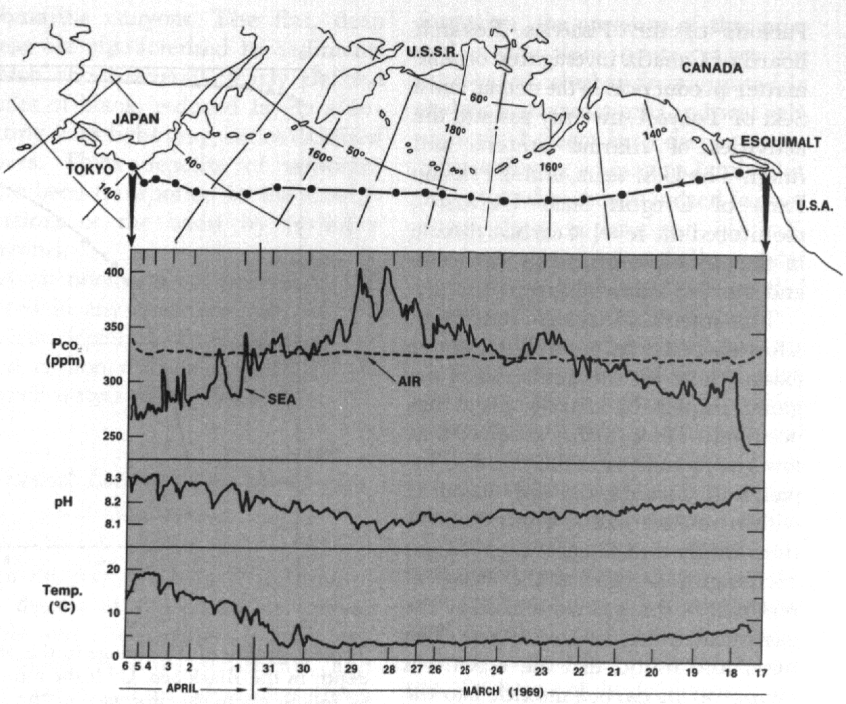
Inspection of a tungsten drill bit by a group of deep sea drilling project officials aboard the *Glomar Challenger* during acceptance trials in the Gulf of Mexico. At some drill sites, bits such as these penetrated the ocean floor 2,500 feet for sedimentary material. (Scripps Institution of Oceanography photo)



The Atlantic and Pacific Tracks of the deep sea drilling project, showing the route covered by the research vessel *Glomar Challenger* during fiscal year 1969. (Scripps Institution of Oceanography photo) beneath deeper water than ever before attempted. The penetration is accomplished by dynamic positioning of the vessel, unanchored, over the drill sites for several days until the task is completed. Dynamic positioning uses a computerized system of pulses from acoustic beacons on the ocean floor that are picked up by a ship-mounted hydrophone array, fed into a computer, and translated into corrective action by propulsion units which automatically keep the ship on station.

A basic core description is being prepared for materials secured during each traverse. The core description is designed to provide enough information for subsequent investigators to recognize and define research programs, and permit specific sample qualities and provides information selections without waste of time or material. Also, the preliminary analysis measures important perishables essential to the objectives of many investigators which they cannot, without duplication and waste of effort, provide themselves. The last aspect is particularly important because it permits participation of investigators with limited resources to do research on the samples to follow.

The preliminary core description includes basic biostratigraphic assignments, photographic and descriptive records, core deformation determinations by X-radiography, textural and compositional descriptions, information on density and consolidation, natural gamma radiation and gamma-ray attenuation, thermoconductivity, carbon and carbonate content, X-ray mineralogy, interstitial water, and paleomagnetism. The initial core descriptions result from the cooperative efforts of many scientists aboard the vessel and later in shore-based laboratories. These participating scientists, as those serving on the advisory planning panels, are drawn from institutions and organizations throughout the country and abroad.



Observations of the levels of carbon dioxide in the sea and in the atmosphere made by an international oceanographic team early in 1969. Notice low levels of carbon dioxide near shores where marine plant production is taking place, and higher levels near Aleutian Islands, where ocean is giving up carbon dioxide to the atmosphere. (After Park, et al.)

After publication of the initial core descriptions, samples of the material will be available to qualified scientists who request them for individual research projects, regardless of prior participation in any phase of the planning or operations.

Carbon Dioxide in the Oceans

The oceans act as a sink for excess carbon dioxide that is produced by human civilization. Studies in recent years show that the oceans, which cover more than 70 percent of the earth's surface, contain 50 times more carbon dioxide than the atmosphere. Recently, C. David Keeling of the Scripps Institution of Oceanography and his coworkers found that during 1959–63 the atmospheric level of carbon dioxide was increasing by 0.2 percent a year. If the same rate of increase prevails, and if the oceans are not capable of absorbing the excess gas quickly enough, adverse climatic changes could occur.

The mechanism of absorption of the atmospheric carbon dioxide by the oceans is complicated by many oceanic processes. For instance, when deep seawater, which is rich in carbon dioxide, surfaces, the oceans give off their extra carbon dioxide into the atmosphere. Therefore, during the period of vertical mixing, generally in winter months, the oceans do not absorb carbon dioxide. In another example, when small plant blooms occur near the sea surface, the demand for carbon dioxide becomes intensified, for the plants need the gas to produce organic matter. At such times, carbon dioxide may be absorbed into the ocean from the atmosphere.

To study these and other processes, an international scientific team from Canada, Japan, and the United States collaborated in joint oceanographic studies in the North Pacific during March and April 1969. Timothy R.

Parsons of the Fisheries Research Board of Canada investigated organic matter production in the ocean. Fumi Seki of Tokyo University assessed the activities of marine bacteria and fungi. The U.S. team, under P. Kilho Park of Oregon State University, monitored the level of carbon dioxide in the atmosphere and in the ocean and studied other chemical matters.

This international team found that a low carbon dioxide level in seawater exists where recent production of organic matter by marine plants has occurred. They further observed that low gas regions, near the coasts of Japan and Canada, did not disappear within several weeks. Their observations imply that either the air-sea gas exchange is sluggish or the biological removal of the gas is matched by the gas input from the atmosphere. The team also found that the ocean was giving off its carbon dioxide into the atmosphere near the Aleutian Islands as indicated in the following figure.

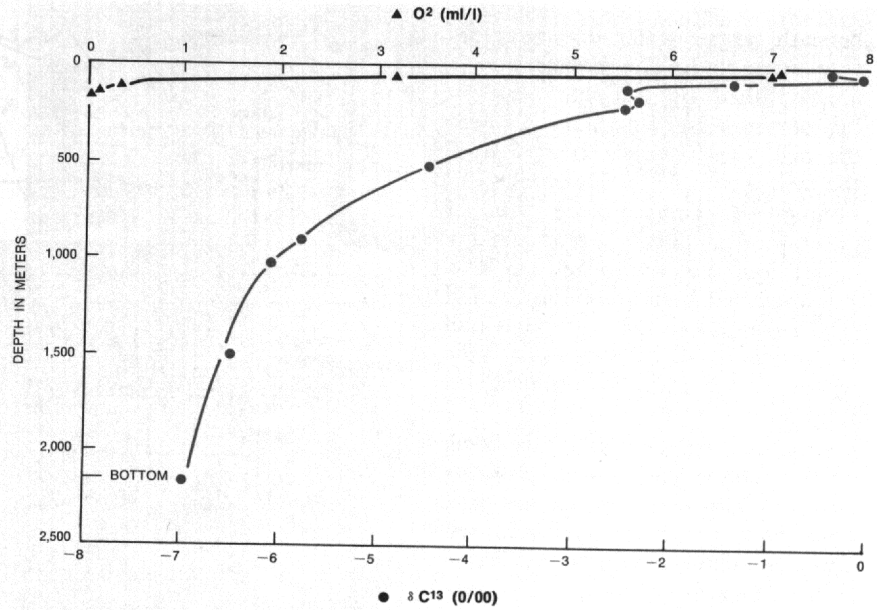
This work demonstrates that the rate of carbon dioxide absorption by the ocean is governed by the physical (current and mixing) and biological (organic matter production) processes occurring in the oceans. With the ever-increasing production of carbon dioxide by the human society, we urgently need to know the mechanisms by which the oceans absorb carbon dioxide.

1969 Black Sea Expedition

A study of the waters, bottom sediment and underlying geologic structure of the Black Sea was made by the Woods Hole Oceanographic Institution under sponsorship of the National Science Foundation.

The investigation was carried out aboard *Atlantis II,* a Woods Hole research vessel, with John Hunt as chief scientist.

In addition to Woods Hole personnel, scientists from seven universities and seven research organizations participated in the cruise. Included in the party were four Turkish and three



Typical profile of the change in the proportion of C^{13} of dissolved inorganic carbon with depth in the Black Sea. C^{13} is the minor stable isotope of carbon and its changes are used to follow chemical processes in the ocean. The decrease in C^{13} indicates that carbon dioxide is being formed in the Black Sea from the bacterial degradation of organic matter. This process has not been observed in open oceans such as the Atlantic and Pacific. (After Hunt et al.)

Russian scientists. Other foreign countries represented were West Germany, Italy, and Sweden.

Atlantis II was the first U.S. oceanographic research vessel ever to call at the Black Sea ports of Novorossiysk and Yalta. The vessel also called at Istanbul where an open house was arranged for teachers from Turkish schools and universities, for local embassy staff, and for the press.

During the 7-week period between March 16 and May 7, 1969, over 50 stations were occupied at which more than 1,000 water samples and about 60 cores of various types were obtained. Continuous geophysical profiling was made over most of the cruise track to define sediment layers in the Black Sea basin and geologic structure in the earth's crust beneath the sea.

Although some of the data collected during the cruise are still being processed, much important information has been learned concerning the geochemistry and geophysics of the Black Sea basin and its waters. For example, a large concentration of particulate matter, several meters thick, was discovered in the water column at the oxygen-hydrogen sulfide interface. The interface ranges from 75 to 250 meters in depth, the deeper portion being along the continental margin. The particles seem to be composed of iron and manganese and probably represent an extremely high concentration of these heavy metals throughout the Black Sea. Hydrogen sulfide concentrations in the deeper parts of the Black Sea were found to be twice the values previously reported by Russian scientists.

Continuous seismic profiling penetrated to depths of 2 kilometers into the Black Sea basin and showed that portions of the Caucasus Mountains plunge beneath the northeastern section of the basin. The center of the sea is flat and is surrounded by narrow continental slopes cut in places by submarine canyons. The flat, deep areas are characterized by sediments which show several clearly defined cycles of black, reduced layers alternating with light gray, more oxidized layers. Thick deposits of sediment have been transported to the eastern portions of the basin by turbidity currents.

A phenomenon not previously observed in any other sea was the systematic depletion of carbon-13 in the total carbon dioxide content in the deeper waters of the Black Sea.

Mineral Discovery in Deep Sea Sediments

In the past, we tended to think of the depths of the ocean as forever stable and unchanging—a final resting place for ships, sediments, and other solids. This view has been altered as evidence of various types has been developed which indicates that ocean floors are in motion and are far from quiescent. New evidence of ocean floor change has been discovered by Enrico Bonatti and Oiva Joensuu of the University of Miami Institute of Marine Sciences who reported the only known occurrence of palygorskite in deep sea sediments. The mineral was identified during routine analysis of sediment cores taken by the university's *R/V Pillsbury* from 5,000-meter water depth in the Barracuda Escarpment area of the western tropical Atlantic.

Basically, palygorskite is a clay-mineral composed predominantly of silicon, aluminum, iron and magnesium oxides. Palygorskite is normally formed in fresh water and lagoonal sediments or in shallow marine environments as a result of the action of magnesium-rich solutions on terrigenous clays. Palygorskite also forms when hot water or steam come into contact with igneous rocks such as basalt.

Considering the possible modes of formation, the presence of this mineral in the deep ocean raises the question of whether it originated in shallow water sediments and was subsequently brought into deeper water by slumping or submarine landslides, or whether the mineral indeed formed at great depth in the ocean. No indication was found for a shallow water origin so that some proof was needed to account for on-site formation.

The conditions necessary for the formation of palygorskite in such areas require magnesium-rich solutions in contact with parent material such as montmorillonite clays. Even though montmorillonite is common in deep sea sediments, magnesium-rich solutions are not present under normal conditions. Examination of the geological conditions in the sampling area, however, gave clues that palygorskite could have formed at that site. Evidence of hydrothermal activity was obtained at a location only a few miles from the coring site. Fragments of basalt were recovered which had been strongly altered hydrothermally. Apparently hot water and magnesium-rich solutions issue from fractures in the ocean's floor adjacent to the Barracuda Escarpment and come into contact with sediment, thereby transforming the clayey constituents into palygorskite.

The discovery is significant in that it provides evidence that the chemical composition of sedimentary deposits is subject to change, even at great depths, and also provides a mechanism for such changes.

Specialized Oceanographic Research Facilities

In the 1950's the oceanographic research fleet, operated by universities and private laboratories and supported by the National Science Foundation, consisted of less than 20 vessels which had been obtained from various sources and which were only partially adapted to the needs of the oceanographers using them. Since 1960, this fleet has been systematically upgraded to the present fleet of 32 vessels at 17 institutions. This upgrading has been accomplished through the construction of new vessels, the conversion of other vessels and the improvement and modifications of those already in the fleet whenever this was practical. Only three of the vessels currently supported by NSF were part of the fleet prior to 1959. Of the 29 additional vessels, NSF financed the construction of six new vessels and 10 conversions.

In the same period, NSF has also supported the construction of new shore laboratories and piers and related buildings that were equally essential to the modernization of oceanographic research.

During fiscal years 1960–68, NSF has provided approximately $35 million to some 20 U.S. institutions with about $15 million going into fleet improvement, about $15 million toward the construction of shore laboratory facilities, and about $5 million for piers and related buildings.

In fiscal year 1969 NSF funds committed to oceanographic facilities totaled $1.4 million. The entire sum was awarded to the Institute of Marine Sciences of the University of Miami toward the cost of constructing a new research vessel. The new vessel, which will be approximately 165 feet long, has the following advantages: (1) it can be operated with a smaller crew than comparable length vessels of conventional design, thus reducing the annual operating costs; (2) its large open deck can be used for portable laboratory units and other modular gear arrays, thus increasing the scientific capabilities of the vessel and facilitating the "turn around" between cruises; and (3) its hull design takes advantage of existing production techniques in stock hulls, thus reducing basic construction costs.

Earth Sciences

The Foundation's role in the earth sciences is to keep active the vigorous pursuit of knowledge on fundamental concepts and processes relevant to the solid earth. In recent years there has been a marked increase in the number of students going into geological fields in the universities. As an example, the number of geophysicists in the colleges and universities increased by 60 percent between 1961 and 1966. The Foundation continues to be the primary source of funds for most geologic research done by academic scientists. To this end, the earth sciences—geology, geophysics, and geochemistry—are currently supported in fiscal year 1969 in approximately 200 research projects at a level of about $8 million.

Modern Processes as a Key to the Geologic Past

Many of the processes of nature that affect the earth's surface today are known to have been active in the geologic past, and the investigation of modern environments is receiving increasing attention as a basis for unraveling earth history. To develop criteria for deciphering the ancient sedimentary rock record, geologists are investigating modern environments where physical, chemical, and biological conditions can be monitored and where the sediment record of processes operating in the immediate past can be interpreted readily. For example, Robert Ginsburg and his research associates of Johns Hopkins University are investigating modern tidal flats in a tropical marine environment where sedimentary features so prevalent in some of the earliest sedimentary rocks in the geologic record are known to be forming today. The study area, one of carbonate deposition, was chosen not only because the conditions responsible for certain sedimentary features could be directly observed, but also because tidal flat processes have been a major contributor to the sedimentary record throughout geologic time. Carbonate rocks are, of course, important reservoirs for water and oil accumulation.

The research has concentrated on one very common, but poorly understood, kind of sedimentary layering—the extremely thin layering in lime muds (each layer or lamination about one millimeter thick). Such thinly

FIGURES

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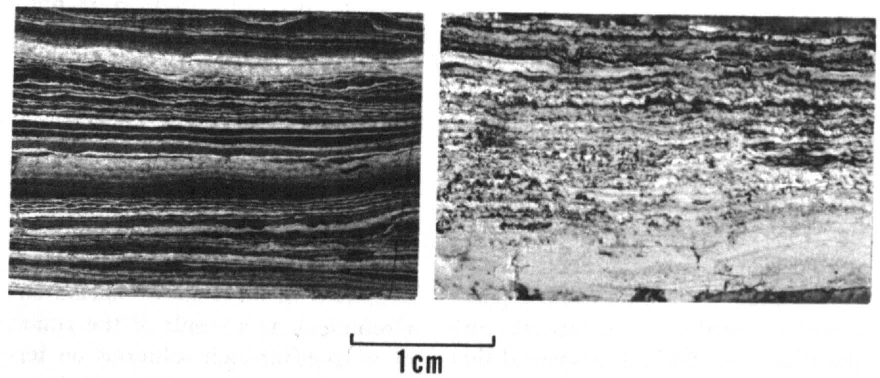
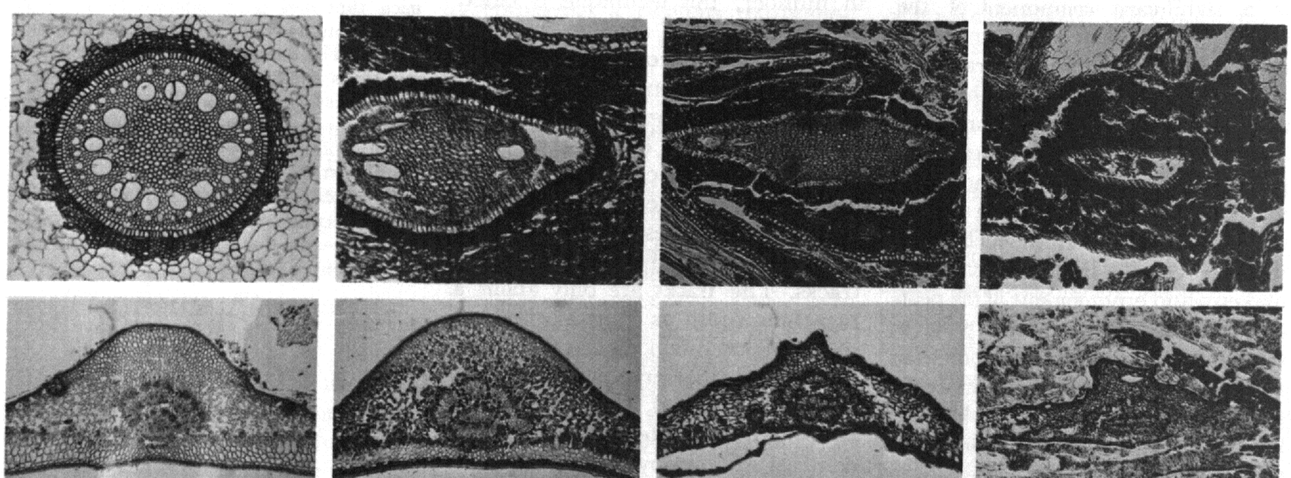


Comparison of ancient laminated carbonate rocks with modern laminated sediments. The photo on the left shows 450-million-year-old limestone from Maryland; the photograph on the right is of lime-mud layers forming today on tidal creek levee, Andros Island, Bahamas. Each lime-mud layer represents sediment deposited during storm-flooding of tidal flats. (Johns Hopkins University photo) layered rocks ("laminites") are typical of ancient tidal flat deposits and are quite remarkable for the very small range in thickness of the individual laminations. The obvious explanation for this uniformity is that the sedimentary events recorded in the laminations are all of about the same magnitude. Some periodicity seems also to be implied. To try to find out just what kind of information is stored in one lamination, or thin layer of lime mud, the Johns Hopkins investigators have been studying the mode and rate of deposition of layers which are being produced today on the modern carbonate tidal flats of Andros Island, Bahamas. A red pigment was placed on the sediment surface in different parts of the higher tidal flats to provide a precise time horizon from which to judge the rate of deposition of sediment. Flooding of the higher tidal-flat areas by sediment-charged seawater occurred infrequently, but after the season's first major cold front brought strong and persistent onshore storm winds to Andros Island, it was found that sediment has been smeared over large areas of the flats, making a single layer or lamination 1 to 2 millimeters thick.

Clearly then, on Andros Island a lamination is a "storm-layer" and the vertical succession of laminations preserved in the tidal-flat sediments is a record of the succession of major onshore storms that have battered the west side of Andros Island in the last several hundred years. But why is each lamination of relatively uniform thickness? Since storms come in a wide range of intensity and duration, one would expect to see a spectrum of lamination thickness. If a cold front "norther" can leave a sediment layer a few millimeters thick, then a tropical hurricane should produce a layer a few tens of millimeters thick. However, the range in lamination thickness was actually found to be surprisingly small, a little less than 1 millimeter to a maximum of 3 millimeters. It was concluded, therefore, that lamination thickness is not determined by storm intensity, but that some other factor is in control. Further careful investigation showed that the entire surface of the tidal flats is covered by an almost invisible organic film, a slime of algae and micro-organisms. This slime acts like "flypaper" capturing (and holding fast) sediment suspended in floodwaters streaming over the tidal-flat surface. Once this flypaper is choked with sediment, it no longer acts as a trap. Regardless, then, of the amount of sediment passed over the flypaper only one thin lamination can be formed during storm flooding. For the recent laminites of Andros Island the remarkable uniformity of lamination thickness does not, therefore, reflect uniformity (or regularity) in the physical processes of deposition. Instead, the lamination is organic, reflecting the action of films of slime that impose on the record a sameness and regularity where none really exists. Regularly banded, finely laminated ancient limestones therefore cannot be interpreted as having formed necessarily in a quiet water environment; they may well have formed in turbid waters.

Another NSF study is aimed at learning how ancient coal beds formed. It has long been known that



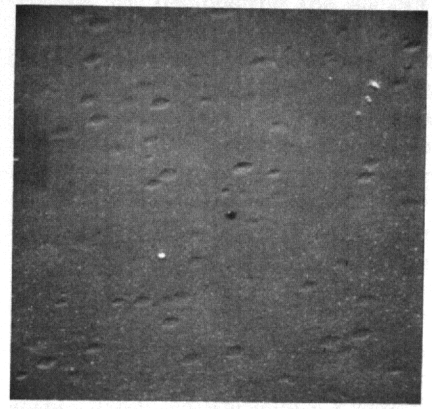
These two sequences of photographs show how plant material is drastically converted as it changes to peat, and illustrates how careful microscopic study of altered debris can serve to identify the original plant material. The most highly altered material (furthest right) is 1,500 to 2,000 years old. The upper sequence is a cross section through a stem of saw grass, the lower sequence of the midvein of a red mangrove leaf. (Pennsylvania State University photo) coal forms from peats, which in turn are derived from plants and other vegetation. But how is vegetation converted into the hard coal we know today? Why are some coals different from others? To better understand the processes involved in coal formation, William Spackman and his associates at The Pennsylvania State University are making a detailed investigation of the relation of plants, animals, and sediments of modern swamp environments of southern Florida where peat is actively forming today, and are carefully examining differences in the peats of successively older age. Laboratory investigations involving microscopic study of thin slices of specially stained peat specimens have revealed significant details of the coal-forming process, particularly as related to the breakdown of once easily recognizable plant materials to obscure constituents of the peats now in the early stages of conversion to coal.

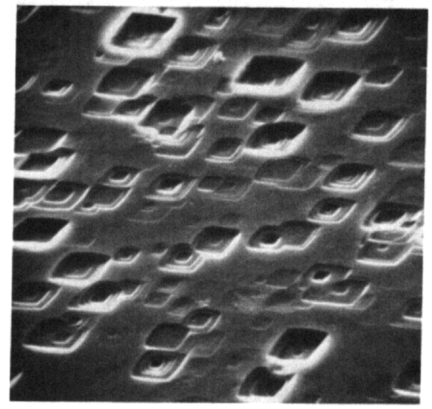
These studies in effect have resulted in the "fingerprinting" of plant materials whose original identity has been profoundly altered. Another important result of the research was the discovery of a "water lily" peat as a significant component of the layers of mud, plant debris, and other sediments. This discovery drastically affects the interpretation of the original environment of the region in the recent past, indicating far greater expanses of open freshwater and dominance of aquatic plants in the swamps than originally believed. Such attention to details in the microscopic makeup and environment of the peats and associated sediments provides vital clues concerning the formation and characteristics of ancient coals, and most importantly, their different botanical and chemical characteristics.

Improved Geologic Dating Technique

Until recently, geologists, geochemists and geophysicists were unable to determine the age of extremely old rocks to an accuracy of about 10 percent. One of the techniques used involved the counting of radiation damage tracks produced by the spontaneous fission of radioactive materials in rocks, chiefly uranium-238. Heavy atomic particles are emitted during fission, and they travel short distances in the solid, colliding with existing structures, and tearing them up. When etched in a solution, the tracks can be observed and counted under an ordinary light microscope. Since the number of tracks is proportional to the original amount of radioactive material in the rock, the age of the material can be calculated from the number of tracks, after determining the original amount of radioactive material from the amount of radioactive material now present.

A new radiation damage technique for geologic and other dating is now under development at Washington University, St. Louis, under the direction of Robert M. Walker and his colleagues. The technique promises to increase the sensitivity of dating geologic and other materials by a factor of about three thousand. Instead of relying on the tracks of heavy particles, which are comparatively few in number, this technique is based on the radiation damage in solids caused by the recoil of the nucleus when the lighter, but more numerous, alpha particles are emitted. Alpha particles are not heavy enough to register tracks directly, but with each alpha emission, the emitting nucleus recoils a little. These recoil nuclei are much heavier and leave permanent tracks. The tracks are only about a two-thousandth as long as those of spontaneous fission, hence they were previously unobserved or unrecognized when etched. They were found by using the latest techniques in phase contrast microscopy and the electron microscope. Because the alpha recoil tracks are much more numerous than the fission tracks (about 2 million alpha tracks to one fission track), the chances of statistical error could be considerably diminished, and dating





Etched tracks in mica as seen with stereo scan electron microscope. ***Above:*** These extremely shallow ~100A° deep) pits were produced by etching a sample of mica that had been exposed to a radon emanation source. The radiation damage produced by the recoil nucleus accompanying alpha decay is responsible for the nucleation of the chemical attack. ***Below:*** These much deeper pits (~2000° deep) were produced by etching a sample of mica that had been irradiated with 30 Mev alpha particles. They result from heavy recoils produced in nuclear collisions between the alpha particles and the constituents of the mica.

of man-made objects and very old geological materials should be accomplished with much greater precision than has previously been possible. Because of the increase in statistical accuracy, the technique could also be used as an analytical tool to measure extremely small amounts of radioactive materials at levels much lower than can now be detected.

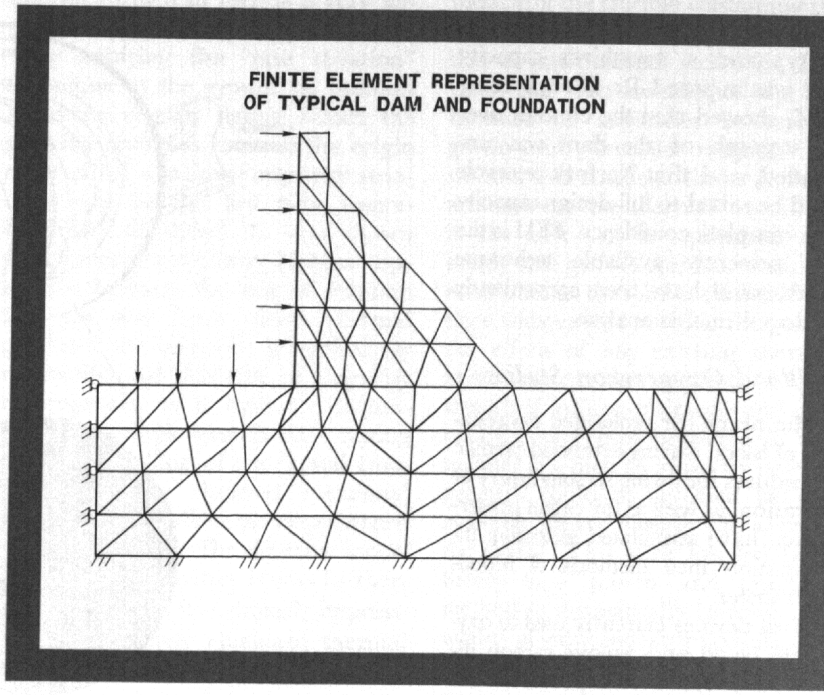
ENGINEERING

Engineering research supported by the Foundation has steadily broadened in scope over the past several years as well as increased in size. The current annual level of support consists of about 500 grants to 100 different schools of engineering, totaling nearly $20 million.

Initially, grants for research support by the Foundation were limited almost exclusively to the classical areas of engineering, mechanics of fluids and solids, thermodynamics, heat and mass transfer processes, electrical theory, and the nature and properties of materials. Although the major portion of current grants remains in these areas, the broadening spectrum of engineering activity is reflected in Foundation support of research in systems studies, operational analysis, computer techniques, earthquake engineering, and oceanographic engineering. Other special programs which have been and will continue to be supported include biomedical engineering, transportation, urban planning, and fire prevention.

The Finite Element Method

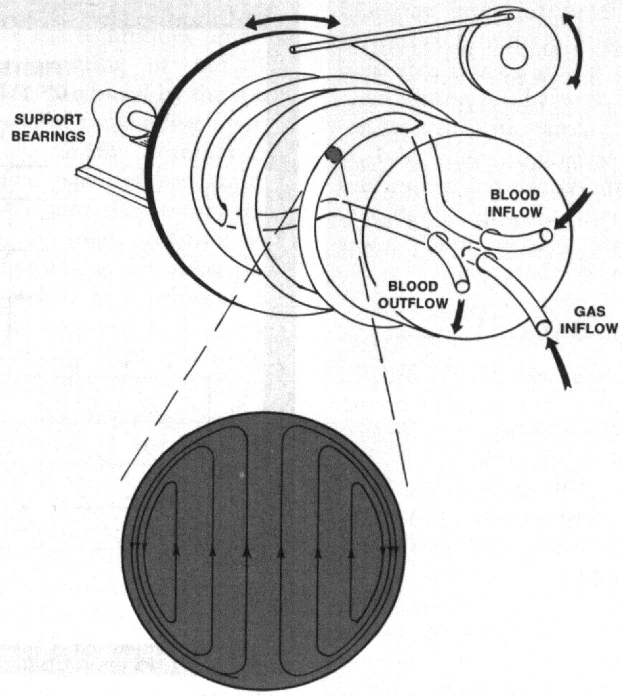
The engineer's dilemma is that he must produce a solution within restricted time limits and he is furthermore held responsible for the results produced by his analysis. In spite of years of development of mathematical techniques, many structural engineering problems defy exact solution because of their complexity. The Finite Element Method (FEM), a newly developed approximation technique, enables a structural engineer to simplify a complex system by dividing it into a finite number of pieces. He then analyzes this simplified system by employing a rigorous mathematical analysis. The FEM has advantages over previous methods because the finite elements can be changed to represent varying physical properties and discontinuities such as cracks at any location in the structure. Since the method requires the manipulation of large matrices, its application only became feasible with the advent of digital computers.



A Finite Element Method representation of a typical dam and foundation. By dividing large structures into a finite number of smaller pieces and studying them, an engineer can now analyze structures formerly considered too complex to be fully studied.

Consider the application of FEM to a structural system. The structure is first approximated by assuming it to be made up of a number of appropriately shaped pieces or elements of a manageable size. Fictitious forces representative of real distributed stresses acting on the element boundaries are assumed to be applied at points where the elements are joined, taking into account the elasticity of the materials involved. Stress and deformation of the elements are analyzed on the basis of the degree to which the material involved can be deformed by the forces in question. The elements used can be either two or three dimensional and large deformations and nonlinear properties can be dealt with.

The aircraft industry was the first to apply FEM. The method was further developed and introduced to civil engineering applications by R. Clough at Berkeley under a series of Foundation grants. With the refinements developed by Dr. Clough, his students, and more recent workers, FEM has became one of the most powerful tools of analysis available to structural engineers. One successful use of FEM was in the analysis of Norfork Dam. The dam, constructed from 1941 to 1944, developed serious cracks due to the release of heat during the curing of the concrete. Because of these cracks, there was serious concern about the strength of the dam, and doubt that the reservoir could ever be raised to design capacity; and a two-thirds capacity limit was imposed. Dr. Clough, using FEM, showed that the concern over the strength of the dam was unfounded, and that Norfork reservoir could be raised to full-design capacity with complete confidence. FEM is the only presently available technique which could have been conveniently employed in this analysis.



Schematic representation of coiled capilliary mixing apparatus for the oxygenation of blood, and detail of induced flow within the capillary. (After Drinker and Moss, et al.)

Blood Oxygenation Studies

The needs for prolonged oxygenation of blood during extended cardiac procedures following serious injury or operation, as well as for organ preservation, have stimulated extensive investigation into methods of blood-gas transfer.

Most devices currently used to oxygenate blood and remove carbon dioxide, act by direct exposure of the blood to gas. In these systems, large exchange surface areas are generated by filming the blood in direct contact with oxygen. Unfortunately, this method is damaging to cells and plasma proteins, hence, the major current applications of blood oxygenators are for the support of patients during temporary cardiopulmonary bypass.

A desire to overcome these problems has led to research into a technique which would avoid direct contact, such as would be possible through the use of synthetic gas-permeable membranes. The earliest membrane oxygenators, although they did demonstrate a reduction of blood damage and other unwanted physiological side effects, proved to be extremely inefficient in terms of gas exchange, and as a result, were of cumbersome design and unreliable in operation.

For the past 2 years, Philip A. Drinker, a physiologist at Harvard, and Richard A. Moss, an engineer at the Massachusetts Institute of Technology, have been working jointly in an effort to improve the rates of gas transfer of membrane type oxygenators. Their work led to a practical method of nontraumatically augmenting the rate of oxygen transfer by constructing the membrane in the form of a coiled capillary tube. The nature of the flow of the blood through the coil induces a mixing which increases the amount of blood which physically contacts the membrane. This method has direct application to the design of blood oxygenators which will permit prolonged periods of cardiopulmonary bypass.

Continuing research under this program involves two distinct areas of interest; analytical and experimental investigation of the fluid mechanics and transfer rates of the system, and experimental evaluation of the oxygenator performance. These two phases will be carried out concurrently, with close collaboration and interchange between the participating staff and students. The ultimate goal of the research is to establish the design parameters and range of potential applications for the oxygenator, and to design, build, and test an optimized real-life prototype system.

Distribution of Impurities in Semiconductors

Most of the current state of development in solid state electronics depends on the effects of impurities deliberately incorporated into semiconductor crystals. An increasing demand for these crystals has made the crystal-grower's art an important one, and scientists are now investigating the theoretical concepts behind the technology developed through experience. For instance, an important part of the incorporation of impurities is their uniform distribution. What factors in the physical process of growing the crystals affect this distribution?

The standard arrangement for the growth of semiconductor crystals consists of placing a seed crystal into a crucible containing a quantity of the semiconductor metal in the molten state. Atoms from the melt aggregate on the surface of the seed crystal, causing it to grow. In order to control the size of the resulting crystal, it is pulled slowly out of the melt, so that the deposition of new material takes place on one end only. Experience until recently showed that desired impurities were more evenly distributed in the crystal if the seed were rotated in the melt during the growth process.

Harry Gatos and August Witt of MIT have investigated the processes which takes place during the growth of crystals. As a result of their research, they have developed analytical techniques which cast considerable light on the growth processes, and furthermore, have grown the most homogeneous single crystals of indium-antimony and germanium ever prepared.

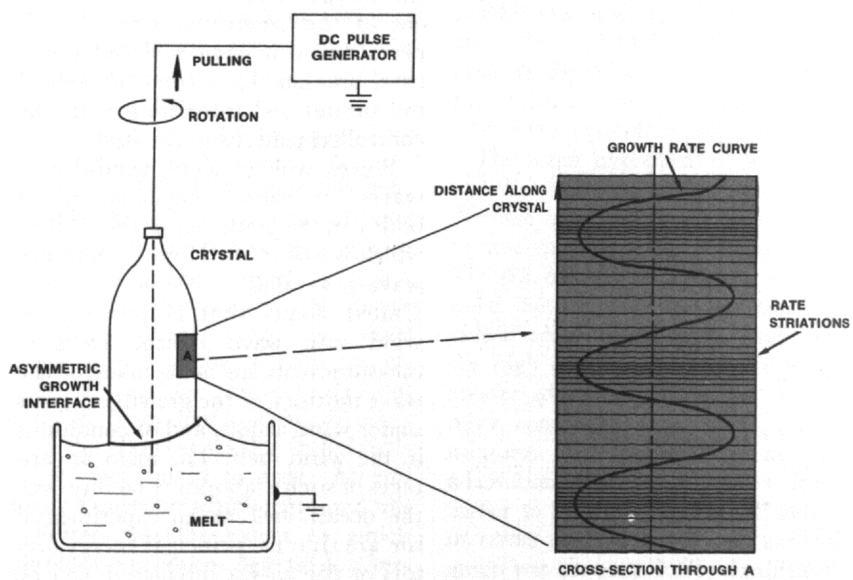
To do this, they first developed etching techniques by which physical heterogeneities, or variations due to impurities can readily be detected with a resolution of better than 0.2 microns—about 0.00008 of an inch. Heterogeneities caused by impurities can thus be revealed and studied with interference contrast microscopy. They have also developed a method which makes possible determination of the rate at which crystals grow from a melt of the parent semiconductor as well as determination of the structural characteristics of the interface between the melt and the crystal. The method is based on the introduction of vibrations of controlled frequency into the semiconductor melt during crystal growth. Such vibrations result in the formation of striations in the impurity growth of the crystal without affecting its overall solidification characteristics. Since Drs. Gatos and Witt can study these striations by their high resolution etching technique, they can determine precisely the growth rates and fluctuations in growth throughout the crystal from the known frequency of the vibrations. Such "rate striations" constitute further a continuous record of the morphology of the crystal-melt interface which in itself is a very important aspect of crystal growth.

By applying the "rate striation" technique to the growth of indium-antimony crystals during which the growing crystal is rotated, the origin of so called rotational impurity striations was for the first time unambiguously identified. It was shown that thermal asymmetry (lateral separation between the axis of rotation and the axis from which thermal gradients are uniform) is exclusively responsible for this type of impurity heterogeneity as it leads to fluctuations in periodic growth rate during rotational pulling of the crystal from the melt. The observed rotational striations thus reflect the dependence of growth rate on the effective incorporation of impurities. It was furthermore found that it is virtually impossible to completely eliminate thermal asymmetry and consequent formation of rotational impurity striations in standard crystal growth arrangements during which the seed crystal is rotated in the melt.

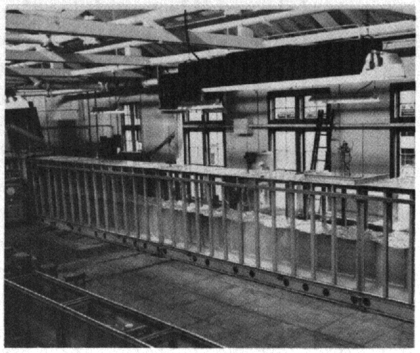
Accordingly, since it is known that rotation of the crucible containing the melt effectively eliminates the formation of nonrotational striations, Drs. Gatos and Witt investigated the distribution of impurities in crystals grown with crucible rotation but without seed rotation. Under such an arrangement the thermal conditions in the melt can be optimized and steady state growth conditions can be established at the solid-melt interface, since without seed rotation the potential effects of any existing thermal asymmetry are not realized. Single crystals of indium-antimony and germanium have been prepared in this manner in which no impurity heterogeneities could be detected by any available means outside the core of the crystal. This work has led from theory to a proven and practical method to dramatically improve the quality of semiconductor crystals, and should have a major impact on solid state electronics in the near future.

Wind Generated Waves

Although observations of the effect of the wind on water have been a



Schematic representation of the introduction of high frequency "rate striations" during semiconductor crystal growth. The rate of growth at any given moment can be determined from the separation of successive striations at a known frequency. (After Gatos and Witt.)



This 115-foot-long glass and steel tunnel at Stanford Universit is capable of simulating a wide variety of waves, with or without wind, allowing engineers to study the ways in which ocean waves are generated and the effects they have on manmade structures. (Stanford University photo)

natural part of man's heritage since he took to the seas, surprisingly little is known about the complex process by which wind makes waves. In view of the economic importance of waves on commerce and the public at large, techniques are needed to predict wave behavior more accurately.

En Yun Hsu and his colleagues, R. L. Street and B. Perry at Stanford University, are making a series of experiments and obtaining answers about many factors in the wave-generation process. Their work is being carried out in a 115-foot-long glass and steel channel which simulates a cross section of ocean. The channel is 6 feet high and 3 feet wide, and can accommodate up to 3 feet of water depth. A wave-generator plate, driven by a hydraulic piston, can be electronically set to simulate various existing sea conditions. A 30-horsepower centrifugal fan sucks wind through the tunnel and over the water at speeds up to 60 miles per hour. A "beach," made of stainless steel lathe shavings held in steel baskets, imitates the action of a real beach by dissipating and absorbing the energy of the waves as they pass out of the generating area. This is necessary to prevent reflected waves from breaking back from the end of the tunnel and interfering with the controlled patterns under study.

Waves without wind, wind-driven waves, or various combinations of both can be produced in the tunnel, which is one of the largest laboratory wave-generating devices in the United States that combines both wind and wave effects. Detailed measurements are being made of the wave motions, of the growth of waves under wind action, and of conditions in the wind itself. The main advantages of such a laboratory facility over the ocean itself as an experimental site are that the principal energy factors of the air-sea interaction can be controlled and the same conditions repeated over and over again in the laboratory.

In the 3 years that the Stanford facility has been in operation, significant experimental results have been produced that are currently being used by theoreticians to modify their models of wave generation. It was first shown that certain important statistical properties of ocean wind waves were properly simulated in the laboratory facility. Then, theoretical predictions of the pressure distributions in the air at the interface, were verified through the use of an extremely sensitive measurement system that rose and fell with the waves at a point in the tunnel, always staying one-quarter of an inch above the water surface. Wave growth measurements made along the tunnel length confirmed limited ocean measurements and clearly showed that predictions of growth were low by factors of 3 to 8. Finally, recent measurements of the turbulence in the airstream above the interface have confirmed the important role of eddying motion in the transfer of energy from wind to wave.

These studies, which make possible the examination in the laboratory of the actual effects predicted by theory, will permit future engineering improvements in manmade structures in the sea which are becoming increasingly prevalent as we further exploit the resources of the seas and the continental shelves.

SOCIAL SCIENCES

The National Science Foundation support of research in the social sciences constitutes about 20 percent of the total Federal obligation in these fields, but a much larger percentage with regard to academically based research. In such support, the Foundation gives special emphasis to projects directly related to current social problems. Although the research techniques may not always be as precise as in more experimental areas and the methods not as easy to control as in laboratory settings, the potential contribution to the problem solving of social problems is nevertheless great.

Social scientists are among the heaviest users of computer facilities on most university campuses. University computing facility needs are in large part supported by another Foundation program, but the social science program finances the special computer requirements of the social sciences, including programming assistance, data tape libraries, and limited amounts of machine time for experimental research. Requests of this nature arise primarily from growing needs in the fields of economics, sociology, linguistics and the political sciences.

In keeping with the history of steady growth in the support of the field, the Foundation increased its awards to approximately $15 million in about 474 different grants during fiscal year 1969.

Specialized Facilities Program—Social Sciences at Institute for Advanced Study

In a grant of signal importance to the future of social science research, the Foundation has contributed to the establishment of a school of social sciences at the Institute for Advanced Study at Princeton, N.J., by furnishing part of the funds needed to construct a social sciences building. The new school of social sciences will be comparable to the institute's existing schools of mathematics, natural sciences, and historical studies, which have achieved international eminence in the pursuit of advanced learning and exploration in fields of pure science. Creation of the new school will require construction of additional physical facilities to house incoming social scientists, some of whom will join the distinguished permanent faculty, and others who will remain for 1 or more years as visiting scholars. Economists studying the theory of choice under uncertainty; sociologists examining the process of decisionmaking in informal groups; political scientists studying the decisionmaking process within political organizations—all find themselves dealing with a similar set of problems which appear to have a common logical structure. A common thread is also apparent in the psychological and linguistic analysis of the problems of language learning.

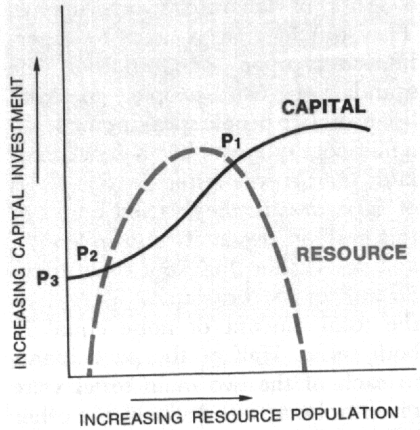
Faculty and visiting scholars in the fields of anthropology, economics, political science, psychology, and sociology will work with historians in applying social science techniques to historical materials in order to achieve a deeper understanding of the forces that shape the course of change in human societies. In addition to such work in the area of social change, social scientists at the institute will concentrate on the analysis of how the small social unit absorbs, processes, and uses information. Thus, the area of social evolution on the one hand and decisionmaking processes on the other will provide foci of convergence for the intellectual interests of social scientists drawn from a variety of disciplines. These are also areas in which the institute is organizationally well suited in the sense that they neither require large team efforts nor elaborate laboratory facilities in order to make significant contributions to social science.

Environmental Stress

As everyone knows who has been exposed to the noise, overcrowding and odors of today's urban environment, simply living in the city is a source of frustration and psychological stress. Psychologists have done many studies in the past on the effects of noise on performance, but none on the issue of adaptation, other than the observation that individuals do, in fact, adapt to noise. An important question which remained unanswered was the extent to which adaptation produces detectable aftereffects in behavior.

David Glass of New York University and Jerome Singer of the State University of New York at Stony Brook have explored this question in a series of laboratory experiments. They put together a noise by superimposing upon one another the sounds of two people speaking Spanish, two people speaking English, a mimeograph machine, a desk calculator, and a typewriter. In one series of experiments, they varied bursts of this noise in regularity and in length, and in another they kept them regular and of fixed duration. They kept the total amount of noise equal in both series. Half of the participants in each of the two main series were given noise at 110 decibels, the other half at 56 decibels. A control group included in the experiment was not exposed to any unusual noise. The participants in the experiments performed a variety of tasks while their responses to the noise bursts were recorded by skin resistance tests. (Base measures were obtained during a 15-minute relaxation period before the noise and performance measures.) Following this, they were given a set of four puzzles to solve, two of which were in fact insoluble, though this was not obvious. The number of attempts they made to solve the puzzles was used to measure tolerance for frustration. Finally, to measure depletion of energy during the adaptation-to-noise period, they were given a proofreading task.

The major hypothesis of the study was that frustration tolerance would decrease more following adaptation to random noise than to fixed noise. The skin conductance measures indicated that experimental subjects did indeed adapt to the noise and that the high noise conditions produced greater adaptation than any of the other conditions. The performance measures also showed evidence of adaptation, with fewer errors from earlier to later trials. The difference in errors over time for the control group was not statistically significant. Furthermore, participants exposed to both random noise conditions showed less tolerance for frustration than those in either of the nonrandom noise conditions or in the control



group, and made more errors in the proofreading task. Thus, it appears that the deleterious effects of adaptation to random noise, whatever its intensity, are greater than for adaptation to predictable noise. (The investigators report that a physiologist whose laboratory was down the hall from their own complained to the project secretary about the noise. "It's not so much the loudness, it's not knowing when it's going to come on.")

The investigators considered a number of possible explanations for the relationship between adaptation and tolerance for subsequent frustration, and explored one in a subsequent experiment. They hypothesized that the unpredictable noise induces feelings of a lack of control over the environment, and subsequently other details of the surroundings may come to have little instrumental utility for the person. Under these conditions, performance efficiency and the capacity to withstand frustration may decline. To test this possibility, a new group of people participated in the experiment, but half of them were told that they could press a button beside their chair to terminate the noise, though the experimenter preferred that they not do so. Even when they did not press the button, their perception of control dramatically increased their tolerance to frustration following adaptation.

Models of Production From Natural Resources

The economic problem of the long-term optimum recovery of natural resources by private firms has received relatively little attention. This is particularly true for renewal resources such as fisheries and timberlands. And yet, formulation of economic theory in these areas is essential for rational production planning, allocating development capital over time, and establishing appropriate public regulatory or development policies.

In coming to grips with this problem, Vernon L. Smith of Brown University has attempted to develop a unified economic theory of production from natural resources. In general, this theory mathematically relates the interactions between the amount or mass of a resource available and the specialized capital for its exploitation. The phase diagram (left) partially illustrates its application to the situation where the resource studied is replenishable, e.g., fisheries.

If initially the resource is at the point of maximum self-sustaining resource population, the influx of new exploitation capital will reduce the population to the intersection of the population and capital curves at P_1. At this point, the industry is in equilibrium with the economy (i.e., an investor's return is equal whether he invests in the exploitation of this resource or elsewhere), and it is also in ecological equilibrium because whatever is harvested is replaced.

If this stability is disturbed, e.g., by disease, so that the resource population is depleted, firms will suffer losses forcing them to leave the industry and reducing its total capital investments. Eventually a new equilibrium is reached at P_2 where a reduced industry is again in balance with the resource population. If however, the harvest exceeds the yield, the point P_3 may be reached where the resource base is totally depleted and the industry must cease operation.

Almost any type of resource exploitation can be qualitatively shown in a phase diagram which will vary according to whether the resource is replenishable or nonreplenishable, and whether significant effects not subject to the control of individual entrepreneurs are present. Dr. Smith's models provide an example of a descriptive theory that transforms elements concerned with costs, demand, and resource growth technology into a pattern of exploitation, and serves as a basis for an integrated economic theory of conservation. The model or variations on it may have still other possible applications, such as (1) a theory of ecological equilibrium in primitive hunter cultures; and (2) possibly the rudiments of an economic theory of species extinction, both historical and modern.

Human Ecological Adaptation

Human practices as they affect man's relation to the natural environment can have critical consequences. This is true of small, nonindustrial societies, as well as the complex industrial nations with which we are more familiar. Assessing the ecological consequences of behavior in relatively simple societies can be an intricate task, but simpler ecological adaptations can often provide valuable insights into more general processes.

For example, the Karimojong of Uganda are one of a number of African societies dwelling in semiarid grasslands who depend on cattle for their livelihood, but who use their animals for subsistence rather than ranching or dairy farming. In terms of a modern market economy, the herding practices of the Karimojong and other African pastoralists may seem inefficient and even irrational. However, Neville and Rada Dyson-Hudson of Johns Hopkins University, who studied the Karimojong in the field, have observed that there are profound rational and functional aspects of the traditional Karimojong pastoral system.

The Karimojong do not systematically sell or slaughter superfluous male stock or female stock of low fertility or low milk yield. Primarily they exploit their cattle by consuming their milk and limited quantities of their blood. Blood will be taken from an animal every 3 to 5 months, unless it is a bull or a cow that is pregnant or giving milk. From 4 to 8 pints are extracted by tying a thong around the neck sufficiently tight to make the jugular vein stand out, but without choking the animal. An arrow with the tip wrapped in string, so that only about an inch will penetrate, is then shot into the vein. The blood flows freely but when enough has been taken and the thong is released, the flow immediately stops.

The Dyson-Hudsons find the pastoral system of the Karimojong is responsive to a number of problems they face: the difficulty of storing herd produce with an undeveloped technology in the hot climate found 2° north of the equator; the fact that only large oxen and cows can be sold in the area, and only at a very low price; and the need for insurance against catastrophic losses of livestock by enemy raids, epidemics, thirst or starvation in an area where periodic shortages of grazing and water can cause high mortality among livestock.

Under these circumstances, the Dyson-Hudsons point out the functional character of the Karimojong practice of maintaining large numbers of animals of low productivity but considerable hardiness to convert the sparse rough herbage into food which they primarily consume as milk and blood.

The Dyson-Hudsons say that when outsiders recommend different approaches as more rational they usually assume that the major limitations of the ecological system can be changed by increasing the energy potential of the system through building dams, drilling for water, improving seed, etc., and by relocating some of the population. However, the Dyson-Hudsons note, the first kind of change would place a heavy financial burden on a developing economy, and the second would present serious political problems for a new nation. Herding practices such as those of the Karimojong and other African peoples in comparable circumstances are highly rational in view of the total ecology in which they live. These findings are further evidence that we must consider the effect on the entire ecological system before we decide as to the validity or invalidity of a given practice.

Science Education

Strong education in science is an important national asset. It provides the solid foundation for excellence in science and technology, and spurs progress in these essential fields. Today the Nation looks increasingly to the wise application of scientific knowledge to cure such disorders of society as air and water pollution, uncontrolled population growth, disabling diseases, urban congestion—and a host of other disturbing conditions. Also, the training of an adequate supply of qualified scientific personnel to help cope with contemporary problems is vital as is the widespread public understanding of the role of science in this age. The task of providing effective science education for nonscientists, prospective scientists, and scientists is a challenge for academic institutions of all levels. To meet this challenge, a substantial amount of the funds appropriated annually to the Foundation supports educational efforts, since the Foundation is the only Federal agency specifically charged with responsibility for science education.

Specific recommendations for building the strength of science and engineering education in the United States were made by the President's Science Advisory Committee in May 1959,[1] and their recommendations have been pursued through various Foundation-supported educational activities. The areas which the President's Committee cited as needing "specific and urgent attention throughout our educational system" are: (1) the curriculum and the content of courses; (2) the quality and effectiveness of teachers; (3) the recognition and encouragement of students; and (4) the development of intellectual leadership. Foundation programs aimed at these targets have made noteworthy progress over the years. As this annual report discloses, current programs and projects continue to stress improvement in the cited areas. In its constant search for the best ways to assist academic institutions in meeting demands of modern science education, the Foundation also encourages appropriate new or modified approaches to problem solving.

Direct support of talented graduate students and advanced scholars in science is a key educational effort of the Foundation. From 1952 to the end of fiscal year 1969, NSF invested more than $342 million in fellowships and traineeships for advanced level training. This represents a total of 51,698 fellowship awards offered to the most highly qualified individuals identified from among 184,224 applicants, and 26,881 traineeships for award by the 216 institutions receiving grants.

In addition, opportunities for advanced scientific training are made available through NSF–supported research projects. These projects provide research assistants with invaluable guidance and experience in academic research, which contributes directly and significantly to graduate education for scientists and engineers.

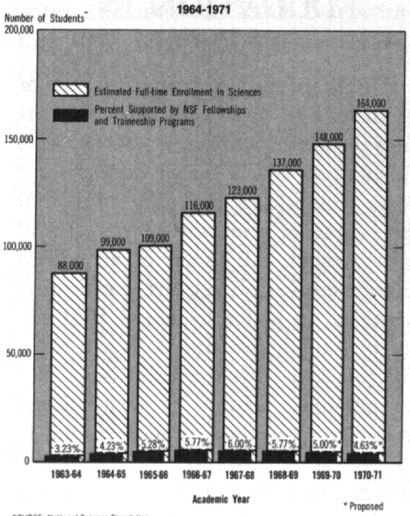
Recently the Foundation completed a study of the support mechanisms and major support sources for full-time science graduate students, based upon information supplied in the fall of 1967 by 209 institutions which grant doctorates in science. It revealed that the largest group of students, about one third, held fellowships and traineeships. Further, the Federal Government was the principal source of funds for fellowships, traineeships, and research assistantships. The National Science Foundation, moreover, provided nearly one fourth of all such federally funded awards. Non-Federal sources provided almost all of the teaching assistantships.

NSF support for special projects in graduate education this year provided funds for a number of activities relating to contemporary social problems. For example, a project

[1] "Education for the Age of Science," statement by the President's Science Advisory Committee, The White House, Washington, D.C., May 24, 1959, p. 30.

Figure E-58

NSF FELLOWSHIPS AND TRAINEESHIPS RELATED TO ENROLLMENT IN THE SCIENCES 1964-1971



SOURCE: National Science Foundation

concerned with a "Teaching Laboratory for Biorheology and Analysis of the Physical Properties of Biomaterials" will provide for better teaching of the mechanical and physical properties of biological materials, and this, in turn, will eventually promote better processing and handling of foods, and safer and quicker distribution of foods. Another special project receiving support aims to produce specialists who can study large-scale socioeconomic systems in a scientific way and better plan to meet the complexities of modern life, particularly in the urban setting.

The Foundation's efforts for strengthening undergraduate education in science were broadened in fiscal year 1969. For the first time the Foundation has provided support for the development of curricula for the training of technicians in engineering and in chemistry. The curricula is intended primarily for use in junior colleges and other 2-year institutions. NSF also announced the establishment of the pre-service teacher education program, designed for undergraduates who plan to become secondary or elementary school teachers of science or mathematics. This program emphasizes a balance between knowledge of subject matter and pedogogy, greater skill and experience in developing and testing course materials, and early direct involvement in teaching.

Significant changes in the area of undergraduate education support occurred also in the College Science Improvement Program. In addition to the Individual Institutional Projects program, the College Science Improvement Programs now include Interinstitutional Projects in 4–Year Colleges and Cooperative Projects for 2-Year Colleges. The cooperative projects offer assistance to junior colleges seeking to improve their science instruction through cooperative activities involving nearby colleges or universities. As the number of junior colleges continues to grow, the Foundation is increasingly concerned about ways and means to help these institutions to provide good science instruction.

At the pre-college level, NSF provides substantial support for the supplementary training of science and mathematics teachers, improvement of course content, development of leadership in science education in school systems, and implementation of new instructional materials in the schools. This year the Cooperative College-School Science Program received significantly increased funds to expand its activities for improving science programs in the schools. These projects include the testing of new course materials for secondary schools, improvement of elementary school science curricula, and assistance to local school systems or to systems representing a wide geographical area. The institute programs for teacher training provide valuable assistance through a num-

Table 7
Education in Science
Fiscal Year 1969

	Number of proposals received	Dollar amount requested	Number of awards made	Funds obligated (net)
Graduate:				$42,465,606
1. Fellowships	9,442[1]	$62,283,172	2,914[2]	(13,095,826)
2. Traineeships and other grants	441	103,806,182	397	(29,369,780)
Undergraduate[3]	2,920	65,615,000	1,384	27,334,602
Pre-College	1,836	85,243,000	1,127	45,497,286

[1] Applications.
[2] Fellowships.
[3] Includes College Science Improvement Program: column 1—108; column 2—$16,776,603; column 3—74; column 4—$8,763,700.

ber of projects for developing specialists, coordinators, and supervisors who will have competency in areas directly relevant to school needs.

Since the introduction of NSF-supported summer institutes in 1953, an estimated 155,000 secondary school teachers of science and mathematics have received supplementary instruction in their respective fields through such institutes. Fiscal year 1969 grants for institutes afford training opportunities for approximately 17,900 participants in summer institutes, nearly 1,375 in academic year institutes, and about 13,600 participants in in-service institutes.

Through the Course Content Improvement Program the development of improved science and mathematics courses continues to receive support. In addition, funds are made available for workshop projects for training college and school resource personnel who are experts in the various new source materials. An estimated 24 percent of the some 14 million U.S. students enrolled in grades 9 through 12 in the fall of 1968 were using curricular materials in science or mathematics developed under NSF support.

Early in 1969 the Foundation announced its policy for the distribution of publications and other materials developed under NSF science education programs. This policy includes practices which have evolved during the course of program administration for the management of income-producing instructional materials. An attempt has been made to keep the policy flexible, so that unusual projects will not be too narrowly circumscribed. Provisions of the policy ensure that the Foundation is not in the position of monitoring or supporting indefinitely the management of the residual business affairs of a particular project.

Mindful of the problems facing educationally disadvantaged students, the Foundation continues to support some activities designed to be of benefit to them. For example, the Agricultural and Industrial State University of Nashville, Tenn., received a fiscal year 1969 grant for curriculum improvement through the application of computers to instructional problems in mathematics for inadequately prepared freshmen. A project funded jointly by the U.S. Office of Education (USOE) and the NSF provides for the development of science courses at 13 predominantly Negro institutions; the program emphasizes student involvement and participation as a means of learning. A current NSF grant to Michigan State University provides for the training of science teachers from innercity secondary schools of nine urban communities in Michigan; this project includes a summer phase for student-participants as well as teachers (USOE also contributes to the support of this project).

In fiscal year 1969, as in past years, the Foundation has sought to invest prudently in science education efforts which have proved most successful and in those which give great promise of beneficial results for the future. Program modifications and innovations, as noted in this report, are aimed at increasing the relevance of NSF educational activities to contemporary needs and challenges.

Detailed information about the various educational activities follows. Table 7 shows the NSF support for fiscal year 1969 science education activities at the three major educational levels.

GRADUATE EDUCATION IN SCIENCE

Highly specialized training needs of scientists and engineers must be met in graduate education in science. The Foundation has a major concern for these individuals for they represent the source of scientific potential and achievement. All facets of advanced science education require continuing attention in order to assure that scientific knowledge and skills are moving forward with the times and that an adequate supply of well-trained scientific manpower is maintained in the national interest. To recognize and encourage graduate students and to develop intellectual leadership in science and engineering the Foundation has stressed assistance for graduate students, career scientists, and science faculty. Graduate-level support is provided primarily by means of NSF fellowships and traineeships. Fellowships are awarded—in national competition—on the basis of merit and ability; the Foundation makes these awards directly to individual applicants. Traineeships are awarded locally by institutions receiving NSF grants for supporting graduate training programs. In the past decade approximately 65,000 NSF fellowships and traineeships have provided direct support for persons pursuing advanced education in the sciences. Fiscal year 1969 support for fellowship and traineeship programs offers approximately 8,900 U.S. citizens op-

Table 8

NSF Fellowship and Traineeship Programs
Fiscal Year 1969

	Awards requested by institutions	Individuals involved in applications	Awards offered	Net amount
Graduate traineeships	17,199 (219)[1]		5,238 (214)[1]	$25,905,000
Summer traineeships for graduate teaching assistants	8,359 (205)[1]		852 (197)[1]	810,721
Graduate fellowships		7,231	2,500	9,154,864
Postdoctoral fellowships		1,087	130	702,404
Science faculty fellowships		1,048	212	2,509,690
Senior foreign scientist fellowships		76	72	728,868
Total	25,558	9,442	9,004	39,811,547

[1] Number of institutions involved.

portunities for appropriate study and research at institutions in the United States and abroad. Table 8 summarizes data on applicants, awardees, and obligations.

Aims of other NSF educational activities at the graduate and advanced levels are to: encourage university graduate departments to experiment with unusual or innovative educational programs; improve course content and instructional materials in the sciences at the graduate level; provide educational opportunities in specialized or frontier areas of science for graduate and postdoctoral students selected from different schools and regions; and increase the understanding of science by the American public.

The NSF Graduate Fellowship and Graduate Traineeship Programs again felt the impact of the recent (spring of 1968) change in the Selective Service Act. Revised regulations have eliminated the essentially automatic deferment of graduate students; in 1968–69 only those students in at least their third year of work toward an advanced degree were considered eligible for deferment on the basis of their student status. For reasons of military or alternate service, 63 individuals who accepted Graduate Fellowships for 1969–70 have postponed commencement of their graduate work; the fellowships will be reserved for future use. Of the 7,231 applications for graduate fellowships received this year, 5,716 were new requests as compared with 7,155 new requests received last year. Data indicating the precise effect of Selective Service on the decrease in applications received are not available. Because Graduate Traineeships are administered entirely by the grantee universities, the impact of the revised draft regulations on the traineeship program is less well known. However, by the close of this fiscal year the Foundation had been notified of 109 student resignations which were associated with military obligations of the trainees.

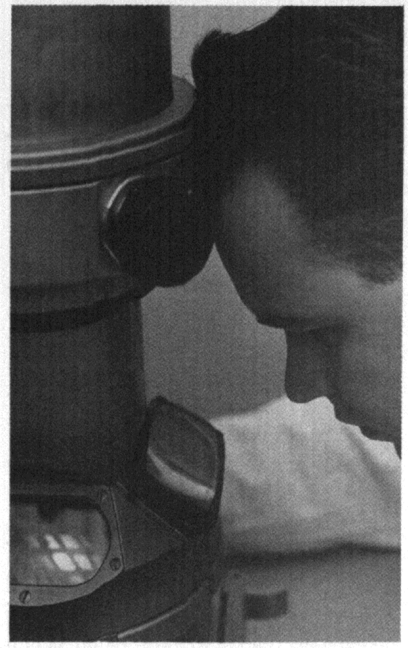
Graduate Traineeships

The Graduate Traineeship Program covers all fields of science supported by the Foundation. Its aim is to increase the number of qualified individuals who pursue and complete advanced study leading to master's and doctoral degrees in any of these fields. Traineeship grants are awarded primarily to institutions with existing facilities and staff to accommodate additional first-year graduate students in strong programs, or whose students can progress more rapidly toward an advanced degree with the aid of traineeships. The grantee institutions determine in which university departments high-ability students shall receive traineeship appointments.

Of the 219 universities applying for new or continuing Graduate Traineeship grants this year, 216 received support. Available funds provided for 5,238 new or continuing 9- or 12-month traineeships (418 fewer than the 5,656 awarded last year to 209 universities). In addition, 852 Summer Traineeships for Graduate Teaching Assistants were supported in fiscal year 1969 (113 fewer than the 965 awarded last year to 193 universities).

Graduate Fellowships

Recognizing that graduate students represent a critical segment of U.S. scientific manpower, the Foundation has supported Graduate Fellowships for the past 18 years. These fellowships, awarded to unusually able students pursuing advanced degrees in science, mathematics, or engineering, are intended to help the recipients complete their studies with the least possible delay. Competition for awards is intensely keen, and only exceptionally capable students are successful in this national contest. As part of the selection process, panels of eminent scientists, appointed by the National Research Council, review and evaluate the qualifications



Graduate student at the University of Wisconsin uses an electron microscope in a research project in zoology. (University of Wisconsin Photo) of each candidate before NSF determines who shall be offered a fellowship.

There were 7,231 applications for Graduate Fellowships in fiscal year 1969; awards offered totaled 2,500 (last year 8,814 applications were received and 2,500 awards were offered). The 18-percent decrease in applications this year may be due, at least in part, to the revised Selective Service regulations affecting graduate students. Other factors may be the less rigid requirements and the larger stipends of several sources of support available to good students.

As in previous years, the largest number of the Foundation's fellowships and traineeship awards were offered to predoctoral students. In the three graduate student programs, fiscal year 1969 awards totaled 8,590 (Graduate Fellowships—2,500 awardees; Graduate Traineeships—5,238 recipients, and Summer Traineeships for Graduate Teaching Assistants—852 recipients).

Fellowships for Advanced Scholars in Science

Advanced scholars in science, with their in-depth experience and knowledge, contribute significantly to the scientific enterprise and the training of future scientists and engineers. In fiscal year 1969 the Foundation offered 414 fellowship awards in support of high-level scientific study for established scientists (130 Postdoctoral Fellowships and 212 Science Faculty Fellowships—all tenable at institutions of the individual's choice; and 72 Senior Foreign Scientist Fellowships—tenable at U.S. colleges and universities only). Senior Postdoctoral Fellowships were not awarded this year due to the limitation of funds.

Science Faculty Fellowships provide an opportunity for junior college, college, and university science teachers to enhance their effectiveness as teachers. This year the Foundation received 1,048 applications for science faculty fellowships; 212 awards were offered. About 25 percent of these award recipients already possess their doctorates; the remaining 75 percent are seeking doctoral degrees and are primarily from smaller colleges and universities across the Nation.

A record-high number of institutions (76 of the 107 eligible) participated in the Senior Foreign Scientist Fellowship Program this year. The awards that were made will permit 72 senior foreign scientists to teach and conduct research at U.S. universities.

At the request of the Department of State, the Foundation administers two North Atlantic Treaty Organization (NATO) fellowship programs, including selection of the fellows. These international fellowships in science, aimed at promoting scientific progress and obtaining closer collaboration among scientists of the member nations, are supported by NATO funds.

In fiscal year 1969 the Foundation offered NATO Postdoctoral Fellowships in Science to 40 U.S. scientists. The awards provide to young scientists training opportunities of 6- to 12-month duration at appropriate educational institutions in other NATO countries or in countries cooperating with NATO. NATO Senior Fellowships in Science, also tenable at institutions in other NATO countries and those associated with NATO, were offered to 27 U.S. senior scientists to enable them to study new scientific techniques and developments.

Advanced Science Education Activities

Strengthening graduate education in science requires support for special kinds of educational efforts which are not within the fellowship and traineeship framework. Under the Advanced Science Education Program, grants are awarded for such activities as special projects in graduate education, advanced science seminars, public understanding of science projects, and travel to international scientific meetings. Institution-oriented activities seek to improve the quality of science training provided by universities and colleges; projects oriented toward the individual offer science instruction or activity of a highly specialized nature. Fiscal year 1969 grants for advanced science education activities amounted to approximately $2.7 million.

Special Projects in Graduate Education

The main function of this program is to promote the development and testing of innovative approaches to graduate science education. Experience has taught that many of today's educational problems cannot be solved in traditional ways. Thus the Foundation supports special projects concerned with experimental courses, curricula, and training aids, as well as conferences on problems of graduate education in science. Often a successful project conducted by one university will help other graduate schools to initiate similar improvement activities.

A growing interest in special projects related to contemporary social problems is evident this year. For example, the development of pest control measures that act only against selected targets and are completely safe for other organisms is the ultimate aim of a major NSF-supported effort. This project involves the participation of Cornell University, North Carolina State University, Oregon State University, and the University of California at Berkeley and at Riverside. It provides for the training of graduate and postgraduate students in pest management, especially the biological control of pest populations.

Among the uncommon areas of science that are subjects of special course or curricular projects receiving support this year are: geophysical fluid dynamics (Case Western Reserve University); Quaternary studies option in anthropology (Washington State University); planning and policy sciences (University of Pennsylvania); and field biometeorological techniques (University of Wisconsin, Green Bay).

Fiscal year 1969 grants for special projects totaled 22, amounting to approximately $1.1 million.

Advanced Science Seminars

Advanced Science Seminar projects supplement graduate school curricula and enable participants to pursue science subjects in greater depth. Directed at regional and national participation, these conferences or seminars cover primarily sophisticated topics in science. Recent information concerning highly specialized fields and interdisciplinary areas of science is commonly made available to teachers of graduate courses through seminars. Some projects provide for research participation under the tutelage of nationally and internationally established senior scientists.

Fiscal year 1969 grants for seminar projects totaled 37, amounting to approximately $1 million. The largest number of grants was made in the social sciences.

Examples of efforts funded are: an interdisciplinary program in behavioral sciences and law for 40 graduate and professional students and postdoctorals, conducted by the University of Wisconsin, and a continuing training program in glaciology and Arctic sciences for 21 graduate students conducted by Michigan State University.

UNDERGRADUATE EDUCATION IN SCIENCE

Science education at the undergraduate level bears directly on the professional preparation of future scientists and engineers and the orientation of citizens for effective roles in a modern society. Thus colleges and undergraduate components of universities have a continuing responsibility for providing stimulating and meaningful instruction in the sciences. In carrying out their mission these institutions face enormous problems: an inadequate supply of well-trained science teachers, rapidly growing scientific knowledge, insufficient funds for necessary science facilities and equipment, ever-expanding student enrollments, and various other pressures.

NSF programs for strengthening undergradaute education in science are aimed at the most critical of these areas. Support is provided for increasing the competence of the science faculty, improving courses and curricula, and making available special educational opportunities for able students majoring in science. There is assistance for the acquisition of teaching equipment and other instructional aids. Lastly, and of great importance, is the Foundation's provision of comprehensive grants to assist colleges in improving all aspects of their undergraduate science programs.

This year marks the end of the first decade of major NSF activity in the realm of undergraduate science education. During this period, support at the undergraduate level totaled approximately $275 million, $27.3 million of this having been invested in fiscal year 1969. Although encouraging progress has been made during the 10-year period, the current rate of expansion in institutions and enrollments is creating an urgent need for increased attention and assistance.

The Foundation's general approach to the improvement of undergraduate science education has been (*a*) to identify problem areas; (*b*) to design programs for bringing Federal support to bear upon these problems; (*c*) to conduct these programs at least long enough to evaluate their effectiveness and to refine their procedures; and (*d*) to arouse a concern in leading scientists and teachers for the problems of undergraduate education and to encourage their participation in improvement efforts.

Among the highlights of fiscal year 1969 activity in undergraduate science education are: the Foundation's entry into the area of science technician training (through the awarding of four grants, totaling $986,500, for developing 2-year curricula for the training of technicians in engineering and in chemistry), initiation of the first formal NSF program designed specifically for 2-year colleges, and announcement of a pre-service teacher education program in science for secondary and elementary school teachers. In addition, the Foundation began a gradual phasing out of College Commission support. These commissions, organized in eight disciplinary areas (agriculture and natural resources, biology, chemistry, earth sciences, engineering, geography, mathematics, and physics), have been generally helpful in focusing attention on problem areas and in collecting and disseminating information about effective ways of improving undergraduate instruction. The consultant and advisory groups of the Commissions have been especially useful in giving specific guidance to smaller institutions interested in initiating local reforms, but a shift in the Foundation's patterns of such support is now indicated to be desirable.

College Teacher Programs

College Teacher Programs provide the kinds of supplementary training necessary for strengthening the effectiveness of teachers of undergraduate science. Collectively they help teachers keep abreast of new discoveries and at the same time assist them in developing workable ways of getting these modern concepts across to their students. Usually the training is conducted at the larger institutions where facilities are adequate and the teaching staff is highly competent. NSF-supported institutes, short courses, and research participation projects for college teachers have aided undergraduate institutions throughout the United States.

Projects supported under the College Teacher Programs are of three general types: those designed to help bring underprepared teachers up to an acceptable level of competence, those designed to refurbish the training of initially well-prepared teachers whose teaching effectiveness is diminished by the passage of time, and those designed to provide more advanced teachers with a concentrated, relatively sophisticated exposure to some specialized area having particular relevance to current advances in their respective disciplines.

More than $5 million was awarded in fiscal year 1969 for the various college teacher activities, providing training opportunities for 3,525 teacher-participants. (These participants represent a geographical distribution covering all 50 States.) In addition, 212 college teachers were awarded Science Faculty Fellowships under the Foundation's fellowship support program, which provides financial assistance to in-service college teachers of science to enable them to undertake further scientific study or work that meets their individual needs. See table 9, NSF programs for college teachers.

The training needs of junior-college science teachers are of growing concern to the Foundation. Two-year colleges are rapidly increasing in number, and more teachers who are adequately trained are needed. These teachers must be equal to the task of giving their students good initial preparation for possible careers in science. As a means of some assistance, more than one quarter of the training opportunities available under the College Teacher Programs are currently offered to junior college teachers.

Summer Institutes

Summer Institutes, ranging from 8 to 12 weeks in duration, offer courses designed to provide further education in a particular discipline to college and junior college teachers. They are held at a time of year when most faculty members are free to work at self-improvement, and when graduate facilities are least taxed by regular students. The courses constitute a specially designed unit, usually planned to permit exploration in depth of an area of particular importance or significance in the scientific discipline.

Fiscal year 1969 grants provided support for 1,766 teacher-participants at 48 institutions conducting summer institutes. More than one-third of the participants selected were junior college teachers.

Academic Year Institutes

Academic year institutes provide college teachers with full-time training in a university environment during regular sessions. The teacher-participants enroll in core courses or seminars planned especially for them, but they may also take established courses and laboratory work presided over by the university's regular faculty.

During the past 10 years, each of 1,204 college teachers participating in this program has received a full year of graduate study in science. Due to current budget restrictions, fiscal year 1969 grants provide support for only five institutes and 71 teacher-participants.

In-Service Seminars

In-service Seminars offer training on a part-time basis (evenings or weekends) to college faculty who are located within commuting distance of the institutions conducting the seminars. Thus the teacher-participants, while continuing their regular teaching, may obtain additional knowledge of subject matter in their scientific disciplines or become acquainted with new textbooks and laboratory equipment of professional interest to them.

The six grants made in fiscal year 1969 for seminars provide training opportunities for 384 college teachers. Stipends are not awarded in this program.

Short Courses

Short Courses, ranging from 2 days to 4 weeks in duration, are designed to deal in depth with selected areas of subject matter in science. Frequently such projects feature as teachers those scientists who are capable of developing sets of related new scientific discoveries in a succinct lecture series. The instruction is intensive and is intended for participants with advanced backgrounds.

Among the topics supported under fiscal year 1969 grants are:

- Estuarine Ecology (University of Delaware)
- Geographic Applications of Remote Sensing (University of Tennessee)
- Systems Analysis for Land Use Planning (Rutgers, the State University, New Jersey)
- Energy and Moisture Balance Climatology (University of Delaware).

The 27 grants awarded this year support training for 769 college teachers.

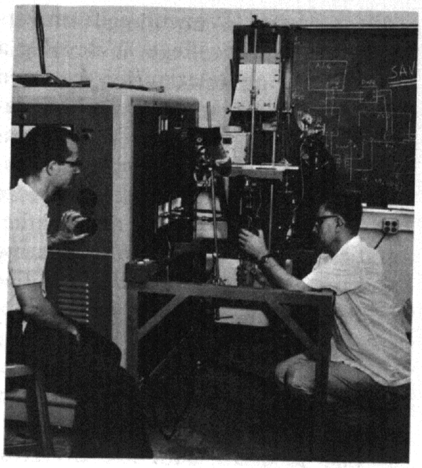
Table 9

NSF Programs for College Teachers

Fiscal Year 1969

	Proposals received			Grants awarded		
	Number	Participants	Amount	Number	Participants	Net Obligation
College teacher institutes	(246)	(8,268)	($11,605,165)	(99)	(2,990)	($3,170,491)
Summer institutes	157	5,308	7,914,855	61	1,766	2,312,382
Academic year institutes	20	340	2,444,780	5	71	290,852
In-service seminars	17	1,019	231,880	6	384	45,874
Short courses	52	1,601	1,013,650	27	769	521,383
Research participation	344	897	2,210,240	231	535	796,633
Science faculty fellowships [1]	--------	1,048	14,971,728	--------	212	2,509,690
Total	590	10,213	28,787,133	330	3,737	6,478,814

[1] Also included in statistics on fellowship programs.



College teacher participant in a summer institute (right) works with crystal growing apparatus in a solid state physics laboratory. (University of Arizona Photo)

Research Participation for College Teachers

The Research Participation for College Teachers program provides to science teachers the opportunity to pursue research activities on a full-time basis during the summer. Usually the participants are from institutions where research facilities are likely to be limited and where heavy teaching schedules make time for research scarce. All applicants for this training must possess at least a master's degree in science (usually in the field of the intended research), making it probable that they will have the academic background needed both to profit from the experience and to make a useful contribution to the investigation.

One-third of the participants are selected for further participation in "Academic Year Extensions." These extra awards provide modest support for the participant to continue the research at his home campus and on a schedule that is convenient for him.

In fiscal year 1969 the Foundation awarded 55 grants for research participation for college teachers; these provide for 359 teacher-participants. In addition, 176 Academic Year Extensions were provided.

Instructional Improvement

Upgrading course materials at the undergraduate level is essential to the improvement of science instruction for college students. Curricular reform in pre-college science and mathematics during recent years has accentuated the need for new teaching materials and approaches at upper academic levels. To effectively implement changes in science curricula, however, undergraduate institutions must have the necessary modern instructional equipment. Hence the Foundation provides support for both curriculum improvement and acquisition of equipment.

Science Curriculum Improvement

The Science Curriculum Improvement Program encourages outstanding scientists and science educators in the various scientific disciplines to devote a significant part of their time to creating better academic environments for both students and faculty—to ponder the questions: "What must one expect students to know, to understand, and to be able to do?" and "What are the best ways of imparting this knowledge, understanding and facility?"

Those individuals who influence selection of the materials to be presented and who exert leadership in recommending how the teaching can best be done have a profound influence on all other efforts to improve the caliber of science teaching. Their task requires that they investigate ways of increasing the vitality, the flexibility, and the pedagogical quality of curriculum arrangements, produce courses or course modules on which others can model their own versions, and create an array of first-rate teaching aids from which the instructor may choose. NSF grants for their efforts also serve to give visibility and stature to teaching activity and thus to enhance the peer image of the scientists who teaches. The aim is to produce a situation in which the rewards of teaching are considered equal to the rewards associated with research activity.

The Foundation supports a variety of mechanisms to encourage both macro- and micro-curricular evolution. The most general type of approach involves curriculum reform on a broad scale. Both interdisciplinary and intradisciplinary efforts are supported. Both are likely to require an entirely new organization and emphasis of subject matter. In some instances, courses require original design to accommodate recent developments which are reshaping a discipline, e.g., use of computers in electrical engineering.

Examples of noteworthy curriculum improvement activities supported by fiscal year 1969 grants are:

- Development of a large-scale curriculum program for chemical technician training (American Chemical Society);

- Development of a single sequence of four physics courses, graded in difficulty and in their mathematical prerequisites, which permits a student to enter and to finish the sequence on the basis of his interest and mathematical background (University of Michigan, Flint College);
- Application of computers to instructional problems in electrical engineering (Colorado State University) and in mathematics for inadequately prepared freshmen (Agricultural and Industrial State University, Nashville, Tenn.);
- Production of educational films in developmental biology (Education Development Center); and
- A study of undergraduate instruction in psychology in the United States, with the aim of developing recommendations for a more cohesive academic approach to the subject (American Psychological Association).

Both the recent growth of modern industrial needs and the expansion of the 2-year college movement have created concern about technical education in the United States. The NSF-supported curriculum development project for training chemistry technicians is intended primarily for use in junior colleges and other 2-year institutions, and will be used in training chemistry technicians for positions in industry, university laboratories, and Government.

So that the training will be consistent with the special abilities and interests of students to be trained, the curriculum will emphasize laboratory work and direct "hands on" experience rather than abstract theory. It will attempt to achieve comprehensive coverage of basic chemical subject matter while retaining sufficient flexibility to encourage the inclusion of modifications and special topics that are important to the user institutions.

Another current project which is concerned with technical training in 2-year colleges involves the development of a curriculum leading to the associate degree in electronics technology. Based at the University of Illinois, a working team consisting of individuals from 2-year institutions will prepare materials for such courses as Resistive Circuits, Single Time Constant Circuits, Pulse Circuitry, and Linear Electronics. Particular attention is being given not only to the sequencing of the technology subject matter, but also to the supporting mathematics courses.

Grants for college science curriculum improvement totaled $5,004,179 in fiscal year 1969, supporting 54 projects.

Instructional Scientific Equipment

The Instructional Scientific Equipment Program helps institutions of higher education to purchase equipment which will assist in the implementation of local course or curriculum improvement efforts. NSF grants for this purpose are limited to not more than 50 percent of the cost of the equipment. Experience has shown that even a modest amount of assistance can spur an institution's progress in providing stronger science courses.

It has been found also that modern equipment opens the way to more meaningful experiments for students, often imparts new confidence in the significance of laboratory work, and tends to challenge both science departments and individual faculty members to improve the content and manner of instruction.

Fiscal year 1969 equipment grants totaled 603, amounting to $4,615,300; this represents approximately 34 percent of the amount requested in the 1,418 proposals submitted to the Foundation this year.

Pre-service Teacher Education

The Pre-service Teacher Education program, established in fiscal year 1969, aims at improving the preparation of prospective teachers of pre-college science. It encourages universities and 4-year colleges to develop a closer working relationship between their science departments and education departments in providing training that will offer undergraduate students both increased knowledge of subject matter in science and mathematics and greater skill in organizing and presenting course materials. The Foundation believes that such an approach to pre-service education should help to alleviate the need for early supplementary or remedial training of new teachers.

The program does not prescribe the curricula through which universities and colleges will achieve these goals, but emphasizes certain curricular elements or characteristics that the Foundation views as highly desirable.

Prior to the formal announcement of this new program in March 1969, the Foundation had supported several pilot projects to experiment with approaches to improving the pre-servive education of science teachers. Among these were efforts conducted by the University of Georgia and five other units of the State of Georgia system, the Illinois State University, the State University of New York College at Plattsburg, and the Nebraska Board of Education of State Normal Schools.

The six grants, totaling $678,600, made in this program in fiscal year 1969 provide funds for the continuation of some of the earlier efforts and for three new projects (a summer project concerned with practical methods in science teaching—East Carolina University; a 3-year project for preservice teachers with double majors in any two of the following: physics, chemistry, mathematics—University of Pittsburgh, Pennsylvania; and a 4-year physics project that includes opportunities for undergraduate participants to construct and test their own instructional units—Austin Peay State University, Tennessee).

Emphasis in the early years of the

Pre-service Teacher Education Program will be on the education of prospective secondary school teachers, but some attention will also be directed to projects for improving the preparation of elementary school teachers.

Special Projects for Undergraduate Education

The special projects program provides support for prototype projects that investigate new approaches to undergraduate science education, giving special attention to identifying those that offer promise for enhancing the education programs of many colleges and universities if applied on a broad scale. It also experiments with projects so identified, examining procedures, testing the devices over a range of institutions so as to define their limits of effectiveness, and the like.

Among the current special projects receiving NSF support are:

- A pilot study to develop and implement a new 4-year B.S. curriculum in nuclear technology (Oregon State University);
- An interdisciplinary research project designed and conducted by a group of outstanding undergraduates—the Associated Students of the California Institute of Technology—for a summer study of "Man and Environment" (California Institute of Technology);
- The development of science courses at 13 predominantly Negro institutions—courses designed to bridge the gap between an uninspiring secondary school education and a college program that emphasizes student involvement and participation as a means of learning (Institute for Services to Education)—funded jointly by USOE and NSF.

Fiscal year 1969 grants for special projects totaled 21, amounting to $715,877 (exclusive of the Visiting Scientists program).

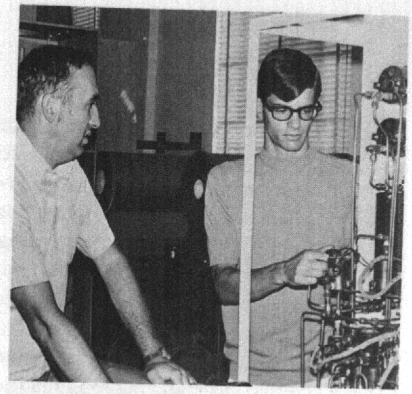
Through the Visiting Scientists (College) program, the Foundation supports arrangements made by the various professional societies to send competent scientists to local campuses for 1- or 2-day visits. The visiting scientists consult with faculty members on local problems relating to course and curricular improvement, deliver lectures on their specialties and assist undergraduate students in making educational plans. The experience and counsel of such senior faculty members from major institutions can be of enormous value to professors in small departments who are seeking to update and upgrade their science programs and to students who desire career guidance or intellectual stimulation in science.

Fiscal year 1969 grants for Visiting Scientists (College) activities provide for 1,426 visits, totaling 2,694 days, at a cost of $275,065.

College Science Improvement Programs

The College Science Improvement Programs support efforts for accelerating the development of science capabilities of predominantly undergraduate institutions. Grants are awarded to colleges and universities for implementation of comprehensive improvement plans based upon careful study and analysis of long-range needs and goals. Plans may include any combination of activities calculated to upgrade the preparation of college students for careers in science or in science teaching.

Initially this effort supported only individual institutional projects, but two additional programs, Interinstitutional Projects in 4-Year Colleges and Cooperative Projects for 2-Year Colleges, were announced in November 1968. The interinstitutional projects provide for a cooperative approach among 4-year colleges if such an approach affords clear advantages over conducting independent projects on each individual campus. Under the cooperative projects for 2-year colleges, regional groupings of junior colleges may participate with a nearby college or university in cooperative activities to accelerate faculty development and related course content improvement. In all programs the grantee institution must be either a university or a 4-year college. For details on the implementation of this program during fiscal year 1969, see page 90 in the chapter on institutional programs.



In a research participation project, this undergraduate student shares in the work of redesigning and building equipment to grow crystals. (Photo Texas Technological College)

Undergraduate Research Participation

The program of Undergraduate Research Participation encourages institutions to provide opportunities for able students to do essentially independent research under the guidance of competent research advisers. These students may participate as junior colleagues in research projects which are conducted by experienced scientific investigators or they may engage in independent study activities oriented toward the theoretical aspects of such subjects as mathematics, physics, physical chemistry, and astronomy. There is evidence that students who engage in this kind of research activity develop more rapidly in scientific maturity and scholarly competence than those educated only by conventional classroom techniques.

In fiscal year 1969 there were 448 grants, amounting to $3,716,393, for undergraduate research participation. These funds provide training for 3,346 undergraduate students.

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PRE-COLLEGE EDUCATION IN SCIENCE

During the pre-college period the experience of students with science and mathematics is of crucial importance. At this stage the base for higher level study and understanding of these subjects is being formed. Both teaching and learning processes must be geared to the challenges of a scientific age. To help schools solve their science education problems the National Science Foundation stresses support for: modern instructional materials, guidance for schools and school systems in putting such tools to effective use, special training opportunities that will permit students to achieve their maximum learning potential, and supplementary education for teachers that will increase their teaching competence in subject matter.

NSF pre-college educational efforts of the past decade have made significant progress in the improvement of science and mathematics courses and curricula and the quality and effectiveness of teachers. Programs for recognizing and encouraging secondary school science students and for developing leadership in science education in school systems also have proved successful. But further progress is necessary, since changing conditions bring new needs.

Recognizing that effective use of teachers and new instructional materials in school systems requires the carefully planned assistance of science educators and supervisors, the Foundation substantially increased funds for the Cooperative College-School Science Program in fiscal year 1969. An encouraging feature of this support, evident in both the Cooperative College-School Science Program and the Academic Year and In-Service Institutes for Secondary School Teachers Programs, is that school systems are showing greater interest in, and making increased financial contributions to, these projects. In some instances, financial assistance has also been provided by industrial concerns.

Academic Year and In-Service Institutes programs are now supporting a variety of projects aimed at developing specialists, coordinators, and supervisors with competencies directly relevant to school needs. Through the course content improvement program, continued and increased support is being given to workshop projects for training college and school resource personnel who are experts in the various new science and mathematics materials. The training is being conducted at a time when the new materials are beginning to be used extensively in the schools, and upon completion of training, these individuals will serve as leaders in In-Service and Cooperative College-School Science Projects. This kind of activity provides a direct link between the course development efforts and the teacher education and school implementation programs for improvement of science instruction.

A brief report of NSF pre-college education in science activities follows.

Improvement of Instructional Materials

To provide for the development of up-to-date instructional materials for classroom use, the Foundation encourages leading scientists, educators, media specialists and other experts to engage in collaborative efforts for the improvement of course content. The impact of their work has been widely felt in schools across the Nation; an estimated 24 percent of the some 14 million students enrolled in grades 9 through 12 in the fall of 1968 were using curriculum materials in science or mathematics developed under NSF support. These materials include texts, supplementary readings, laboratory experiments and manuals, laboratory equipment, and films and other visual aids. Course improvement may involve only small segments of courses or may encompass an entire course or course sequence incorporating new approaches to specific subject matter. Among the fields covered are: biology, physics, chemistry, mathematics, earth science, engineering, and social science (anthropology, geography, and sociological resources for social studies).

While widespread adoption of NSF-supported course materials is one indication of their success, the problem of effective use of the materials is a matter of continuing concern. Since the new materials differ in content and approach, training of teachers and providing assistance to schools in the implementation of these materials have been given increased emphasis by the Foundation. This year grants were awarded for 36 projects for implementing project materials through development of resource personnel capable of helping schools in the adoption of materials of the schools' choice. These projects provided opportunities during the summer of 1969 and the following academic year for nearly 1,400 college faculty, science supervisors and administrators, and teacher-leaders to become familiar with, and gain experience in, teaching one or more science curricula at the pre-college level. Training opportunities were offered primarily to those who could be expected to train others rather than offered to those who will be involved only in teaching their own classes. Sources of support for future teacher-education activities of those trained include State and local funds as well as Federal support.

Due to budgetary limitations the funds for the Course Content Improvement Program were reduced from approximately $13.5 million in fiscal year 1968 to approximately $8 million in fiscal year 1969. Only a small number of new curriculum development projects could be supported in view of the large requirement for funds to support ongoing meritorious projects. Grants awarded in fiscal year 1969 to start new projects include support for: A senior high school 3-year interdisciplinary science sequence (Portland State College, Oregon); a junior high school 3-year interdisciplinary science sequence (Florida State University); a ninth grade course in mathematics (University of Illinois); and films for the LIVING BIOLOGY FILM SERIES (City College of New York).

Among the long-term projects receiving support this year for completion of substantive work were:

- the HIGH SCHOOL GEOGRAPHY PROJECT (American Association of Geographers)
- the EARTH SCIENCE CURRICULUM PROJECT (American Geological Institute)
- A STUDY OF MATHEMATICS ACHIEVEMENT IN GRADES K–3 (Stanford University)
- the HARVARD PROJECT PHYSICS (Harvard University)—Funded jointly by USOE and NSF.

In addition, modest fiscal year 1969 grants were made for curriculum conferences and video tapes for teacher training.

The Foundation believes that keeping instructional materials in step with current and future classroom needs also involves continued support for such activities as planning and coordination projects to stimulate the initiation of appropriate curriculum development efforts, projects aimed at increasing the practicing teacher's ability to deal with new approaches and teaching techniques, and projects for investigating the learning process as a basis for the development of improved curriculum materials.

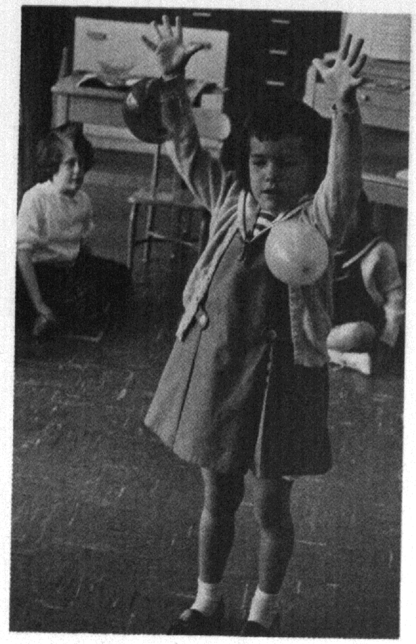
COOPERATION IN SCHOOL SYSTEM IMPROVEMENT

The Cooperative College-School Science Program provides for collaboration between the teaching and administrative staff of a school system and the science faculty of a college or university in bringing about improvement in school science programs. Projects are supported through grants to institutions of higher education, but the school systems are equal partners in the initiation, design, and operation of the projects. Most projects include on-campus summer training for teachers, followed by an academic-year phase in which the colleges assist the schools in a consultative and advisory role during the first year of the new program's utilization in the classroom.

Activities conducted under this program by grantee institutions vary greatly in nature and scope. For example, projects may focus on implementation of new course materials for secondary schools, improvement of elementary-school science curricula, assistance to a local school system or to systems representing a wide geographical area, or improvement of instructional programs for educationally disadvantaged students.

Cooperative College-School Science Projects in operation this year total 146. These projects provide training for more than 7,000 teachers; some include students who serve as members of demonstration classes and thus assist the teachers in learning to present new subject matter and instructional materials. About 1,500 students will participate in projects awarded support in fiscal year 1969.

A current project at the University of California, Berkeley, illustrates an NSF improvement effort for elementary school science. To assist the Berkeley school system, the university provided science training to 50 teachers from the Berkeley schools for a 4-week period in summer 1969. The training has prepared the teachers to introduce the curriculum of the Science Curriculum Improvement Study to their classes during academic year 1969–70. Through meetings held during the academic year for the teacher-participants and through classroom assistance, the university will help the teachers implement the new materials. The schools will furnish the necessary laboratory kits to make the implementation possible and the teachers who are trained will



Are both balloons filled with air? Kindergarten children are introduced to the study of gases in a course-content improvement project. (Photo University of California, Berkeley)

Watching mice in a pressurized chamber with a magnifying glass this summer science student estimates respiration rate of the animals. Project was a study of the effect of high altitude on the heart. (Photo Roscoe B. Jackson Memorial Laboratory)

undertake to assist other staff members of their schools so that they, too, can gain experience with the new curriculum.

Several fiscal year 1969 grants provide for implementation projects that will have a wide geographical impact. For example, some projects operating in St. Louis, Chicago, New York, and Philadelphia will train teachers in the use of Madison Project mathematics materials. Similarly, projects using materials produced by the University of Illinois Committee on School Mathematics (UICSM) will provide instruction for implementing UICSM materials in schools located in Hawaii, Philadelphia, and Los Angeles-San Bernardino, Calif.

A current mathematics project conducted by Michigan State University illustrates an effort for improving instruction for educationally disadvantaged students. The University will undertake to train teachers from inner-city secondary schools of nine urban communities in Michigan. The project provides a summer phase for student-participants as well as teachers. Association with students from the inner city will enable the teachers to gain experience with fresh instructional approaches to such learners. The project also includes a substantial series of academic-year activities for the further training of teachers. This project is supported jointly by the Foundation and USOE.

In fiscal year 1969 approximately $5 million was awarded to support 131 of the 146 projects in operation. This represents a substantial increase over last year's support of 84 projects, totaling nearly $3.4 million.

Activities for Secondary School Students

Among the large population of U.S. secondary school students there are a relatively small number who have the intellectual ability and personal traits needed for developing into scientists and engineers of the next generation. The Foundation seeks to identify those who possess such potential and to reinforce their motivation for pursuing careers in science.

Through the Student Science Training Program (Pre-College) carefully selected students are given opportunities to associate closely with scientists active in education and research, and thus to clarify their conceptions of a career in science and, at the same time, add to their knowledge of science. In 1969 this program provided training opportunities for 4,158 highly able secondary school students to spend from 5 to 10 weeks on the campus of a college, university, or research institution to engage in college-level special studies or to act as members of a research team. An additional 1,692 participants are undergoing comparable training as Saturday commuters during the academic year 1969–70. Grants for this program totaled $1,872,516, a decrease of 7.4 percent below the fiscal year 1968 level. The number of projects supported was 112, as compared with 139 in the previous year. Budgetary limitations necessitated the decrease in support.

In addition to the Student Science Training Program activities, a variety of projects benefiting secondary school students were awarded Foundation support in fiscal year 1969 (24 grants amounting to $166,157). These include science seminars, the presentation of student papers before Junior Academies of Science, a mathematics talent search, and various other efforts. The academic community has shown a strong interest in such special activities.

Pre-College Teacher Education Activities

Sound instruction in modern science and mathematics requires fully competent teachers. Consequently, upgrading the subject-matter knowledge of science teachers has been a major concern of the Foundation since its early days, when many secondary school teachers found that their science training of an era ago was grossly inadequate for teaching the science and mathematics of today.

While the quality of science instruction has been vastly improved through NSF-supported teacher training institutes and projects of the last decade, a critical need for continued supplementary training remains. Among the factors bearing on the problem are:

- science and mathematics curricula taught in the schools continue to be upgraded, due largely to the influence of NSF-supported course content improvement;
- school systems continue to employ not-fully-qualified teachers because the regular teacher-training programs of colleges and universities can supply only about 15,000 certificated teachers annually to fill 28,000 net vacancies covering expansion of science offerings and replacement of those leaving teaching;
- scientific research and scientific knowledge continue to expand and teachers are expected to keep their knowledge current;
- demands for trained science supervisors and other leaders in science education, needed to help implement the many school improvements resulting from massive Federal aid programs, continue to increase; and
- science teaching is being upgraded as a profession for which graduate training in subject matter is a requisite.

The total NSF program of supplementary training for pre-college teachers has been designed so that individual projects will assist in coping with one or more of these existing conditions and the total array of projects will provide overall assistance, with appropriate balance of subject fields, geographical location, and school level.

Sequential programs designed to offer graduate training, often leading to a master's degree, have been somewhat increased. More attention is being given to the training of supervisory personnel. Additional institutes designed especially to meet the needs of junior high school teachers are being supported. At the same time, fewer multiple-field institutes designed for the all-purpose teacher of several subjects are being supported; this reflects the increased specialization of teaching assignments which accompanies school expansion and consolidation and the increased emphasis on science.

The major trend in 'pre-college teacher education activities has been to increase substantially training opportunities directly related to the implementation of specific new courses. However, whether institutes focus on new curricular materials or traditional courses, increased emphasis on applicability of materials and implementation in the classrooms of the teacher-participants characterizes the institute program in general.

The subject-field coverage of the total program of institute projects again closely approximates the national distribution of teacher assignments within the natural sciences and mathematics. Noteworthy this year also is an increase (from 52 to 58) in institutes and conferences in computer science.

Diversity is the hallmark of the 1969 program of Summer Institutes for Secondary School Teachers. The duration of these institutes ranges from 4 to 12 weeks, the number of teacher-participants from 10 to 180, the level of work from introductory to graduate, the subject-matter fields from single-field to many combinations of fields, and the teaching level from junior and senior high school to advanced placement work.

Summer institutes in biology illustrate the diversity of projects in a single field. Each of the 56 biology institutes receiving support this year is of a different nature. For example, both Northern Arizona University and Michigan Technological University offer ecology institutes. The Northern Arizona program utilizes a general approach to the study of ecology, including such topics as biogeography, biotic relationships, aquatic and marine aspects, applied ecology, and human ecology. Michigan Tech, on the other hand, emphasizes quantitative techniques employed in modern ecological investigation, and each teacher-participant will construct simple ecological equipment which he will use in the program and which will later be used by students in his classes during the academic year.

An unusual summer institute is being conducted in physical science this

Table 10
Pre-College Teacher Education Activities
Fiscal Year 1969

Prrograms	Proposals received			Grants awarded		
	Number	Participants	Amount	Number	Participants	Net obligations
Institutes for secondary school teachers:						
Academic year institutes	77	1,776	$12,166,097	67	1,367	$8,300,702
Summer institutes	698	28,636	35,503,513	411	17,455	18,999,128
Summer conferences	31	1,010	456,102	15	438	200,772
In-service institutes	384	18,260	6,032,404	280	13,079	3,255,725
In-service activities	13	2,405	230,275	4	525	22,905
Subtotal	1,203	52,087	54,388,391	777	32,864	30,779,232
Supplemental projects for other pre-college personnel	8	45	86,592	4	40	30,519
Total	1,211	52,132	54,474,983	781	32,904	30,809,751

Note.—Total number of proposals received and grants awarded include double count on combined activities: i.e., 25 combined summer-inservice institutes, 1 combined summer institute and supplemental project and 1 combined summer conference and supplemental project.

year by Pan American College, Edinburg, Tex. It focuses on the problem of underprepared junior-high school teachers drawn from the Mexican-American population of the lower Rio Grande Valley. This institute is specifically designed for them since many of these teachers encounter language barriers and cultural differences that constitute problems for them if attempting to participate in other institutes covering this field.

Typical of four summer institutes for science supervisors being supported this year is one at the University of California, Berkeley. This institute is designed specifically for science departments heads and supervisors to acquaint them with recent developments in physics, chemistry, biology, and other science areas as they relate to the total secondary-school science program.

A combined Summer/In-Service Institute for upgrading the scientific backgrounds of local sociology teachers and to assist them with implementation of new curriculum materials in Sociological Resources for the Social Studies is being conducted this year by the University of Michigan, Dearborn, with NSF support.

There were 427 Summer Institutes for Secondary School Teachers awarded support in fiscal year 1969 (17 of these received partial support from other agencies, 14 being funded jointly by the Atomic Energy Commission and NSF).

Academic year institutes receiving NSF support in fiscal year 1969 totaled 67. All provide for a full school-year of in-depth training in science and mathematics; 24 have special major objectives. Of the latter group, 10 institutes address themselves specifically to the problems encountered by the junior high school teacher as he moves from the general science approach to the implementation of the new course content materials designed for the junior high school. Seven institutes provide training for science and mathematics specialists, coordinators, or supervisors, with some designed for individuals already engaged in such work, and others aimed at teachers seeking to undertake supervisory work. Three institutes focus on problems of replacing the in-service teacher so that he can take advantage of the training afforded by an academic year institute with the least possible dislocation in the operation of his home school. In the process, all three projects make use of intern teachers who also receive intensive subject-matter training prior to embarking on their careers in secondary school science and mathematics. The remaining four institutes are concerned with one-of-a-kind projects, including the special training of secondary school mathematics teachers for service in inner-city schools and assistance to teachers in the preparation and use of computer-assisted instructional materials in science education.

The major themes running through 1969–70 In-Service Institutes Program are the continuing search for ways of reaching the approximately 50 percent of the Nation's secondary school science and mathematics teachers who have had no institute experience, and the utilization of in-service institutes as a vehicle for the implementation of curriculum revisions.

A recently supported In-Service Institute approach focuses on the search for means of reaching teachers who are unable, for various reasons, to avail themselves of the training opportunities afforded by institutes conducted along the more conventional lines of instruction. Presently the investigation is concerned with the utilization of television.

Several in-service projects supported in fiscal year 1969 provide for State educational officials to play an important role in helping to plan institutes which have a statewide orientation. These usually involve the participation of groups of colleges and universities and are characterized by central coordination.

In the 1969–70 school year 282 NSF-supported In-Service Institutes will involve more than 13,000 participants. These include, at off-campus centers or regional campuses, about 2,800 teachers who do not have university instruction immediately accessible.

Table 10 provides a statistical summary of the pre-college teacher education activities, fiscal year 1969.

Special Projects in Pre-College Education in Science

This program encourages the development and testing of imaginative approaches to science education problems at the pre-college level. Support is provided for small-scale experimental projects, usually one-of-a-kind efforts. This year 18 such projects were supported for a total of $393,602.

The unique nature of these activities is illustrated by a few of the following current projects:

- A project being conducted at the University of Nebraska is attempting to mesh the content of the Physical Science Study Committee program and the Chemical Education Material Study program into a four-semester physical science course. Through this project existing course materials will be modified to meet local needs.
- An unusual collaborative effort, involving Bridgewater State College, Bridgewater, Mass., the State Department of Education, nine State colleges, and the University of Massachusetts, is seeking to improve elementary school science curricula throughout Massachusetts.
- A project being conducted at the Oregon Museum of Science and Industry will enable 60 secondary school students from Portland area schools to engage in research-type project work under the supervision of museum personnel and with the assistance of practicing scientists and engineers with whom the students will consult.

Special projects serve an important purpose in the improvement of pre-college science education. The experimental activities which prove to have significant potential for increasing the quality of science instruction can lead the way to efforts of larger scope and impact.

Public Understanding of Science

Projects for public understanding of science seek to increase the U.S. citizens' knowledge and appreciation of science through various means. This is especially important at the present time because of the numerous problems confronting our society in which science is involved. Among the approaches are conferences for science writers, public science exhibits, television projects, training for science communicators, and curriculum development. Some recent activities aim at increasing the awareness of the social and cultural consequences of science and technology and try to explain the relation of science to other intellectual endeavors.

In fiscal year 1969 the Foundation awarded 13 awards, amounting to almost $200,000, for public understanding of science projects.

Institutional Programs

The Foundation conducts a number of programs in support of institutions or their subdivisions, both for strengthening and sustaining academic science. There are five programs designated as such. They are Institutional Grants for Science (IGS), Graduate Science Facilities (GSF), University Science Development (USD), Departmental Science Development (DSD) and College Science Improvement (COSIP). The first two are to a large degree sustaining programs; the latter three are developmental in nature. IGS provides flexible funds for institutional use on a formula basis; GSF funds are awarded on a matching basis for construction or renovation of facilities; USD and DSD provide support principally for the improvement of graduate education and research, and COSIP principally for undergraduate activities.

Within the institutional relations activities there is an architectural group whose function is to provide evaluative services to the Foundation in matters dealing with the construction and renovation of laboratory facilities. This group also provides similar advice and information to academic institutions and pertinent professional societies. In fiscal year 1969 slightly more than half of its activities were in support of the graduate science facilities program and the remainder of its efforts were shared with university science development and the specialized facilities programs of the Foundation.

The following table (table 11) summarizes Foundation obligations for instituitonal programs in fiscal years 1968 and 1969.

Two major developments during 1969 served to reflect the growing concern with the need for institutional support per se, as distinct from Federal support of individual scientific research and education projects in the nation's institutions of higher education. First, the initial annual report of the National Science Board to the President and the Congress, "Toward a Public Policy for Graduate Education in the Sciences" (NSB 69–1), recommended among other actions "that there be inaugurated a substantial program of institutional sustaining grants . . . [and] . . . that there be established a substantial program of departmental sustaining grants." Further, the report recommended ". . . a substantial program of developmental grants . . . [and] . . . a substantial program of graduate facilities grants." With the exception of the departmental sustaining grant, a limited program in support of each of these recommendations already exists within the Foundation; the

Table 11

Obligations for Fiscal Years 1968 and 1969

(Millions of dollars)

Program	Fiscal year 1968		Fiscal year 1969	
	Number of awards	Amount	Number of awards	Amount
Maintenance of institutional strength:				
Institutional grants for science	497	$14.2	(1)	(1)
Graduate science facilities	50	17.8	14	$6.0
Development of science capability:				
University science development	9	29.6	9	23.1
Departmental science development	22	12.0	15	8.6
College science improvement	55	9.6	74	8.8
Total	63.3	83.2	112	46.5

1 Timing of awards changed from June 1969 to fall 1969. Hence the program was temporarily suspended in fiscal year 1969.

problem is primarily one of magnitude. Secondly, Congressional proposals continue to reflect considerable interest in formula grants as one means of Federal financing scientific activities in higher education. Hearings were held in February 1969 on a revised version of the Miller-Daddario bill (H.R. 35). The bill, modified since the hearings and reintroduced as H.R. 11542, provides for a national program of formula-computed institutional grants to be administered by the Foundation, and authorizes first-year funding of $400 million.

Despite these developments, the year was one of major fiscal retrenchment for institutional programs, reflecting the overall limitation on funds available to NSF. Operations of the individual programs during fiscal year 1969 are described in the following sections.

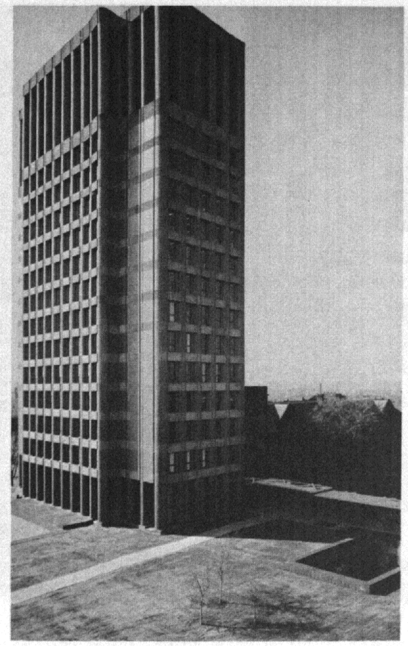
INSTITUTIONAL GRANTS FOR SCIENCE

The Foundation program of institutional grants for science provides funds for the general support of science in U.S. colleges and universities. Because of the freedom of campus officials to determine the use of the funds, the institutional grant funds, which may be spent for any direct costs of science programs, are uniquely adaptable to local needs and opportunities.

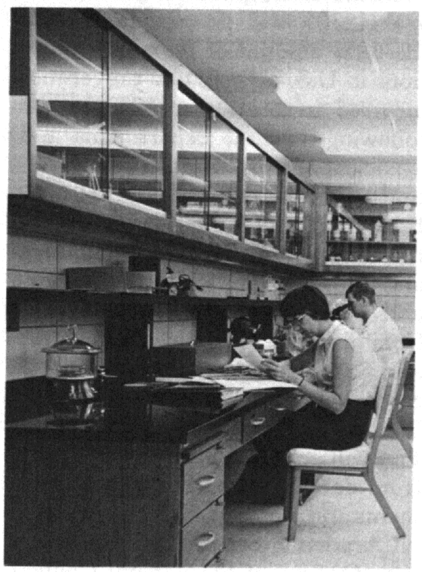
Late in 1968 the Foundation informed college and university presidents of a major change in the administrative procedure for the award of institutional grants. Instead of making the grants in June as in previous years, on a formula based on NSF awards alone, the Foundation would make the awards in the fall of 1969 on a broader base of research awards from several Federal departments and agencies. As a result of the change in the date of making awards, the Foundation incurred no obligations for institutional grants in fiscal year 1969 except for amendments to 1968 awards.

The important change in the program is not the time of making awards, which is merely a shift in schedule necessitated by other factors, but rather the new base to be used in computing the grants. For several years, the Foundation had planned to include research awards of other Federal agencies in the institutional grants base, but in order to avoid overlap with the formula-grant programs of the National Institutes of Health (NIH), the move was deferred. Changes in the NIH program of general research support in fiscal year 1969 made it possible for the Foundation to put the planned extension into effect.

Institutional grants in 1969 (fiscal year 1970) will be computed from the total amount of research obligations to U.S. colleges and universities incurred in fiscal year 1968 by the following Federal departments and agencies: Departments of Agriculture; Commerce; Defense; Health, Education, and Welfare (exclusive of the Public Health Service); Housing and Urban Development; Interior; and Transportation; Atomic Energy Commission; National Aeronautics and Space Administration; National Science Foundation; and Office of Economic Opportunity. The Foundation will compute institutional grants from data reported by these departments and agencies to the Committee on Academic Science and Engineering (CASE) of the Federal Council for Science and Technology. In addition to research obligations, the computation base will continue to include awards under Foundation programs of undergraduate research participation and research participation for college teachers. As in earlier years, the grants will be calculated by applying a graduated arithmetical formula to the total amount of an institution's appropriate awards. The formula will provide 100 percent of the first $10,000 of an institution's base figure, and lesser percentages



Kline biology tower at Yale University. (Photo Yale University)



Bessey Hall, botany and forestry research building at the Iowa State University, and a corner of the cytology research laboratory. (Photo Iowa State University)

thereafter; it is expected that the largest institutional grant will be approximately $150,000. Substantially more colleges and universities will qualify for the grants under the expanded program.

Since the beginning of the program in fiscal year 1961 the Foundation has awarded $79.4 million in institutional grants to approximately 750 colleges and universities.

GRADUATE SCIENCE FACILITIES

The Graduate Science Facilities Program provides assistance for the construction and renovation of graduate academic facilities for research and graduate education in all fields of science (except the clinical sciences) and engineering. The program, established by the Foundation in fiscal year 1960 to help maintain and strengthen academic institutions of established merit, has provided $182 million for facilities costing approximately one-half billion dollars. It is estimated that these facilities are accommodating in excess of 36,000 academic research and training personnel. All grants awarded by the program require that the recipient institution provide, from non-Federal sources, at least 50 percent of the cost of the grant-supported project. In some instances the program follows a grant procedure wherein only a portion of the award is made immediately available for planning purposes, with the remainder made available upon receipt of satisfactory documents indicating that the project could be accomplished substantially as proposed. This procedure has proven effective and will be applied to more facilities grants in the future.

During fiscal year 1969 a total of 30 proposals, requesting an average of over $1.0 million was submitted. Because of the reduction in funds available, the Foundation limited the maximum size of new grants to $750,000. Grants of this size could be considered only contributory rather than matching. Nevertheless, it seemed desirable to limit the size of each grant in order to increase the number of institutions assisted.

Fourteen grants totaling $6,250,000 (gross obligations) were awarded to 13 institutions in 11 States. The size of the average grant was $446,000. Although this was a 26-percent increase over last year's average size, it was in response to a 34-percent increase in the average dollar amount requested in fiscal year 1969.

Federal agencies supporting construction projects at universities and colleges have been working together since 1966 to equalize differences in their proposal and grant administration policies. As a result of this effort, a series of recommendations has been accepted by member agencies of the Federal Council for Science and Technology. In addition to these recommendations, additional agreements were reached by the Foundation and the Department of Health, Education, and Welfare to equalize various allowances in facilities grants.

A Foundation study of estimated needs for graduate science facilities during the period fiscal years 1968–73 indicates that an average of $440 million per year will be required for the construction and remodeling of such facilities if adequate space for the increasing number of academic research and training personnel is to be provided. The total estimated Federal expenditure required to meet these needs amounts to $250 million per year.

SCIENCE DEVELOPMENT

University Science Development

The University Science Development Program is assisting a number of universities to implement plans designed to improve significantly the quality of their scientific research and education programs. This year marks the fourth complete year since the first few of these development grants were awarded. Some institutions have now completed work under their initial grants and have been awarded 2-year supplementary grants to finish initially proposed 5-year plans for upgrading their scientific programs.

In fiscal year 1969 the Foundation obligated $23.1 million through the university science development program. Initial grants amounting to $8.2 million were awarded to two institutions: New York University and the University of Pittsburgh. Supplementary development grants totaling $14.1 million were granted to six institutions: Polytechnic Institute of Brooklyn, the University of Florida, the University of Southern California, Washington University, the University of Arizona, and the University of Virginia. One institution, Kansas State University, received a 3-year special development award of $0.8 million. Special awards of this type are similar in concept to university science development grants, but the development objectives are more limited in scope.

To date, 31 institutions have received university science development awards totaling $146.4 million, and seven institutions have received special science development grants amounting to $6.4 million. In accordance with plans developed by the institutions, Foundation funds have been allocated, in aggregate, as follows: personnel (faculty, postdoctoral scientists, graduate and undergraduate students, technicians, and clerical staff), 41 percent; equipment and supplies, 35 percent; and facilities (renovation and new construction), 24 percent.

Since its inception, the program has sought to encourage universities to engage in realistic planning for improvement of the quality of their scientific capabilities. The Foundation, in its study and review of institutional development plans, has attempted to identify those plans which take account of institutional strengths and weaknesses and which chart development goals that are both meaningful and attainable. The role of the institution is to blueprint the pathway toward outstanding programs in academic science. Further, institutional planning must include thinking through ways of strengthening all of the parameters which support quality developments—administratively, academically, and fiscally. Finally, institutions which hope to participate in university science development awards must be willing to make commitments of their own resources to their plans.

Although it is clearly too soon to assess fully what has been accomplished through the program, a number of things are evident:

First, academic institutions can construct plans which set forth meaningful and attainable goals. Almost all of the universities which have completed the initial years of their development grants have been able to adhere closely to such plans and to achieve objectives which were identified at the time proposals were written. Some deviation from plan has occurred, but this was expected, particularly in the light of new opportunities unforeseen prior to developmental work under the grant. But, for the most part, faculty development, augmentation of professional staff, and the ability to attract promising graduate students have proceeded in line with plans.

Second, it can be demonstrated that most institutions contributed from their own resources at least as much as they had initially projected. In most cases, university contributions to their development plans exceeded initial projections. This observation lends strength to the belief that what is being accomplished through the program is far more than the dollar contribution of the Foundation.

Third, there are indications that a university science development grant has both catalytic and synergistic consequences. On the one hand, the grant is an instrument whose characteristics of broad-base institutional support, resource flexibility, and prestige make possible achievements which otherwise might well be unattainable. Thus the grant is a catalyst. On the other hand, the grant complements existing forms of support and tends to attract additional support to the institution as a whole and to individual scholars within it.

Fourth, and most importantly, many of the universities which have progressed to the point of seeking supplementary developmental support have been able to demonstrate significant progress in improving the quality of their scientific research and training programs. This is the result the Foundation is seeking to achieve.

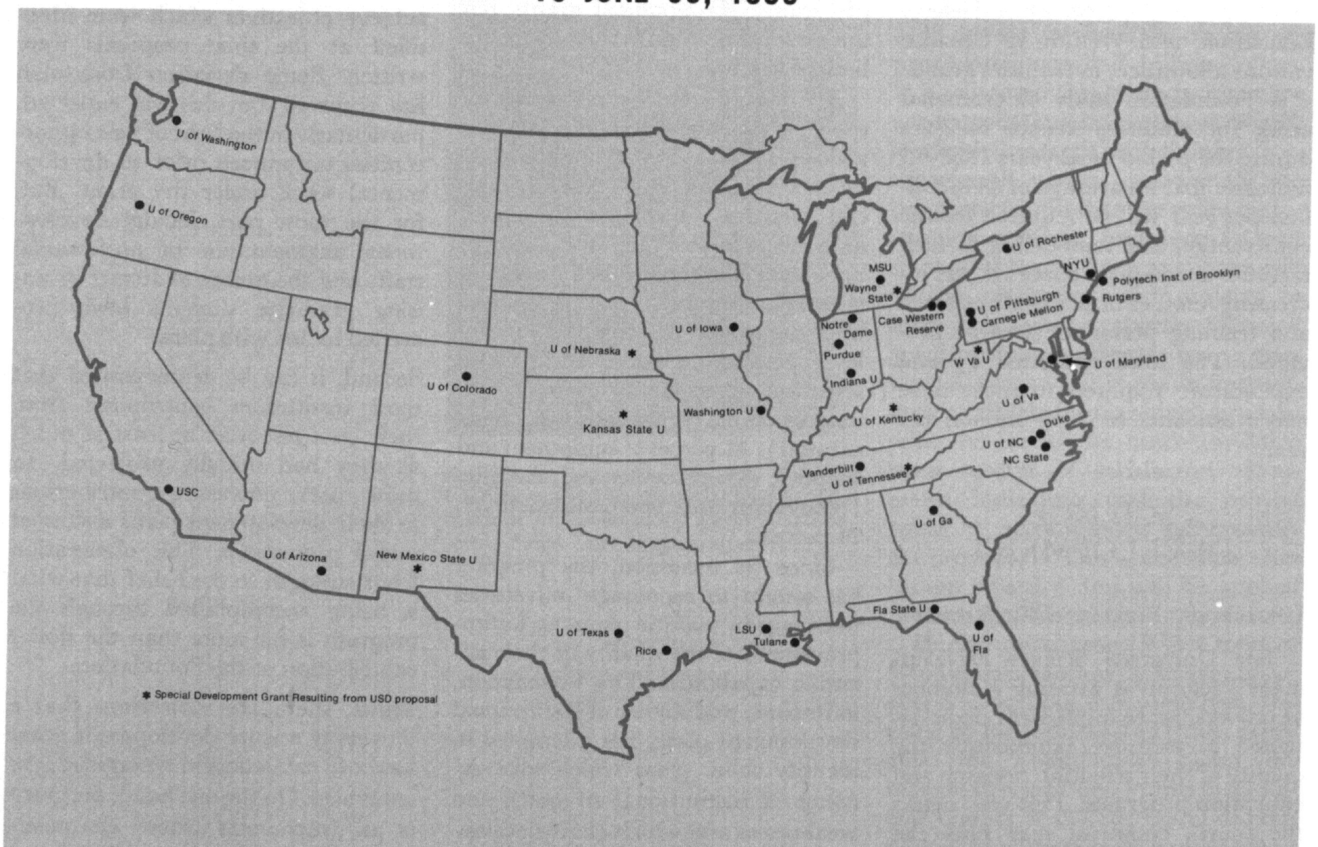
Departmental Science Development

The Departmental Science Development Program aims principally at improving the quality of graduate science, education and research, and strengthening the Nation's educational resources for science and engineering in as many regions and populations centers of the Nation as possible. This program focuses on the department, area of science (including interdisciplinary areas), or some other subunit of an institution's organizational structure. Special emphasis is placed on those departments with the greatest potential for development and the program anticipates that each activity supported will stimulate other parts of the institution to higher levels of quality and productivity, thereby increasing the institution's stature and visibility in the competition for available manpower and resources.

During the past fiscal year, $8,634,670 was obligated for departmental development in 15 institutions. This was seven awards and $3.5 million less than the previous year. Thirty-six proposals were received during the year and 19 proposals were declined or withdrawn during this same period. To a large degree the grants and declinations of fiscal year 1969 were based on proposals submitted in the previous year.

From 107 proposals received to

UNIVERSITY SCIENCE DEVELOPMENT GRANTS TO JUNE 30, 1969



date, 41 awards have been made and an almost equal number withdrawn or declined. This grant action has involved the obligation of $22.6 million, averaging $550,000 per award.

The 41 grants made to date were distributed among 39 institutions, Clark University and Rensselaer Polytechnic Institute having each received a second departmental development award. The University of Nebraska has received both a special science development award and a departmental science development grant. Awards have been made to institutions in 24 States. In 10 States more than one award was made; three were made in Texas and Pennsylvania, seven in New York, two in Ohio, California, Massachusetts, Michigan, Illinois, Wisconsin, and Utah. The 41 awards were distributed to institutions in 21 major metropolitan areas—population centers in excess of 250,000. Multiple awards were made in several of these centers, e.g., New York, Milwaukee, Philadelphia, Worcester, Chicago, and Albany-Schenectady.

Within the group of departmental science development institutions are representatives of every type of the Nation's universities. They range from some of the smallest (Bryn Mawr and Wesleyan) to some of the largest (Texas A. & M. and the City College of New York); they include institutes of science and technology (Rensselaer and Lehigh), consortia (Claremont), municipal (Hunter), public (Oklahoma State), and private (Southern Methodist) institutions.

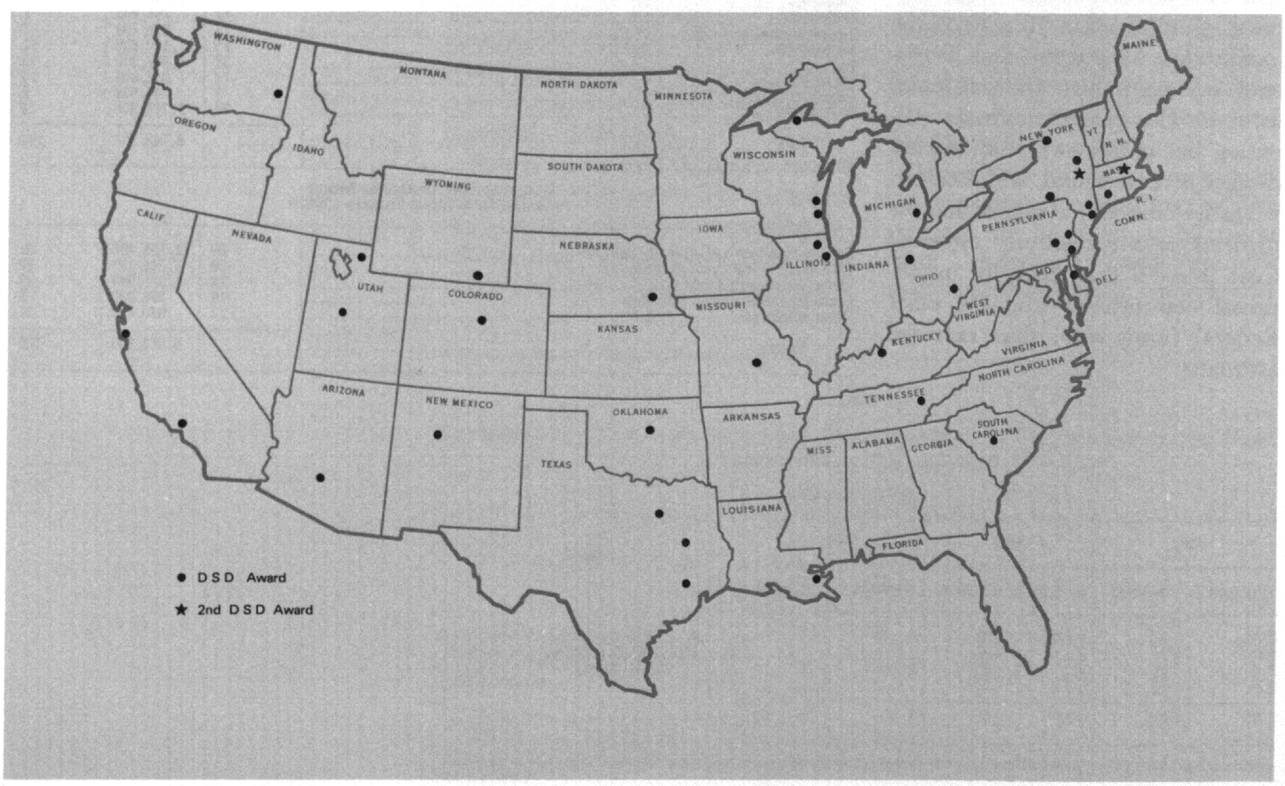
The awards are distributed fairly well by field or area of science, considering the fact that the selection process is to a large degree institution-dependent. The following table (table 12) shows the number of awards in each major field of science.

Table 12

Field	Number of awards
Physics	7
Engineering	7
Mathematics	5
Biological sciences	5
Multidisciplinary	5
Chemistry	5
Social sciences:	4
Psychology	(3)
Geography	(1)
Environmental sciences	2
Astronomy	1
Total	41

Program philosophy has stressed and continues to stress manpower improvement—especially faculty and graduate students—as the central element in departmental development.

DISTRIBUTION OF DEPARTMENTAL SCIENCE DEVELOPMENT GRANTS
Fiscal Years 1967—1969



Of the $22.6 million obligated to date, 63 percent of the funds were earmarked for manpower development—28 percent was for faculty and 18 percent for graduate student development. Postdoctoral support was held to 6 percent of the total; program philosophy maintains that postdoctoral associates are embryonic scientists still in training and thus should be associated closely with senior, highly productive scientists who are more likely to be in residence at the highly developed institution.

Equipment and supplies made up 24 percent of the obligation; renovation, 4 percent; computer costs, 5 percent; and library resources, 2 percent. The allocation for renovation, although small, is critical, for too frequently the development plan is totally dependent on the availability of additional or modernized laboratory facilities.

Total funds committed from all sources to the plans of the 41 awardees amounted to $125 million. The Foundation share of the commitment came to about 18 percent, the institution's 53 percent, and 29 percent was committed from all other sources. The commitments are estimates, but it is known from the few cases where technical and fiscal reports are currently available that the projections are relatively conservative; in each case, both the institutional commitment and the other Federal funds more than exceeded estimates.

College Science Improvement

The primary purpose of the College Science Improvement Programs, initiated in fiscal year 1967, is to accelerate development of predominantly undergraduate institutions and to enhance their capacity for continuing self-renewal. To improve the full range of undergraduate education in science, the programs are intended to benefit faculty and students, subject matter and methods of instruction, curricula and individual courses, facilities, equipment, and teaching materials. In fiscal year 1969, the original emphasis on individual institutional projects was expanded to include interinstitutional projects at 4-year colleges and cooperative projects for 2-year institutions.

In fiscal year 1969 the Foundation awarded 35 grants, totaling $5,953,-700, for individual institutional projects; eight grants, totaling $829,100 for interinstitutional projects in 4-year colleges; and 31 grants, totaling $1,980,900 for cooperative projects for 2-year colleges. Fiscal year 1969 grants for college science improvement programs thus totaled 74, amounting to $8,763,700.

Table 13
College Science Improvement Programs Activities
Fiscal Year 1969

Disciplines	Grants		
	Number	Amount	Dollars as percent of total
Disciplines Affected by Awards			
Biology	33	$1,592,600	18.2
Chemistry	30	1,247,600	14.2
Engineering	17	754,200	8.6
Environmental sciences	12	252,700	2.6
Mathematics	25	1,190,500	13.6
Physics	31	1,367,300	15.6
Social sciences	17	952,600	10.9
Interdisciplinary	5	204,900	2.3
Multidisciplinary	21	1,201,300	14.0
Total	----------	8,763,700	100.0
Type of Activity Affected by Awards Individual Institutional Projects—COSIP			
Faculty research and scholarly activities	29	$1,858,900	31
Local course and curriculum studies	29	1,743,700	29
Instructional equipment	28	1,371,900	23
Undergraduate student activities	16	338,800	6
Other activities	24	640,400	11
Total	----------	5,953,700	100

Computing Activities in Education and Research

In fiscal year 1969, the second year of its existence, the Office of Computing Activities administered a variety of programs and studies in support of the computing requirements of education and research, and continued to coordinate other programs of support for computing activities throughout the Foundation.

During the year ending June 30, 1969, the Office of Computing Activities considered 489 proposals requesting a total of $105,453,138. In response, the Foundation made 194 awards obligating $17 million for an award-to-request ratio of approximately 1 to 6. For those proposals resulting in awards, the amount awarded averaged approximately 50 percent of funds requested.

Awards were made to 153 institutions in 39 States and the District of Columbia. Fifteen awards were made to support studies or conferences concerning the use of computers in education and research. Seventeen were made for projects involving precollege education. Of the $17 million granted 96 percent was awarded to educational institutions or consortia, and 4 percent was awarded to nonacademic institutions.

Prior to the establishment of the office, the Foundation had provided support to university computing facilities and to research projects in computer science for over 10 years.

COMPUTING SERVICES

Perhaps the most striking feature of computing activities at academic institutions today is the growth of demand for sophisticated computing services in instruction. This phenomenon appears in the utilization statistics reported by university and college computing centers. It is reflected in changes of course offerings, and frequently in requirements for a programing course in the freshman or sophomore year of college. It also appears in the increased investment institutions have made from their own funds to provide academic computing services.

Institutional Computing Services

The Foundation institutional computing services program is the only Federal program offering institutional support, as distinct from individual project support, for the cost of academic computing services. In fiscal year 1969, $6.5 million was awarded to 23 institutions to assist with necessary expansion or initial installation of computing services. The grants ranged in size from $14,000 to $1.2 million.

An example of the importance of the institutional computing services program can be noted at Michigan State University, an institution with approximately 31,000 undergradu-

Table 14

Computing Activities in Education and Research Awards by Program Categories, Fiscal Years 1967, 1968, and 1969

[Millions of dollars]

Program	1967		1968		1969	
	Number	Obligations	Number	Obligations	Number	Obligations
Institutional computing services	27	$11.3	42	$10.6	23	$6.5
Education and training activities	----	----	39	4.5	81	4.3
Computer science research	21	1.4	25	1.6	35	1.6
Special projects*	----	----	67	5.3	55	4.6
Total	48	12.7	173	22.0	194	17.0

*Special Project activities are undertaken in all program categories and are described when appropriate in the accompanying text.

ates and 8,000 graduate students. The university operated a computing center which contained a large second-generation computer at an annual operating cost of about $1 million per year, as well as nine smaller special-purpose computers with annual costs ranging from $11,000 to $250,000 each. However, the demand for computing services for undergraduate instruction and for members of the university community who had not previously used computers was growing explosively. In 1 month in 1967–68, the computer center was used by 77 departments and institutes to process nearly 30,000 tasks, almost 60 percent of them for students in connection with course work. Also, financial support for computing from State appropriations, tuition, and income from sponsored research lagged behind the expenditures required.

To overcome these problems the university proposed to purchase a large third-generation computer and sought a grant from the Foundation to help provide financial stability while it developed other sources of support. A grant of $1.2 million for 3 years was made in fiscal year 1969. The figure below shows the history of support for computing at Michigan State.

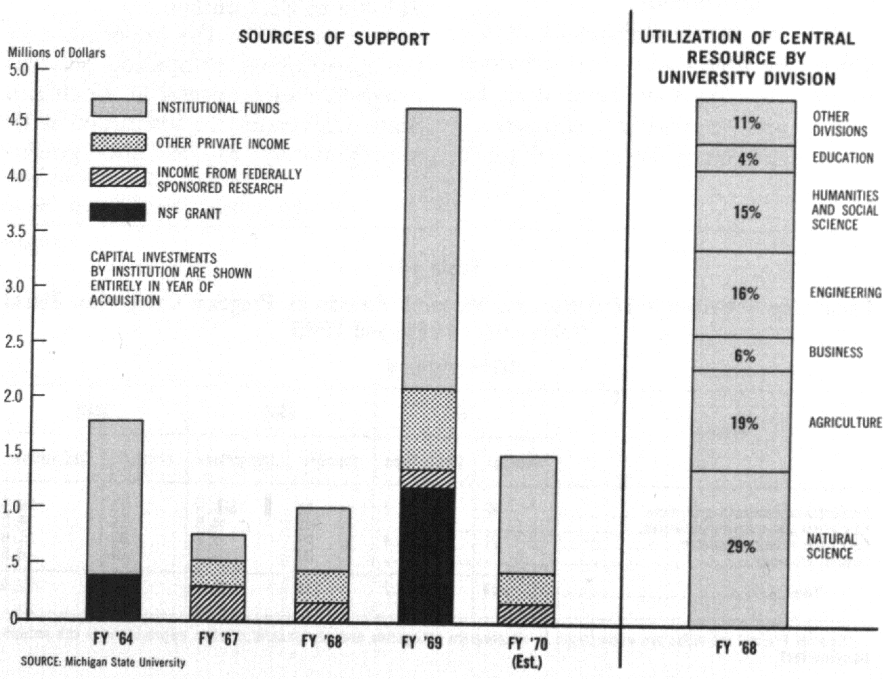
The Catholic University illustrates a different situation—one in which the existing machine had never been able to service more than a limited subset of campus requirements. Although there had been a computing center for several years, the primary equipment lacked the capability to handle major research problems, so faculty members had employed various expedients to secure service from Federal laboratories and other universities. Motivated by desires to eliminate this inconvenience to faculty and to expand computer use in undergraduate instruction, the university requested partial support for the purchase of a medium-scale modern computer. Final action on this proposal was a grant of $275,000 in partial support of a 3-year program.

Regional Computing Activities

Another interesting development in institutional support for computers is the formation of cooperatives, consortia, and other regional arrange-

Students at Michigan State University prepare their program decks for running at the computing center. (Photo Michigan State University)

MICHIGAN STATE UNIVERSITY COMPUTER CENTER



ments to help provide computing services for educational institutions. The Foundation, through its regional computing pilot projects, has been exploring the merits of these arrangements.

In fiscal year 1968, a major effort involved the inauguration of 10 regional computing activities. Typically, each was centered about a major university which provided computer services to a cluster of nearby colleges. These projects were designed to make effective use of the experience and equipment at universities to help colleges and a few secondary schools introduce educational computing to their students and faculty.

In fiscal year 1969, five additional regional experiments were established, to enlarge the range of models available for study and evaluation, with total awards of slightly over $2.1 million. Altogether, the regional centers now include 12 major universities, 116 participating colleges, and 27 secondary schools located in 21 States. The figure illustrates a project centered about the Illinois Institute of Technology (IIT), which serves nine participating institutions in Illinois and Wisconsin, and also shows the location of all of these Foundation-supported regional activities. In each of these activities there is a good deal of concern with faculty training, cooperation in the use of instructional materials, and sharing the results of experience with educational use of a computer.

EDUCATION AND TRAINING ACTIVITIES

Curriculum Development

The full impact of computers on education will not be felt until the modes of thought characteristic of computing are incorporated into curricula. Concepts such as the logic of programming procedures, the use of models, the interrelationship of complex events, and the uses of data are emphasized in computing and must inevitably affect the educational process.

A systematic approach to an exploration of the benefits of the computer in undergraduate study in chemistry has led to the support of a carefully selected set of projects. Donald Secrest of the University of Illinois is developing a number of experiments for an undergraduate physical chemistry laboratory in which a time-shared computer is an integral part. Samuel Perone of Purdue University, who has directed two summer faculty workshops in the use of computers linked to instruments for chemical measurements, is also concerned with uses in undergraduate chemistry laboratories. Since the computer is essential to the solution of theoretical as well as experimental problems, David P. Shoemaker of MIT is exploring ways to give the student access to computational services which include capabilities that result from applied numerical analysis.

A project designed to explore fundamental curriculum revision at the elementary school level is directed by Wallace Feurzeig of Bolt, Beranek & Newman in Cambridge, Mass. The goal is to demonstrate through classroom presentations that the teaching of the set of concepts related to programing can be used to provide a natural foundation for the teaching of mathematics, and indeed for logical thinking in general. A new programing language permits the expression of mathematically rich algorithms, both numerical and nonnumerical, but is so simple that it can be taught to second graders. Although it is premature to evaluate the significance of this experiment, initial results are encouraging.

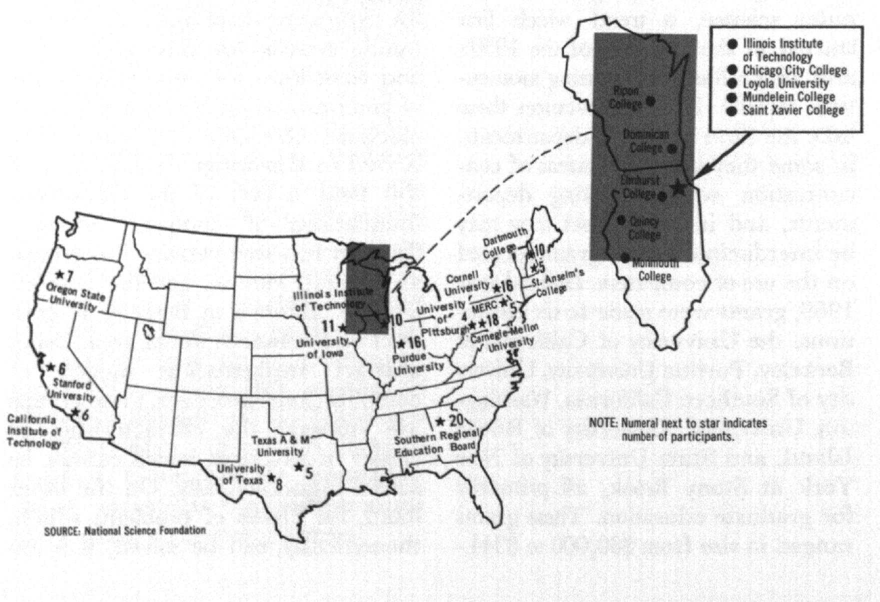
Training

The intimate relationship between curriculum development and training activities in many computer projects is well illustrated by the following example in statistics.

A grant to the University of North Carolina in fiscal year 1968 supported the cooperative efforts of the departments of statistics, psychology, and biostatistics in the development of data sets, collections of problems, and programs for use in teaching elementary statistics.

Programs were developed for several types of computing services including commercial time-sharing, a

LOCATION OF REGIONAL COMPUTING ACTIVITIES SUPPORTED IN FY 1968-FY 1969 AND SCHEMATIC OF ONE CENTER



SOURCE: National Science Foundation

large university computing center, and a small stand-alone computer. In the summer of 1969, the university organized a workshop for 32 teachers from colleges and universities to explain and demonstrate the results of the project. Foundation support will enable these teachers to use the materials developed at the university to integrate computer use in the teaching of statistics at their home institutions. This group of teachers will reassemble at the University of North Carolina in the summer of 1970 to evaluate their experience.

A different type of training project was conducted in the summer of 1969 in the Los Angeles area. Richard Bellman of the University of Southern California directed an experimental program in computing for underprivileged secondary school students that had an enrollment of 80 for a 4-week course. The curriculum included a mathematics class, a programing class, a programing laboratory, and instruction in the use of equipment. Another phase of the project involved 20 additional students, with nonscientific backgrounds, who received an 8-week course in data processing applications typical of hospitals and medical centers.

Computer Science Education

Many universities and colleges are initiating academic programs in computer science, a trend which first started in the last half of the 1950's and which has been gaining momentum rapidly. In some instances these take the form of formal departments, in some they constitute areas of concentration within existing departments, and in other cases they may be interdisciplinary programs focused on the use of computers. In fiscal year 1969, grants were made to six institutions, the University of California at Berkeley, Purdue University, University of Southern California, Washington University, University of Rhode Island, and State University of New York at Stony Brook, all primarily for graduate education. These grants ranged in size from $80,000 to $344,000 and totaled $1,028,600. Four of these awards will help initiate graduate programs in computer science and two will help strengthen programs that have existed for a few years.

RESEARCH ACTIVITIES

The Foundation supports research in three major areas, computer science, computer-based instructional technology, and computer applications.

Computer Science

The emergence of computer science as an academic discipline has been given impetus by the increasing complexity of computer systems. Although early workers in this field were trained in other areas, the growth of information about computers has been so great that the definition of computer science as a discipline and research area has been a natural consequence.

Today research workers in computer science are concerned with the basic understanding of the potential and limitations of computers; with improved design and more versatile components—in both hardware and software; and with the discovery of better ways of utilizing equipment. Among the research projects being supported are investigations of the properties of algorithms, languages for expressing these algorithms, computing systems for processing them, and techniques for improving means of communication between man and machine. One area of research that is vital to long-range development of this field is that of the theoretical foundations of computer science. Support has been provided to groups at Cornell, Purdue, and the University of California at Berkeley to conduct basic research in this area. Using abstract mathematical models of computational processes, these groups are studying the characteristics of classes of problems which cannot be solved algorithmically. On the other hand, for classes of problems which, theoretically, can be solved, it is ex-

This computer is creating pictures that can be seen with a third dimension—depth. The pictures generated on the screen by the computer have only the dimensions of height and width, but when viewed through the stereoscope mounted in front of the screen they merge into a single, realistically three-dimensional figure. (Photo Brown University) tremely interesting to obtain lower bounds for computational time and for storage requirements, and such bounds are being investigated.

Electronics technology appears to be approaching a point where the speed of computers of conventional design is limited by the speed of light. Thus, significant increases in computing power are likely to depend upon new highly complex machine architecture. Jacob T. Schwartz, at the Courant Institute of Mathematical Sciences, New York University, is studying highly parallel machine structures, where several tasks of a large computation are performed simultaneously. He is learning how the parallel units must communicate with each other and coordinate their actions. He is also measuring how much inherent parallelism there is in various computations and thus how much computational power is added by this type of design.

Instructional Technology

A popular impression of the computer's primary use in education is as a teaching machine. Experiments in the use of the computer to present flexibly controlled instructional material—often referred to as computer-assisted instruction (CAI)—or to provide the teacher with more direct information about student progress have shown exciting promise in certain applications. However, these experiments have also pointed to inadequacies in the current state of technology and to more fundamental inadequacies in our understanding of basic areas of learning.

An understanding of both the benefits and the limitations of CAI will depend on its being tested at different educational levels in a variety of circumstances. As part of a limited program of testing and evaluation, grants were made to Patrick Suppes of Stanford University in fiscal years 1968 and 1969 to study the effect of CAI on teaching programing and data processing concepts to 80 innercity secondary school students. This project will serve both to test the effectiveness of this technique in a difficult learning situation, and to collect data about the learning patterns of these students.

In this case, the students are located in San Francisco, Calif., and the instructional material is stored in a computer at Stanford University in Palo Alto, Calif. The choice of remote terminals was dictated by transmission costs: less expensive teletypewriters were used, although visual display terminals might have been superior from an educational viewpoint.

Careful evaluation of the obstacles inhibiting developments in this field led the Foundation to try a different approach in addition to specific project activities. This approach is to strengthen a few major centers to promote longer range basic research in instructional technology. The three centers supported in fiscal year 1969 are located at the University of Pittsburgh, Stanford University, and the University of Texas. Altogether six grants in computer-based instructional technology were made in fiscal year 1969 with total support exceeding $1.2 million.

Computer Applications

Although computers were first developed to assist with complex numerical calculations, it was soon realized that nonnumerical information could be coded and stored in the computer memory equally well and subsequently analyzed or altered by programed procedures. During fiscal year 1969, the Foundation made several grants for study of computer techniques for handling nonnumerical information. A grant will enable William H. Huggins of Johns Hopkins University to conduct research in computer graphic symbols. Another to John L. Clough of Oberlin College will support work on the synthesis of sound by computer. Still another to David L. Bonsteel of the University of Washington will aid the development of techniques for simulating visual experience in architectural space using computer graphics.

Sea Grant Programs

The National Science Foundation Sea Grant Program supports activities in research, education and training, and advisory services for development of the Nation's marine resources.

In fiscal year 1969, approximately $6 million was awarded by the Foundation for these purposes as shown in table 15.

Table 15

National Science Foundation Grant Program Awards Fiscal Year 1969

Category of grant	Number	Amount
Institutional support	7	$4,326,100
Project support:		
Interdisciplinary projects	5	878,500
Education and training	5	361,600
Applied research	6	377,000
Planning	6	45,865
Total	29	5,989,065

Although research results are not normally expected for a number of years after project initiation, the first 16 months of Sea Grant activity produced some striking accomplishments.

In February 1968, a project grant was made to investigators at Francis T. Nicholls State College, Thibodaux, La., to attempt management of natural shrimp stocks in marsh impoundments. While the brackish and freshwater marshes of the region are rich nursing grounds for shrimp, natural predators are a major factor in limiting shrimp population growth. Two ponds were built by the Louisiana Land & Exploration Co. as a contribution to the college's share of the project cost, and shrimp larvae were permitted to flow into the ponds from the surrounding marshes. One pond was left untouched, while natural predators, such as saltwater catfish, were destroyed in the other before the seasonal arrival of the shrimp larvae. Blue crabs, a marketable predator, were harvested during the shrimp growth period. Through this relatively simple program of predator control, the managed pond produced about three times the weight of shrimp surviving in the unmanaged pond. This result, at the halfway point in the project, shows promise both for increasing the offshore shrimp harvest and for the aquaculture of shrimp. A large commercial firm is already taking advantage of the research.

One of the first institutional Sea Grants was awarded to the University of Wisconsin in June 1968. Building on previous research there and by other Great Lakes universities, researchers supported by the Sea Grant Program located potentially valuable deposits of manganese pellets at Green Bay in Lake Michigan. Research into the minerology, abundance, and utility of the pellets, analogous to deep sea manganese nodules, is still in progress, but preliminary estimates indicate that the commercial value of this single discovery may equal or exceed the entire Sea Grant budget in the fiscal year of the grant.

Hawaiian tuna fishermen still use the method of chumming, or seeding the immediate fishing area with live bait fish, to attract tuna. The efficiency of this method is limited, since the bait fish, a species of anchovy, cannot survive for more than 3 days in the ship bait wells, thus reducing productive fishing time. With institutional Sea Grant support, the University of Hawaii Institute of Marine Biology has developed methods of extending the life of bait fish for up to 10 days. These methods include the design of improved bait tank systems employing more scientific techniques of aeration and water purification. Investigators are also examining less delicate fish species which might be effective for use as bait.

Other types of Sea Grant activity do not produce results so quickly, but their potential can be readily recognized. These include the development of new course materials in ocean engineering at Massachusetts Institute of Technology; a unique training program at Florida Atlantic University in which academic study in ocean engineering is supplemented by actual work experience with marine industry; and an extension service at Orgeon State University which has made substantial progress in assisting fishermen in development of a better insurance program for their equipment.

INSTITUTIONAL SUPPORT PROGRAM

In fiscal year 1969, two additional universities—the University of Miami and the University of Michigan—were added to those already receiving Sea Grant institutional support. The original six—Oregon State University, University of Rhode Island, University of Washington, University of Hawaii, University of Wisconsin, and Texas A. & M. University—were initially awarded institutional support in fiscal year 1968, and their programs of research, education and training, and advisory services continued to show progress in 1969. Planning grants, for assistance in developing Sea Grant institutional programs, were made to a consortium of institutions of higher education in North Carolina, and to Florida State University.

Research under the Sea Grant institutional program covers a broad spectrum of marine interests, ranging from legal studies to scientific research and engineering development involving many disciplines. At the University of Washington, for example, oceanographers, economists, political scientists, and lawyers are making a concentrated study of an embayment in Puget Sound to determine how it may best be developed for human use while maintaining the environment and living resources. In Hawaii, where a shortage of sand is critical, physical oceanographers, marine geologists, engineers, and biologists are working jointly on locating deep sand deposits, techniques for economical recovery, and understanding of the processes through which sand is produced by the coral reefs so that such processes can be maintained and protected.

Education and training are integral parts of institutional programs at various levels. At the graduate level, new courses have been developed by most institutions to expand the marine-related options available to all students, including those in the liberal arts and social sciences. The University of Rhode Island has instituted the Nation's first marine affairs graduate course, specifically designed for social scientists, international specialists, and administrators. For training of marine technicians, the Sea Grant institutions have enlisted the cooperation of 2-year technical institutes and junior and community colleges. Four such 2-year institutions have developed a unified training plan under the University of Washington Sea Grant, with each school training a particular type of technician. Texas A. & M. University has cooperative programs with two schools. Other institutions have single partners in marine technician training and are developing future programs with others.

Advisory service activities, to communicate results of scientific and engineering research to users, have increased. In most cases actual operations were delayed pending completion of training for extension agents. Oregon State University organized for extension services very quickly, introducing productive activity immediately by expanding existing cooperative extension services. New leadership reorganized the University of Rhode Island regional marine information service and began several new programs.

PROJECT SUPPORT PROGRAM

Project activities in fiscal year 1969 included four new technician training programs in various specialties and a project in ocean engineering education. Research grants included projects to determine the population biology of the California spiny lobster, the economic feasibility of a submerged buoyant pipeline for transporting natural gas through deep ocean water, investigation of seaweed extract effects on growth of plants, and management and utilization of estuarine resources.

Multidisciplinary grants, known as coherent projects, were awarded to the Virginia Institute of Marine Sciences, the University of California at Santa Barbara, and Humboldt State College, Calif., for broadly based research programs related to marine problems in their areas. In addition to two grants for planning major institutional programs, small grants were made to the Dade County (Fla.) Board of Public Instruction and the Washington Technical Institute, D.C., for planning and activities related to marine instruction and careers for innercity and other underprivileged youth.

Renewal awards for fiscal year 1969 included coherent projects at Louisiana State University for intensive aquaculture in marshes, and at Scripps Institution of Oceanography for graduate instruction and research in applied ocean engineering sciences.

In addition to their continuing studies of marine pollution, biologists at Lamont-Doherty Geological Observatory have initiated a new project exploring the use of nutrient-rich bottom water as a culture medium for plankton upon which commercially valuable organisms can feed. This aquaculture program is being conducted in tanks and in a pond at St. Croix in the Virgin Islands. The water is pumped from the ocean from various depths a short distance from shore.

Science Information

The Office of Science Information Service continued to support scientific and technical information activities during fiscal year 1969 through universities, professional societies, research institutes, museums, and other organizations. The Foundation's science information program is an essential aid to scientists and engineers, and helps ensure that their information services are able to adapt to changing conditions.

In fiscal year 1969, the Foundation awarded 118 grants and contracts, and obligated $10.7 million, with major emphasis on support of information systems development. Among the major accomplishments for fiscal year 1969 are the following:

1. Information systems development continued to make good progress. The formulation of a concept of a national information system for the geosciences was started. The definition of information system programs in physics and astronomy, psychology, and linguistics continued in the major scientific societies representing these disciplines.

2. The discipline-oriented information system based in the American Chemical Society reached a maturity which allowed the society to begin exploiting the data base, both to improve present services and create new ones.

3. As part of the Foundation's support for university-centered information systems, the University of Washington is developing a computerized data bank on treaty information contained in 550 volumes (8,641 treaties) of the U.N. Treaty Series.

4. The Science Information Research Centers at Georgia Institute of Technology and Ohio State University advanced in the development of research and training programs in the information sciences.

5. In the area of planning, coordination and cooperation, the report of the Committee on Scientific and Technical Communication (SATCOM) of the National Academy of Sciences and the National Academy of Engineering was published in June 1969. The report contains 55 recommendations on national scientific and technical information activities.

The Foundation's Office of Science

NSF INFORMATION SYSTEM DEVELOPMENT AND IMPROVEMENT IN SCIENTIFIC DISCIPLINES OTHER THAN CHEMISTRY

DISCIPLINE	FY 1969 STATUS	FY 1970 PLANS
Physics & Astronomy	• Defining comprehensive program of development/acquisition • Developing computerized bibliographic and type-setting capabilities	• Initiate program
Psychology	• Defining comprehensive program of development/acquisition	• Initiate program
Linguistics	• Defining comprehensive program of development/acquisition	
Mathematics	• Preliminary study/liaison • Developing computerized typesetting and editing capabilities	• Initiate program definition
Environmental Sciences	• Preliminary study/liaison	
Engineering Sciences	• Preliminary study/liaison	
Life Sciences	• Developing computerized bibliographic and other capabilities	
Other Social Sciences	• Developing computerized biobibliographic capability in economics	• Preliminary study/liaison

Information Service programs are oriented to four areas of program emphasis as discussed below.

INFORMATION SYSTEMS DEVELOPMENT

The main elements in this type of support are: (1) Exploitation of technology for greater speed, efficiency, and dependability; (2) integration of information processes and functions, whereby only one intellectual processing of any item for the information system is needed; and (3) coordination with other information systems in order to serve multiple requirements.

Discipline-Oriented Science Information Activities

The development of discipline-oriented science information systems is a long-term process involving several phases: conceptualization, program definition, system acquisition, transitional operational capability, and steady state operations. The efforts of the scientific societies to develop their systems through each of these phases were supported. Awards were also made for (1) development of computer-controlled photocomposition; (2) bibliographic organization and control of scientific literature; and (3) modernization and improvement of the translation processes through provision of computer aids to editors of scientific translations.

Chemical Information System.—Unlike some of the other discipline-oriented science information activities which are still in early phases of development, the modernization and improvement of the discipline-oriented information system based in the American Chemical Society (ACS) reached a state of maturity in fiscal year 1969 which allowed for a significant start in exploitation of the data base. The significant achievements in fiscal year 1969 are as follows:

1. The CAS Chemical Registry System exceeded a million compounds with a million and a half names and two million references related to the structure records contained in the registry files.

2. The three experimental university-based information centers established or partially supported last year have developed large user groups and are currently processing several thousand search profiles.

3. The center concept is being expanded by the ACS to include input centers. This expansion will provide a means of sharing the processing load, both manual and computer-based, thus reducing the expense to the individual center and also reducing the cost to the individual user. An initial experimental agreement has been made with the Chemical Society of London as agent for the United Kingdom Consortium on Chemical Information, consisting of 10 professional organizations, to process primary publications data directly into the computer systems.

4. Projects utilizing the ACS files and system facilities have also continued to develop in Federal agencies. The National Library of Medicine and the National Cancer Institute have extended their direct contracts with Chemical Abstracts Service (CAS), while the National Aeronautics and Space Administration and the Food and Drug Administration have undertaken negotiations indirectly through university-based centers.

5. A number of agency groups are experimenting with computer search systems for substructures of chemical compounds. Workshops conducted by CAS have helped in the necessary training in the use of their search techniques. Because about 80 percent of chemical information is related directly or indirectly to chemical structures, the new techniques show considerable promise in opening up fields of information services not hitherto possible.

The realization of a massive machine-readable data base has highlighted new problems which must be solved, but in spite of these problems, the support provided by the Foundation helped maintain a rate of progress that will enable the American

INFORMATION SYSTEM DEVELOPMENT AND IMPROVEMENT IN CHEMISTRY

FUNCTION	FY 1969 STATUS	FY 1970 PLANS
ACS Central Processing Development	• Work is underway on subsystems for direct-access for structure handling, unified input system, integrated output system, interface modules, photocomposition, substructure searching system • Work is underway on processing development in computer-supported editing, system engineering, computer-supported documentation	• Continue scheduled development; initiate work on cross-reference and text search subsystem • Support application studies on editing via computer terminals; generalized photo-composition and techniques for on-line mass storage; pilot trials of nomenclature translation by computer
Operational Development of Unified Data Base	• In the computer files: 960,000 chemical structures 1,300,000 references 2,000,000 names	• Continue input from current literature, convert or create index files, pilot test special data files
Distribution Centers Development	• University based Experimental centers established • Foreign-based OECD cooperative effort to assist centers in 8 countries through training and liaison • Industrial Technical liaison with industrial centers for experimental use of new data bases • Government agencies: Experimental use of special data bases by Food Drug Administration and National Library of Medicine systems completed	• Start experimental services at centers • Continued training and liaison • Expand decentralized use activities

Chemical Society to reach its first goal on schedule—full computer operation of CAS publications during 1971.

University-Centered Information Systems

Paralleling the development of discipline-oriented systems based in the national professional societies is the need for a campus-based system to (1) accept the end products of the discipline-oriented, society-based systems, and those of the Federal agencies and the commercial sector; (2) develop an information system for interdisciplinary areas of research as well as for specialized segments of broad disciplines; and (3) encourage the modernization of library services (including the development of regional networks).

Highlights of activities in this area during fiscal year 1969 include (1) the development of a computerized data bank on treaty information contained in 550 volumes of the U.N. Treaty Series (8,641 treaties). This is an interdisciplinary information project at the University of Washington oriented toward research by a worldwide audience of political scientists and students of international law; (2) continued support for the development of the Stanford Physics Information Retrieval System (SPIRES), an on-line operational reference-retrieval system for use by faculty scientists as well as the staff of the Stanford Linear Accelerator Center; and (3) the improvement of library systems and services of traditional libraries through experiments in management techniques, application and use of new technology, and development of statewide or regional networks for library service. For example, the University of Colorado began the final phase of a project to establish a centralized processing agency for acquisition of library materials to service all of Colorado's academic institutions. This project will attempt to show that costs (as well as time) of acquiring and processing library materials can be reduced. In addition, specialized information services (as a byproduct of centralized book processing) may be provided to scientists and engineers.

OPERATIONAL SUPPORT FOR SERVICES AND PUBLICATIONS

The principal objective of this activity is to maintain existing information systems and services at an operational level which will serve the essential needs of scientists and engineers for information.

While new information services and systems are being developed, users must continue to depend upon the capabilities of existing publication and dissemination services to fulfill their requirements. In fiscal year 1969, therefore, the Foundation's effort was concentrated on (1) the publication of original research in five journals, 22 monographs, and three conference proceedings; (2) maintenance of capability in abstracting and indexing services in engineering, mathematics, geology, atmospheric sciences, biology, and the social sciences as well as assistance for 12 specialized bibliographic and indexing services; (3) translation and republication in English of approximately 100,000 pages of foreign scientific and technical literature which 95 percent of U.S. scientists and engineers cannot read in the original language; and (4) the support of the Science Information Exchange (SIE).

RESEARCH AND DEVELOPMENT

The objectives of this program are realized through support of projects undertaken by individual researchers and research projects conducted by investigators associated with science information research centers such as those at Ohio State University and Georgia Institute of Technology. The Foundation's support for discipline-oriented and university-centered information systems emphasizes the need for new techniques to evaluate and measure the performance of evolving information systems. In fiscal year 1969, a Foundation-supported project with Westat Research, Inc., resulted in publication of a "Procedural Guide for the Evaluation of Document Retrieval Systems." The guide identifies the best available statistical techniques for measurement of document retrieval system performance as well as localization and diagnosis of malfunctions of the system. Information systems developers and operators without advanced mathematical and statistical training will find the guide invaluable in design and evaluation studies.

The high cost of all phases of information services is of great concern. In an attempt to provide data on cost effectiveness of purchasing serial titles versus borrowing of such titles by research libraries, the Center for Research Libraries developed mathematical models to determine at what frequency of use of any given serial title it becomes cheaper for the library to borrow or photocopy an item when needed. Preliminary results indicate that such models can be used to decide whether to purchase or borrow a serial title.

During fiscal year 1969, the science information research centers at the Georgia Institute of Technology and Ohio State University made good progress in the development of sound programs of research and training in the information sciences. The Georgia center has developed a broad base of research investigations, including two main lines of activities: theoretically oriented studies in the theories of information, information processes, and information systems; and application-oriented investigations in information and computer engineering. During the 1968–69 academic year, the School of Information Science increased its number of graduate students to 137 and added 10 new courses to its curricula.

The Ohio State center has experienced a similar growth pattern during the last year. An integrated research program has been developed encompassing the areas of human information processing, applied linguistics, information analysis, artificial intelligence, biological information processing, and information storage and retrieval. During the year, the center increased its number of graduate students to 89, and now offers approximately 45 courses in its curricula.

PLANNING, COORDINATION, AND COOPERATION

Adequate means must be provided for planning, coordination, and cooperation between existing systems and services, both nationally and internationally.

With the development of discipline-oriented information systems, the formation of university-centered information systems, the continual expansion of information systems and services, the need for planning in science information activities becomes mandatory. The situation is analogous to the construction of a building without the aid of blueprints—the resulting structure may be functional, but its structural soundness, serviceability, and value would be doubtful.

In fiscal year 1965, the Foundation provided support to the National Academy of Sciences and the National Academy of Engineering for the establishment of the Committee on Scientific and Technical Communication (SATCOM). SATCOM's charge was to investigate the present status and future requirements of the scientific and engineering communities with respect to the flow and transfer of information. The 3-year effort of SATCOM resulted in the publication in June 1969 of a report entitled "Scientific and Technical Communication—A Pressing National Problem and Recommendations for Its Solution." The report recognizes the need for a planning and coordinating mechanism for the heterogeneous complex of scientific and technical communication) activities that have emerged in response to locally perceived needs and opportunities rather than having developed in an orderly, planned manner. The report recommends the establishment of a Joint Commission of the Academies to stimulate greater coordination among private groups and to facilitate their interaction with appropriate branches of the Government and lists 54 additional specific recommendations on scientific and technical information tasks that need attention.

The subsystems of an information network must be able to exchange information. Information, especially in machine format, can be interchanged if the same standards are used for input and output by the exchanging systems. Recognizing the importance of standards to information systems development and operation, the Foundation has supported the activities of the U.S.A. Standards Institute Committee Z–39 on Library Work, Documentation and Related Publishing Practices for many years. This committee of information specialists has published, in fiscal year 1969, several standards, for example: "Bibliographic Information Exchange on Magnetic Tape" and "Abbreviations of Titles of Periodicals." These standards, when used by the major information services, facilitate the exchange of information between systems.

Fiscal year 1969 witnessed a significant change in management and a broadening of the former Special Libraries Association Translations Center at the John Crerar Library into a National Translations Center (NTC), and the beginning of the development of Federal policies governing various aspects of Federal translations activities. The center became the focal point in the United States for the handling of translations while the Clearinghouse for Federal Scientific and Technical Information (CFSTI) assumed a lesser role as the central depository and distributor of U.S. Government-sponsored translations. The Panel on International Information Activities of the Committee on Scientific and Technical Information accepted a Foundation-prepared statement of "Policies Governing the Announcement and Dissemination of Translations by Agencies of the U.S. Federal Government." The adoption of this policy statement will facilitate continuing cooperation among Federal agencies in making their translations readily available through the CFSTI and NTC.

Scientific progress, both in the United States and in other countries, is dependent upon international exchange of information. One of the objectives of the Foundation is to ensure that the U.S. scientist or engineer has access to published foreign scientific results; participates in international meetings and symposia; and has available appropriate guides and directories to scientific and engineering resources in other countries. One of the means used to accomplish this objective includes support for the (1) Participation of the U.S.A. Standards Institute in the work of the International Organization for Standardization; (2) the U.S. National Committee (through the National Academy of Sciences) of the International Federation for Documentation; and (3) the Abstracting Board and the Committee on Data for Science and Technology of the International Council of Scientific Unions. These organizations are all involved in various aspects of scientific and technical information of interest and importance to the developing systems and services in the United States.

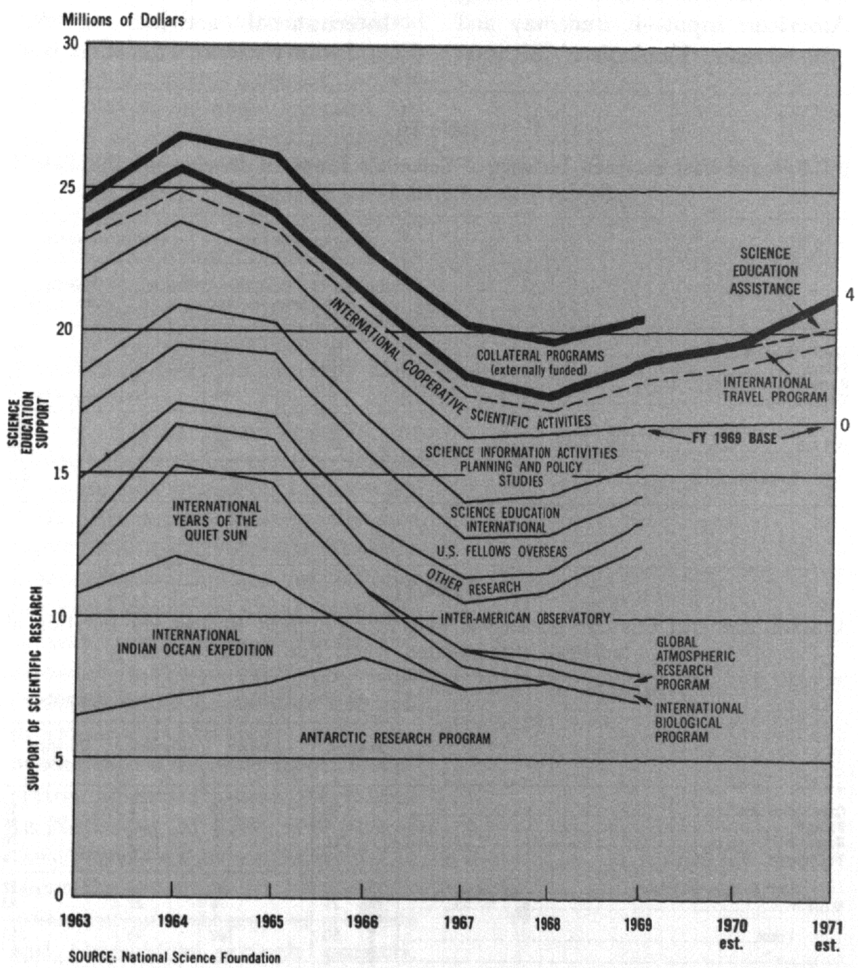
As an example of the kind of international cooperation in science information that is in process, one may cite the International Council of Scientific Unions/U.N. Educational, Cultural, and Scientific Organization Joint Study Project on the feasibility of creating a world science information system. The project has the organizational name of UNISIST, and the Foundation is represented on the project's central committee. Adequate representation of U.S. interests by specialists and organizations is maintained in the various working groups and an advisory body of key information services. The leading nations participate in this voluntary cooperative effort to assure the effective transfer of information worldwide through new and highly complex transfer modes. The formation of UNISIST and the enthusiastic participation by many nations augurs well for future coordination and cooperation in the establishment of international science information networks. Although projects of this type require no funds from the Foundation, they demand professional staff expertise and time.

International Science Activities

Foundation authority to participate in international science activities was considerably broadened by the passage of Public Law 90–407 signed by the President on July 18, 1968. Under this act, the Foundation ". . . is authorized to initiate and support specific scientific activities in connection with matters relating to international cooperation . . . by making contracts or other arrangements . . . for the conduct of such scientific activities." The impact of this broader mandate is not reflected in this report of fiscal year 1969 activities, but its influence can be expected to affect the scope of Foundation international programs in the future.

Most of the Foundation's international activities are an integral part of programs aimed at strengthening science and science education in the United States, and are supported by almost all units of the Foundation. In addition, to facilitate the international exchange of information, the Foundation supports the translation of a number of important scientific journals and articles written in languages not understood by many

NATIONAL SCIENCE FOUNDATION OBLIGATIONS FOR INTERNATIONAL ACTIVITIES, FY 1963-71



SOURCE: National Science Foundation

American scientists. The Foundation also carries out some activities in science education funded by the Agency for International Development.

RESEARCH AND EDUCATION PROGRAMS

International scientific activities are increasing, and the American scientific community and the Foundation are taking part in these expanded opportunities. One important example is the International Biological Program (IBP), which is designed to discover more about man and his interaction with his environment. U.S. participation in this program—designed and planned by international committees with strong American input—is underway and will increase. Emphasis of IBP is on problems of ecology, rather than conventional biological research, and projects will employ the knowledge and technology of many disciplines.

The Global Atmospheric Research Program (GARP), designed to learn more about the atmosphere and the weather, is gathering momentum. The U.S. Antarctic Research Program (USARP) continues to support scientists from the United States in carrying out a large number and variety of research projects in the Antarctic; these include exchanges of personnel in collaboration among scientists of the 17 nations adhering to the Antarctic Treaty. The Inter-American Observatory at Cerro Tololo, Chile, is supported by the Foundation to provide astronomers of many nations with facilities for studies of the southern sky.

International activities of the Foundation's science education programs include fellowship awards, both to Americans for study abroad and to distinguished foreign scientists to visit this country to contribute to the research and teaching programs of American institutions. Of 2,842 NSF fellowships offered to U.S. citizens in fiscal year 1969, 99 provided for study at foreign institutions. A total of 72 scientists from 23 foreign countries were invited to visit institutions in the United States under the NSF Senior Foreign Scientist Fellowship Program.

In coordination with the Department of State, the Foundation also administers NATO-funded fellowship programs, which permit American scientists to study in NATO and other cooperating countries; under these programs in fiscal year 1969, 40 Postdoctoral Fellowships and 27 Senior Fellowships were awarded. In addition, and with Foundation support, 83 young U.S. scientists were awarded grants to attend NATO Advanced Study Institutes in fiscal year 1969. In another program, 127 foreign science educators were brought to this country to participate in teacher-training institutes. Travel grants were made to assist 671 U.S. scientists and science educators to attend meetings and conferences abroad. In the past year Foundation education programs also made grants to scientific educational activities abroad. Among these is a grant of $330,200 to the Organization for Tropical Studies—a consortium of 25 American institutions—established to enable faculty and students from U.S. institutions to study tropical biology in Costa Rica.

Through its research projects support program, the Foundation provides research support directly to a limited number of foreign institutions. In fiscal year 1969, eight such project grants were awarded in the amount of $200,000. The Foundation also provides funds to U.S. institutions to support U.S. scientists conducting research abroad.

Table 16

U.S.S.R. and East European Exchange of Scientists Programs Number and Duration of Individual Vists Initiated, Fiscal Year 1968

	American scientists		Foreign scientists	
	Number	Duration (man-months)	Number	Duration (man-months)
Czechoslovakia	10	50	9	60
Poland	16	28	7	56
Romania	9	9	9	53
Yugoslavia	6	23	6	23
East Europe, subtotal	41	110	31	192
U.S.S.R.	32	90	26	118
Total	73	200	57	310

Table 17

U.S.S.R. and East European Exchange of Scientists Programs Number and Duration of Individual Vists Initiated, Fiscal Year 1969

	American scientists		Foreign scientists	
	Number	Duration (man-months)	Number	Duration (man-months)
Czechoslovakia	13	39	7	40
Poland	4	26	3	36
Romania	13	13	8	30
Yugoslavia	9	15	5	16
East Europe, subtotal	39	93	23	122
U.S.S.R.	21	76	22	93
Total	60	169	45	215

INTERNATIONAL BILATERAL PROGRAMS

The Foundation administers six bilateral programs, two of which, with Romania and India, are primarily concerned with the exchange of scientists. The other four—with Japan, Italy, Australia, and China (Taiwan)—involve cooperative research as well as exchange of scientists and scientific information.

The oldest of these bilateral programs is the United States-Japan Cooperative Science Program, established in 1961, which has been extremely effective in increasing communication and collaboration between scientists of the two countries. Activities conducted under this program include cooperative research programs, visits by scientists of one country to the other, scientific meetings, and exchange of educational materials. In fiscal year 1969, 38 cooperative research projects were in progress with 10 new projects funded this year; NSF support amounted to $388,068. In addition, there were 47 seminars and project meetings held, of which 16 were in this country and 11 in Japan; approximately 240 United States and 270 Japanese scientists participated. This year awards totaling $147,268 supported research by 14 American scientists in Japan.

Projects supported under the United States-Japan program include a study of the homing behavior of chum salmon, a geologic study of active faults in the earth's crust in Japan and the Western United States, and economic studies. The seminars supported include a wide variety of subjects; among them are the neurophysiological basis for learning and behavior, earthquake prediction, new biological approaches to pest control, and mathematical and statistical analysis for transportation planning and regional development.

The United States-Italy program was initiated in June, 1967, and encompasses in general the same types of activities as the United States-Japan program, although so far only cooperative research projects have been activated. In fiscal year 1969 there were 25 on-going projects, including 10 started this year. The National Science Foundation contributed $436,233, with other agencies of the Government and U.S. universities contributing an additional $306,265. Projects under the United States-Italy program include an oceanographic study at sites in the Indian Ocean off the coast of Somali and in the Ligurian Sea north of Corsica; and comparative studies of enzyme structure, photochemistry, and mechanisms and research in neutron diffraction.

The United States-Australian Agreement for Scientific and Technical Cooperation was signed on October 16, 1968. Activities initiated under the agreement, in cooperation with other Federal agencies, include collaboration in acquiring and analyzing meteorological data for predicting thunderstorm hazards to air traffic; a visit by an Australian scientist to study forest fire research in the United States; experiments in acoustic sounding of the lower atmosphere; and a meeting of United States and Australian Government scientists to consider cooperation in arid land activities.

The United States-Republic of China (Taiwan) Cooperative Science Program was signed on January 23, 1969. Discussions between the two implementing agencies—the National Science Foundation and the National Science Council in China—are underway to determine mechanisms and priorities in this program. Exchange of scientists and cooperative research programs will be stressed.

The United States-Romania Cooperative Science Program was signed on November 26, 1968, as a part of the cultural exchange agreements between the two countries. Planned activities include exchanges of scientists and cooperative research projects,

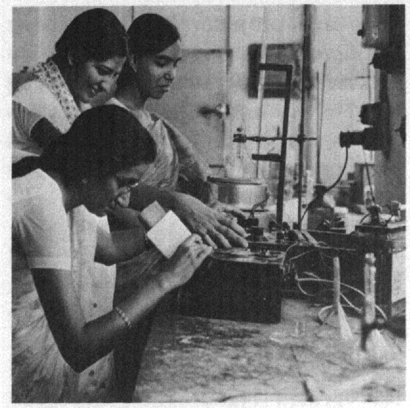


Photo shows women participants in a college-level institute in chemistry at Udaipur, India, in the summer of 1969. (NSF Photo) but no projects have yet been initiated.

The United States-India exchange of scientists and engineers, which began in 1967, calls for exchange visits totaling 800 man-days per year for each country. In fiscal year 1969, 15 grants totaling $30,178 were awarded to Indian participants for their travel and expenses in the United States; the international travel costs for the Indians were paid by their own country. Twelve Indian scientists visited the United States during this fiscal year, and three will follow early next year. Among the visitors were three directors and one deputy director of Indian national laboratories supported by the Indian Council on Scientific and Industrial Research (CSIR). Seven Americans were selected to participate in this exchange; three visited India during this year, and four will go next year. The grants to cover their international travel, from NSF, amounted to $9,014; travel and living expenses in India are paid by CSIR and host institutions.

EXCHANGE OF SCIENTISTS WITH THE U.S.S.R. AND EAST EUROPEAN COUNTRIES

During fiscal year 1969, the Foundation continued to support exchanges of scientists between the U.S. National Academy of Sciences and its counterpart academies in Czechoslovakia, Poland, Romania, Yugoslavia, and the U.S.S.R. In comparison with the highly successful conduct of the program in fiscal year 1968, exchanges decreased in fiscal year 1969 owing to fiscal stringencies affecting the Foundation and, in the case of the U.S.S.R., delay in completing administrative arrangements. Restoration of the internationally agreed level of exchanges with these countries is anticipated for the future. During the year, progress was made toward initiation of exchanges with Bulgaria and Hungary. Tables 16 and 17 below give details of the exchange program for fiscal years 1968 and 1969.

INTERNATIONAL NONGOVERNMENTAL SCIENTIFIC ORGANIZATIONS

Many international scientific cooperative programs such as the International Biological Program and the Global Atmospheric Research Program are conceived and coordinated by the international scientific unions and associated organizations. These unions are also increasingly active in sponsorship and coordination of exchange of information through scientific meetings, publications and information systems, and the establishment of standards, units and nomenclature necessary for international collaboration and comparison of experimental results. The Foundation encourages the participation of American scientists in this work, principally through support to the National Academy of Sciences-National Research Council, which is the U.S. national member of some 30 leading international nongovernmental organizations.

The past year was marked by increasing expression of concern, in both scientific and governmental circles, over problems of the human environment, and the creation of an ad hoc committee of the International Council of Scientific Unions was authorized to report on the detrimental alteration of man's environment, and to point out international environmental problems toward which the Council's advisory and coordinating resources could effectively be applied. Another current trend is continued intensification of relations between the nongovernmental scientific unions and United Nations organizations such as the Economic and Social Council, the World Meteorological Organization, and the United Nations Educational, Scientific, and Cultural Organization.

DEVELOPMENT ASSISTANCE PROGRAMS

India

In 1966 the Foundation and the Agency for International Development (AID) concluded a contract under which NSF assumed responsibility to assist the Government of India in improvement of Indian science education. This program encompasses the basic sciences, mathematics, engineering, and technical education (polytechnics). The program activities include summer institutes for teachers (school and college); curriculum materials development; college development; university/college/school cooperative development; and engineering and polytechnics development. For the summer of 1969, using funds transferred from AID, the Foundation provided 135 short-term consultants.

Latin America

Only a limited level of program activity was conducted in Latin America during fiscal year 1969, although interest there remains high, and contact has been maintained with many Latin American scientists and science educators. A grant was made to a Harvard University scientist to provide advisory service to the Chilean Government on an appropriate program for fishery development and oceanographic research in that country.

One small contract with AID enabled the Foundation to support international activities in biological education in Latin America and elsewhere through the Biological Sciences Curriculum Study (BSCS); to help limited activities in mathematics abroad through the School Mathematics Study Group (SMSG); and to undertake a study of low-cost scientific equipment at the University of Maryland.

Science Planning and Policy Studies

The planning and policy study activities of the Foundation are carried out to aid in the development of better policies for the promotion of science and science education. With the information developed through these studies, it becomes possible to assess alternative courses of action and frequently to arrive at the most appropriate policy recommendations bearing on the national science effort and on the internal activities of the Foundation. National policy recommendations are made by the National Science Board and the Director to the President, the Office of Science and Technology, the Bureau of the Budget, the Congress, and to the public. Policy formulations for the Foundation itself are made by the Director and the National Science Board and are reflected in the implementation of the various NSF programs. Consequently, NSF policies and policy changes are summarized in the Introduction and Summary chapter and are interwoven in the reports on the various NSF programmatic activities.

Planning and policy study activities are focused in three major areas:

1. Studies of policy issues including evaluation of the needs of science and science education and their role in society.
2. Development of the basic tools for science planning and policymaking.
3. Development of national science policy study and planning capabilities.

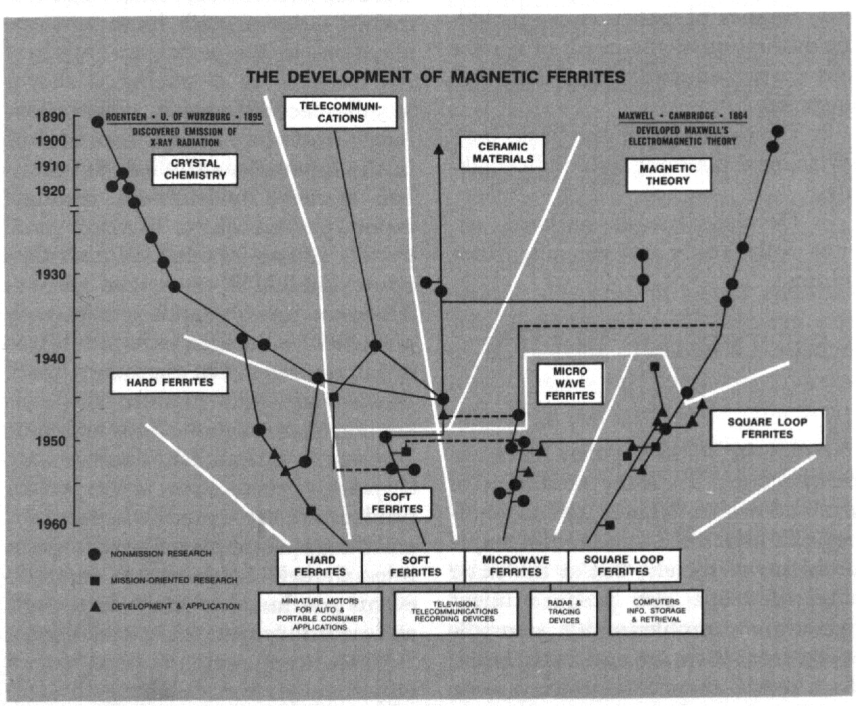
STUDIES OF POLICY ISSUES

Issues in science policy development require a variety of studies in size and scope. Science and technology can help solve some of the major problems of society, but at the same time they can also produce unexpected new problems that stem directly from their use and application. As a result, there is a growing sense of urgency for analyses of the impact of science upon society. Although the problems are exceedingly broad, increasing attention from the scientific and academic communities and the Congress is being devoted to these problems. Efforts carried out or supported by the Foundation are designed to open up new areas of study or are concentrating on problems of most current interest.

An important study recently completed under contract by the Illinois Institute of Technology traces the relationship between different types of research and development in the evolution of five major technological innovations. The study is called "Technology in Retrospect and Critical Events in Science," or by the acronym TRACES. The study developed "tracings," that is, historical charts of key research and development events which led to five specific technological innovations with major economic and sociological impacts: ferrites used extensively in computer memories and other electronic equipment; the contraceptive pill; the electron microscope; the videotape recorder; and chemical matrix isolation with important applications in the petroleum industry. An example of a tracing is shown in the accompanying illustration. Analysis of the findings showed that in the innovations studied, the number of key fundamental research events peaked 20 to 30 years prior to the actual innovations and that approximately 90 percent of all fundamental key research events took place before the innovation itself was even conceived. On the other hand, the average time between the conception of these innovations and their first practical demonstration was only 9 years. During this time period, product-oriented applied research and development played predominate roles though fundamental research events continued to make important and necessary research contributions.

There frequently is need for a major study effort involving the collection of new data relevant to a particular current problem affecting national science policies. The effect of the leveling of total Federal support to academic science in recent years and the special impact of expenditure ceilings imposed in fiscal year 1969 had reverberations which require a special effort to determine the impact of these developments upon the health of the academic science enterprise. In late fiscal year 1969 the Foundation initiated a special survey to obtain systematic and objective information on the consequences of recent changes in the level of Federal funds allocated for the support of academic science. A survey methodology was developed and initiated, and data will be compiled, evaluated, and reported in the fall of 1969. Information analyzed will deal with financing and effects on: proposal policies, students, faculty, postdoctorals, equipment, construction, and research and teaching activities. The population studied in the survey comprises approximately 100 institutions of higher education granting Ph. D.'s in the sciences and will include departmental information for selected science fields. The results of the survey are expected to identify and assess the major impact areas and dislocations experienced by universities and the accommodations made to them. Furthermore, the results of this survey will establish a benchmark for data of a fundamental nature to be collected periodically for the use of Federal agencies in planning their support for academic science in the United States.

The Foundation staff contributed significant support to the development of the National Science Board's first annual report, a two-volume work on graduate education, "Toward a Public Policy for Graduate Education in the Sciences" and "Graduate Education Parameters for Public Policy." These reports outline the existing and predicted patterns of graduate science education and discuss policies for supporting the development of graduate education in the future. The report makes a series of recommendations for State, regional, and university planning of graduate science education and to the Federal Government for programs to support graduate education in the sciences.



In the spring of 1969 the Foundation released a report, "Junior College Teachers of Science, Engineering, and Technology, 1967," on the characteristics and educational qualifications of an estimated 11,000 junior college teachers. This study of the most rapidly growing segment of the nation's system of post-secondary education showed that, despite the rapid growth in the number of junior colleges and in the number of students they serve, there is a considerable degree of academic strength in their faculties, and an unexpectedly large amount of activity among faculty members to work toward continued improvement. The Commission on Science Education of the American Association for the Advancement of Science supervised the study made under a grant from the NSF. Among findings reported in the study were those indicating that: three-fourths of junior college teachers held a master's degree, another 9 percent held a doctorate, and 16 percent had been admitted to candidacy for the doctoral degree.

A study entitled "Contract Research and Development Adjuncts to Federal Agencies" was completed and is scheduled for release later in 1969. This report, prepared under contract by the Denver Research Institute, represents an evaluation of the organizational mechanism known as federally funded research and development centers (FFRDC's). The report concluded that the research centers have been helpful in meeting new and emerging Government R. & D. needs in such areas as "big science" research, large technological development, systems analysis and systems engineering. However, the continuing need for such centers by the Federal Government clearly requires further study especially in view of the research capabilities of Federal in-house laboratories and of profit organizations.

The Federal-private technological interaction was investigated by the National Planning Association in a project initiated by NSF. The study entitled "Methods of Government Business Cooperation in the Field of Oceanics" has been completed. Various working papers and a preliminary general report were prepared to assist the National Council on Marine Resources and Engineering Development in preparing its recommendations to the President and to Congress. The final report of the Council includes chapters written under the auspices of NSF on problems related to economic exploitation of specific marine resources, case studies of successful marine ventures in mineral discovery and production, and case studies of nonoceanic industries with substantial Federal support. The report presents a review of problems and a survey of policies that might affect government in its efforts to assist industry to exploit marine resources.

Continued support was provided for activities of the National Academy of Sciences' Committee on Science and Public Policy (COSPUP). During fiscal year 1969 two volumes of a three-volume report on the mathematical sciences appeared under the aegis of this committee. The first volume presents the present general status of research and education in mathematics and related disciplines, with recommendations for research and graduate education in the field. The report recommends increased Federal support for graduate students in mathematics, for research apprenticeship programs and for mathematics faculty improvement awards. The second volume is a collection of 22 essays by distinguished mathematicians on achievements and prospects in mathematical work. The last volume will appear in fiscal year 1970 and is concerned with the special problems of undergraduate education in mathematics in the United States. Similar studies of the life sciences and the behavioral and social sciences were completed and will be reported in the fall of 1969. Field evaluation studies were begun in physics and astronomy. The physics study will relate the field of physics to other sciences and to society as a whole. The objective of the astronomy study is to outline the scientific priorities in the broad area of both space and ground-based astronomy. The study evolved from a series of discussions between the Bureau of the Budget, the Office of Science and Technology, NASA, and NSF.

The role of chemistry and chemists in industry and the contributions of the chemical industry in the industry-university-government research triad are the subjects of a joint effort of the Foundation and the American Chemical Society begun during the past year. The study is the first undertaken to assess in depth the impact of a single science on the national economy.

The interest of the Foundation in promoting research in technology assessment and forecasting was expressed in an award to the Institute for the Future at Wesleyan University. The work supported will focus on the application and testing of a cross-impact matrix technique in two assessment areas—first, the future impact of an evolving technology-cryogenics, and second, the impact of present policies on the technology gap with developing countries.

Developing effective allocation mechanisms for science resources is one of the most critical and difficult issues in science policy. Thus, better understanding of the impact of past funding patterns and mechanisms is needed. Studying such effects on different institutions within a higher education system has been the subject of a 2-year endeavor by Michigan State University. The first results covering 12 institutions were included in a report entitled "Impact of Federal Support of Science on the Publicly Supported Universities and Four-Year Colleges in Michigan" which indicates how research is supported and administered within a State system and where impacts on the financial, administrative, and reporting systems were especially pronounced.

To obtain understanding of the application of the R. & D. process to industrial innovation requirements, the Foundation supported studies by the National Planning Association to analyze the transfer of technology and the innovational phase of R. & D. in three different types of industry (computers, railroads, and housing). This study, now completed, will be published in the fall of 1969.

During fiscal year 1969 the programing, planning and budgeting efforts of the Foundation shifted in emphasis toward in-depth treatment of important issues. One of the issues undertaken during this fiscal year was a PPB analysis of the International Biological Program which afforded a unique example of an effort to develop a systematic plan for a program involving multiagency interest and participation.

DEVELOPMENT OF BASIC TOOLS FOR SCIENCE PLANNING AND POLICY FORMULATION

The National Science Foundation is responsible for determining the size, characteristics, and distribution of national resources devoted to science and technology. To fulfill this responsibility, the Foundation, through its planning and policy studies, secures statistical and other information and conducts or supports a variety of descriptive, analytical, projective and evaluative studies. This program includes the conduct of periodic and special surveys from primary data sources and the compilation of data from secondary sources with accompanying comprehensive analysis. The results of these surveys are contained in the following examples of principal studies completed or in process dur-

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ing fiscal year 1969. The accompanying figures are examples of data made available for use in science planning activities.

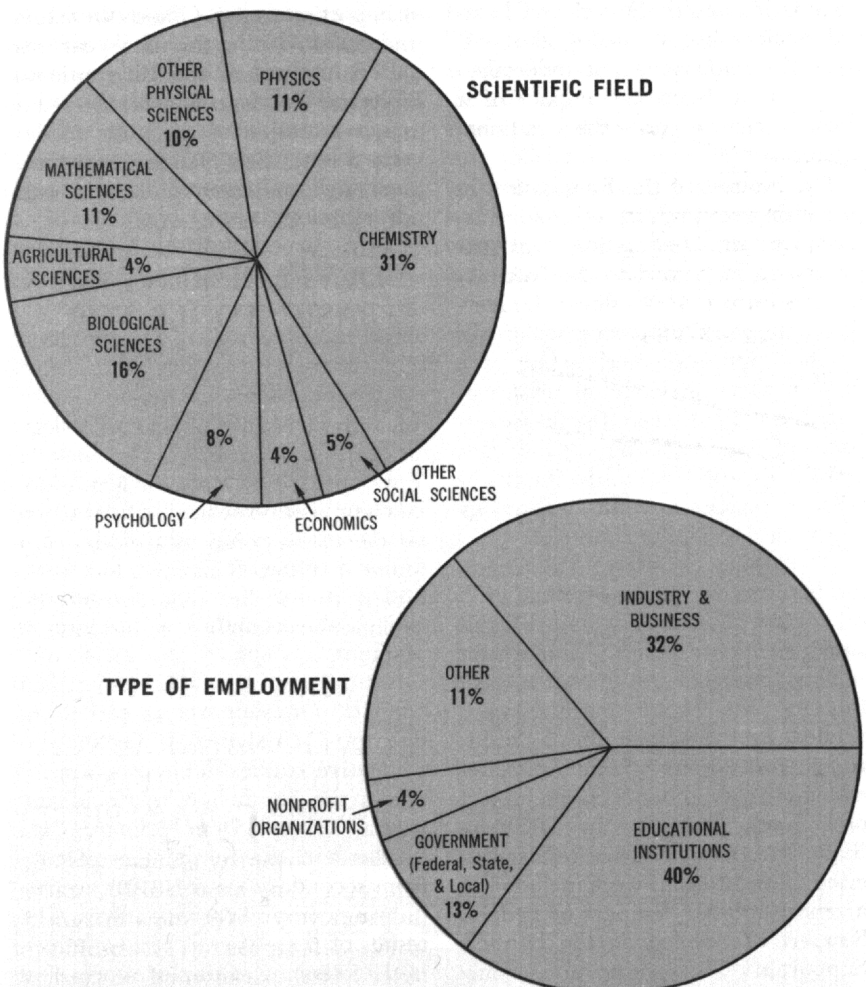
The 18th annual survey of Federal support for science and technology, "Federal Funds for Research, Development and Other Scientific Activities," reported that Federal obligations for research and development declined in fiscal year 1968 to $15.9 billion from the fiscal year 1967 level of $16.5 billion, a 4 percent drop. Estimates for fiscal year 1969 of $15.8 billion show a continued decline but at a reduced rate. The decrease in total support was due to a decrease in funding for development which declined from $11.3 billion in 1967 to $10.6 billion in 1968 and $10.4 billion in 1969, largely representing decreases in this area for the Department of Defense and NASA. The report includes a section on the geographic distribution of R. & D. and R. & D. plant obligations for fiscal year 1968. In the future, geographic data will be developed annually.

The first report of local government involvement in research and development, covering fiscal years 1966 and 1967, was issued in "R. & D. Activities of State and Local Governments" and completes the picture of governmental—Federal, State, and local—R. & D. activity. Total R. & D. expenditures by local governments totaled $31.7 million in 1967, of which more than one-half was financed by Federal agencies. Municipalities represented about 60 percent of the total R. & D. activity by State and local governments, and counties accounted for more than 25 percent. The principal area of R. & D. activity was health and hospitals, followed by education. More than 40 percent of the total local government R. & D. expenditures were represented by New York City, Los Angeles County, Los Angeles City, Philadelphia City, and Nassau County, N.Y.

A report, "Federal Support to Universities and Colleges, Fiscal Year 1967," was prepared by the Foundation under the auspices of the Federal Council for Science and Technology Committee on Academic Science and Engineering (CASE), and released early in 1969. The report showed that Federal obligations to the nation's universities and colleges began to level off in fiscal year 1967 at slightly more than $3.3 billion. Subsequent, as yet unpublished, data indicate that the level for fiscal year 1968 was $3.4 billion, an increase of 1.7 percent. The report showed that academic science obligations reached $2.3 billion in 1967; subsequent data received showed that the fiscal year 1968 obligations were also $2.3 billion. Due to inflation and increased complexity factors, fiscal year 1968 funding represented, in fact, a decreased level of activity support.

In conformance with a request from the Chairman, Federal Council for Science and Technology, the National Science Foundation is under-

SELECTED CHARACTERISTICS OF SCIENTISTS BY SCIENTIFIC FIELD AND TYPE OF EMPLOYMENT, 1968

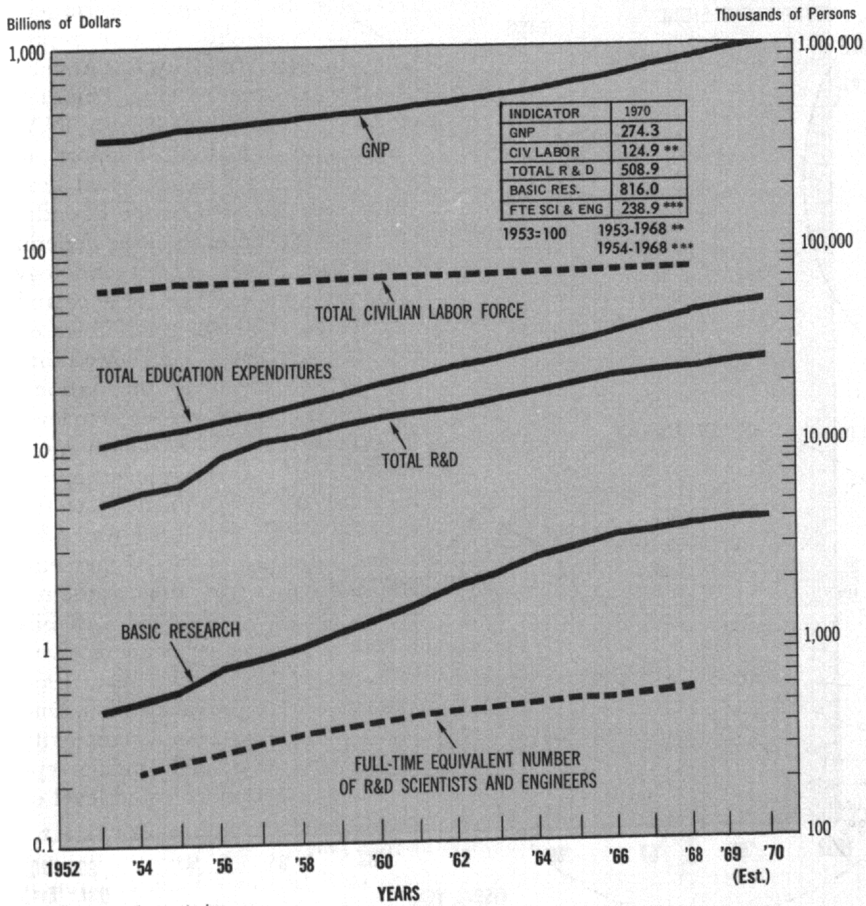


SOURCE: National Science Foundation
National Register of Scientific and Technical Personnel, 1968

taking an inventory of all Federal laboratories and federally funded research and development centers (FFRDC's). Based on returns of a survey of Federal agencies, an indexed directory will be prepared which will be available for public use. Publication of the directory is scheduled for early 1970.

"Research and Development in Industry" is an annual report which provides detailed information on the R. & D. activities of industrial firms. The report issued in fiscal year 1969 showed that these companies increased their R. & D. spending by 6 percent between 1966 and 1967 to $16.4 billion or nearly 70 percent of the nation's total R. & D. effort. The increase was spread evenly between basic research, applied research and development with gains of 5 percent, 5 percent, and 6 percent, respectively, over their 1966 levels. A special report on a major part of the industrial sector, "Research and Development in the Aircraft Industry," was prepared and released during 1969. This report examines the financial and manpower resources allocated to R. & D. programs in this industry. In 1967, aircraft and missile companies accounted for 34 percent of all industrial R. & D. spending. Federal contracts amounting to $5.6 billion were the source of 81 percent of these expenditures which in turn amounted to 54 percent of the total Federal R. & D. dollars contracted to industrial firms.

R&D FUNDS, R&D MANPOWER, AND OTHER ECONOMIC AND EDUCATION INDICATORS, 1953-70*



* Financial data in current prices.
SOURCE: National Science Foundation, Department of Commerce, and Department of Health, Education, and Welfare.

Comparable employment statistics of scientists and engineers over an extended period of time have long been needed for projections of future occupational requirements. In recognition of this need, the Foundation arranged to have the Bureau of Labor Statistics, U.S. Department of Labor, construct a consistent statistical series on the employment of scientists and engineers in the United States. The resulting NSF report, "Employment of Scientists and Engineers in Industry, 1950–66," encompasses for the first time a comprehensive employment series for scientists and engineers.

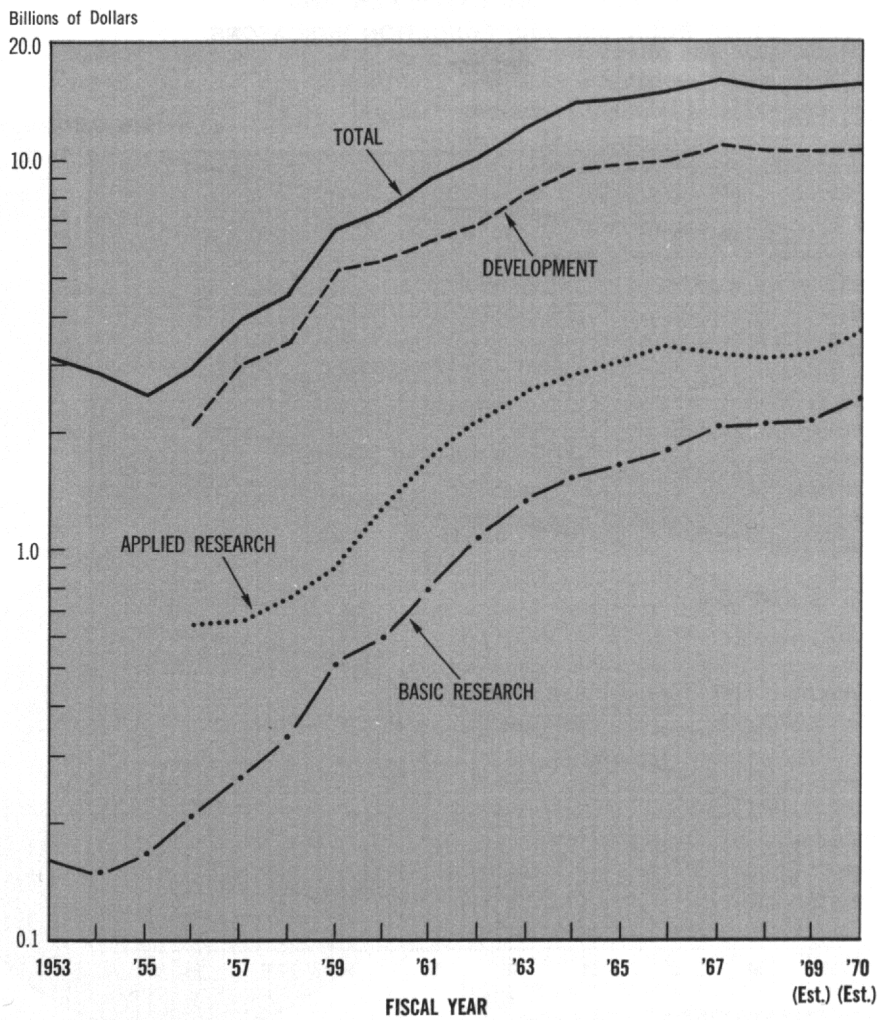
A survey of computers and computer science degree courses and their use by universities and colleges in this country was carried out, under contract, by the Southern Regional Educational Board. This survey was entitled "Inventory of Computers in U.S. Higher Education" and reports on computers and peripheral equipment in U.S. universities and colleges as of June 30, 1967; it also includes data on expenditures for acquisition and application of the facilities as well as the institutional uses of the computer facilities. This inventory is believed to be the most current and comprehensive effort of its kind to date.

DEVELOPMENT OF NATIONAL SCIENCE POLICY STUDY AND PLANNING CAPABILITY

The University Science Policy Planning Program (USPP), started in fiscal year 1968, aims to remedy three deficiencies: (1) insufficient educational background of students to assess policy issues related to science and technology; (2) inadequate means for formal education of those who want to engage in careers in the field of science and public policy resulting in an insufficient supply of young people prepared to enter this field; and (3) inadequate use of the great intellectual resource represented by the academic community in the study of science policy issues. Although individual project grants of interest to the Foundation are made to university scientists through the regular program of science policy research grants, several awards for broad universitywide integrated training and research programs in the area of science policy studies were made in fiscal year 1969 to expand the USPP coverage to seven universities. New awards were made to: University of Indiana where a major focus will be on policy and planning problems associated with man's interaction with his environment; Cornell University to develop criteria for evaluating university-based scientific research and to explore the interplay of Federal funding, laboratory organization, and scientific research production; and the State University of New York at Albany (SUNY) where a planning grant was given for support of intensive conferences on the use of science and technology in economics and social development at the recently organized Center for Science and the Future of Human Affairs.

The State and local science policy

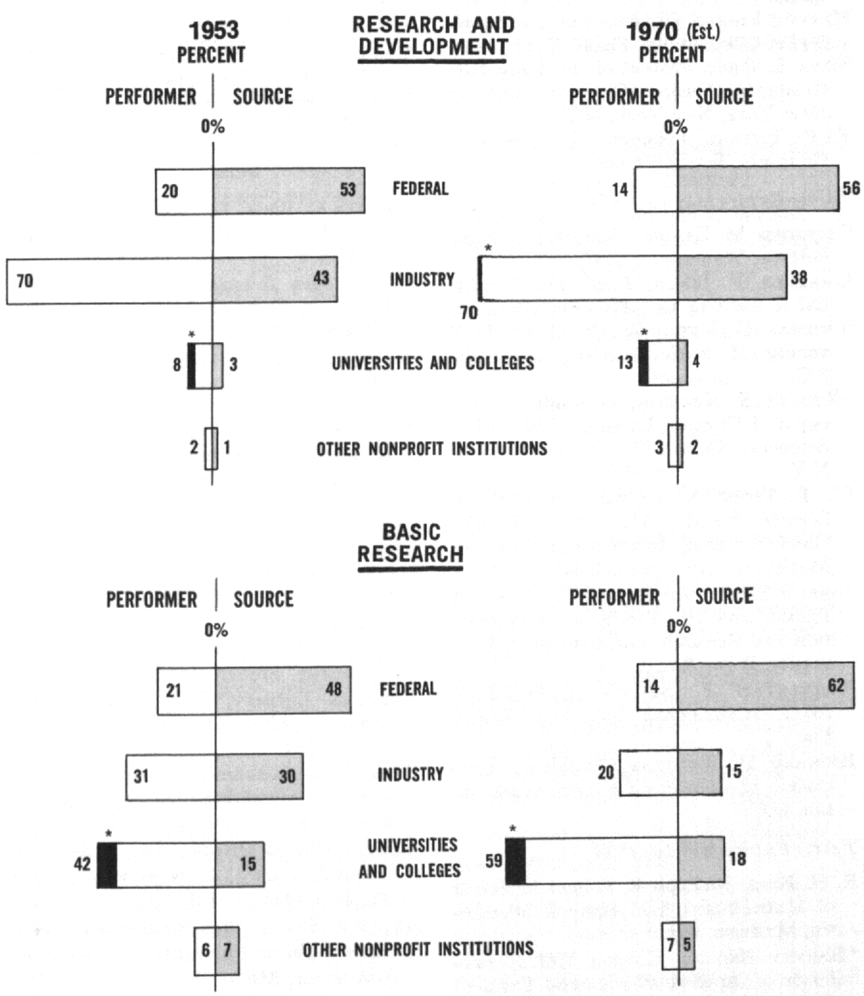
FEDERAL OBLIGATIONS FOR BASIC RESEARCH, APPLIED RESEARCH, AND DEVELOPMENT, FY 1953-70



SOURCE: National Science Foundation

program has the objective of improving planning capabilities for the use of science at the State and local level of government and of improving inter-governmental communications. A 2-day conference at Louisville, Ky., on "Science, Technology, and State Government," was arranged by the Southern Interstate Nuclear Board with Foundation support. The conference was attended by representatives from Federal and State Governments, academic institutions, and industry. The meeting dealt with interrelationships and applications of science and technology to various facets of public affairs at the State and local level. NSF awards were made for further conferences, including a western regional conference on water resources and a northeastern regional conference, sponsored jointly with the Department of Housing and Urban Development, in which the principal area of interest will be urban problems. A grant was made to the University of Tennessee to study the role of State government in stimulating development through science and technology and to make recommendations for formulating and implementing a science policy for Tennessee. Such planning efforts are designed to produce a useful model for use of other States.

PERCENT DISTRIBUTION OF R&D EXPENDITURES BY PERFORMER AND SOURCE OF FUNDS, 1953 AND 1970



* Associated Federally Funded Research and Development Centers.

SOURCE: National Science Foundation.

Appendix A

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Appendix A

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Appendix B

Financial Report for Fiscal Year 1969

Salaries and Expenses Appropriation

Receipts		
Fiscal year 1969 appropriation	$400,000,000	
Unobligated balance brought forward from fiscal year 1968	47,667,028	
Recovery of prior year obligation	7,955,536	
Reimbursement from non-Federal source	143,946	
Subtotal	455,766,510	
Less: Bureau of Budget reserve established under Public Law 90–218	−20,000,000	
Transfer appropriation to GSA for rent	−3,857	
Total available for obligation		$435,762,653
Net obligations		
Support of scientific research:		
Scientific research project support:		
Mathematics	12,696,597	
Physics	30,346,738	
Chemistry	17,848,276	
Biological sciences	38,307,362	
Astronomy	6,816,879	
Atmospheric sciences	8,205,695	
Oceanography	19,381,729	
Earth sciences	7,917,288	
Engineering	19,265,222	
Social sciences	15,238,808	
Subtotal	176,024,594	
Specialized research facilities and equipment:		
Biological sciences research facilities:		
Specialized biological facilities and equipment	879,828	
Oceanographic research vessels and facilities	699,646	
Environmental sciences research facilities:		
Oceanographic research facilities	697,055	
University atmospheric research facilities	297,964	
Physical sciences research facilities:		
Chemistry research instruments	1,699,728	
University astronomy research facilities	323,600	
University physics research facilities	1,299,639	
Engineering research facilities	880,457	
Specialized social science research facilities	437,900	
Subtotal	7,215,817	
National research programs:		
Antarctic research programs	6,858,655	
Weather modification program	2,433,974	
Ocean sediment coring program	2,435,000	
International biological programs	1,215,800	
Global atmospheric research program	536,490	
Subtotal	13,479,919	
National research centers:		
National Radio Astronomy Observatory	7,278,214	
Kitt Peak National Observatory	5,699,510	
Cerro Tololo Inter-American Observatory	4,550,000	
National Center for Atmospheric Research	11,036,737	
Subtotal	28,564,461	
Subtotal, support of scientific research		225,284,791
National sea grant program		$5,989,065
Computing activities in education and research		16,979,280
Institutional support for science:		
Institutional grants for science	$0	
Graduate science facilities	5,979,815	
Subtotal	5,979,815	
Science development programs:		
University science development program	23,103,000	
Departmental science development program	8,634,670	
College science improvement program	8,763,700	
Subtotal	40,501,370	
Subtotal, institutional support for science		46,481,185
Science education support:		
Precollege education in science:		
Course content improvement	7,710,535	
Cooperative college-school program	4,823,563	
Special projects	311,440	
Institutes	30,779,232	
Research participation and science activities for teachers	0	
Science education for students	1,872,516	
Subtotal	45,497,286	
Undergraduate education in science:		
Science curriculum improvement program	5,004,179	
Undergraduate instructional programs	8,205,122	
College teacher programs	3,967,124	
Special projects	715,877	
Pre-service teacher education	678,600	
Subtotal	18,570,902	
Graduate education in science:		
Fellowships and traineeships	39,811,547	
Advanced science education projects:		
Special projects	1,158,938	
Advanced training projects	1,309,367	
Public understanding of science	185,754	
Subtotal	42,465,606	
Subtotal, science education support		106,533,794
Science information activities		10,664,451
International cooperative scientific activities		1,800,696
Planning and policy studies		2,421,717
Program development and management		16,490,514
Total obligations, NSF salaries and expenses appropriation		432,645,493
Unobligated balance carried forward to fiscal year 1970		3,117,160
Total		435,762,653

Trust Fund

Receipts	
Unobligated balance brought forward from fiscal year 1968	7,493
Donations from private sources	630
Total availability	8,123
Obligations	
Total obligations for fiscal year 1969	48
Unobligated balance carried forward to fiscal year 1970	8,075
Total	8,123

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 the following four patents by the U.S. Patent Office covering inventions arising out of Foundation-supported activities on each of which the Government has received a nonexclusive, irrevocable, nontransferable, royalty-free, worldwide license:

Patent No. 3,335,081 entitled "Method of Treatment of Sewage by Bio-Oxidation and Apparatus Therefor" was issued on August 8, 1967,[1] on an invention made by Ahmed Sami El-Naggar during the course of research supported by a grant to Valparaiso University, Valparasio, Ind. This invention relates to a method and apparatus of sewage treatment.

Patent No. 3,371,854 entitled "High Capacity Orbitron Vacuum Pump" was issued on March 5, 1968,[2] on an invention made by Raymond G. Herb during the course of research supported by a grant to the University of Wisconsin, Madison, Wis. This invention relates to high-voltage generators of the electrostatic type capable of producing extremely high voltages up to several million volts. One object is to provide a new and improved electrostatic generator in which the charging belt is replaced with one or more endless strings of conductive pellets insulated from one another and adapted to carry charges to the high voltage electrode.

Patent No. 3,424,904 entitled "Process for Producing Negative Hydrogen Ions from Protons" was issued on January 28, 1969, on an invention made by Bailey L. Donnally during the course of research supported by a grant to Lake Forest College, Lake Forest, Ill. This invention concerns a process for producing negative hydrogen ions from protons by passing a beam of relatively low energy (e.g., up to about 2,000 electron volts) protons through atoms of an alkali metal in order to produce a beam of particles containing metastable and ground state hydrogen atoms and charged particles.

Patent No. 3,434,335 entitled "Apparatus for Acoustically Detecting Minute Particles Suspended in a Gaseous Atmosphere" was issued on March 25, 1969, on an invention made by Gerhard Langer during the course of work performed under NSF Contract C-160 with the University Corporation for Atmospheric Research. This invention relates to a new aparatus for detecting and counting minute particles suspended in a gaseous atmosphere which apparatus responds to the particles in a jet stream by emitting sounds.

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[1] License received Dec. 9, 1968.
[2] License received July 3, 1968.

Appendix D

National Science Foundation-Supported Scientific Conferences, Symposia, and Advanced Science Seminars Held During Fiscal Year 1969

Scientific Conferences and Symposia in the Biological and Medical Sciences

Second International Congress of Primatology.—Yerkes Regional Primate Research Center, Emory University, Atlanta, Ga.; June 30–July 3, 1968; Chairman: Geoffry Bourne, Emory University; sponsor: Emory University.

Third International Symposium on Olfaction and Taste.—Rockefeller University, New York City; Aug. 19–21, 1968; Chairman: Carl Pfaffmann, Rockefeller University; Sponsor: Rockefeller University.

Fifth International Congress of Photobiology.—Dartmouth College, Hanover, N.H.; Aug. 26–31, 1968; Chairman: Warren Butler, University of California at San Diego; Sponsor: National Academy of Sciences.

Symposium on Organic Matter in Natural Waters.—College, Alaska; Sept. 2–4, 1968; Chairman: Dr. Donald W. Hood, University of Alaska; Sponsor: Institue of Marine Science, University of Alaska.

Third International Conference on Magnetic Resonance in Biological Systems.—Warrenton, Va.; Oct. 14–18, 1968; Chairman: W. D. Phillips; Sponsor: Du Pont Co., Varian Associates, National Science Foundation.

Fifteenth Annual Symposium on Systematics.—Missouri Botanical Garden, St. Louis, Mo.; Oct. 18–19, 1968; Chairman: Hugh B. Cutler, Missouri Botanical Garden; Sponsor: Missouri Botanical Garden.

Regional Conferences of the Society for Developmental Biology:

West Coast Conference.—San Fernando Valley State College, Northridge, Calif.; Oct. 22–24, 1968; Chairman: Mary Lee Barber, San Fernando State College; Sponsor: Society for Developmental Biology and the National Science Foundation.

Southeastern Conference.—Tallahasse, Fla.; April 25–26, 1969; Chairman: Dr. Morton L. Burdick, Florida State University; Sponsor: Society for Developmental Biology and the National Science Foundation.

Midwest Conference.—Indiana State College, Terre Haute, Ind.; April 30–May 2, 1969; Chairman: Dr. Norman A. Dial, Indiana State University; Sponsor: Society for Developmental Biology and the National Science Foundation.

Northwest Conference.—Friday Harbor, Wash.; May 16–18, 1969; Chairman: Dr. Arthur H. Whiteley, University of Washington; Sponsor: Society for Developmental Biology and National Science Foundation.

Workshop Conference on Topical Problems.—Corvallis, Oreg., Nov. 22–23, 1968; Chairman: W. P. Stephen, Oregon State University; Sponsor: West Coast Population Biologists.

Symposium on Chemical Mechanisms of Enzyme Catalysis.—New Orleans, La.; Dec. 27–29, 1968; Chairman: Dr. William Jencks, Brandeis University; Sponsor: National Science Foundation.

First Conference on Mechanisms of Amphibian Metamorphosis.—Wakulla Springs, Fla.; Jan. 9–11, 1969; Chairman: Dr. Earl Frieden, Florida State University; Sponsor: Florida State University.

Conference on Mossbauer Spectroscopy in Biological Systems.—University of Illinois, Urbana, Ill.; Mar. 17–18, 1969; Chairman: H. Frauenfelder and I. C. Gunsalus, University of Illinois; Sponsor: University of Illinois.

Fourth International Symposium on Laboratory Animals.—Washington, D.C.; Apr. 8–11, 1969; Chairman: Robert H. Yager, National Academy of Sciences; Sponsor: National Academy of Sciences.

Conference on Establishing a Troop of Japanese Macaques in the United States for Behavioral and Ecological Research.—Columbia, Mo.; May 2–4, 1969; Chairman: Dr. John T. Emlen, University of Wisconsin; Sponsor: University of Missouri.

Second International Symposium on Carotenoids Other Than Vitamin A.—New Mexico State University, Las Cruces, N. Mex., May 6–9, 1969; Chairman: Owen Weeks, New Mexico State University; Sponsor: International Union of Pure and Applied Chemistry, Hoffman-La Roche, New Mexico State University, National Science Foundation.

Thirty-Fourth Cold Spring Harbor Symposium on Quantitative Biology.—Cold Spring Harbor, N.Y.; June 5–12, 1969; Chairman: John Cairns, Cold Spring Harbor Laboratory of Quantitative Biology; Sponsor: National Science Foundation, National Institutes of Health and Atomic Energy Commission.

Conference on Mechanisms of Vertebrate Vision.—Rochester, N.Y.; June 12–14, 1969; Chairman: Robert Boynton, University of Rochester; Sponsor: National Science Foundation.

Symposium on Adaptive Aspects of In-

sular Evolution.—Mayaguez, P.R.; June 14–20, 1969; Chairman: A. C. Smith, University of Hawaii; Sponsor: Association for Tropical Biology.

Twenty-Eighth Symposium of the Society for Developmental Biology.—University of Colorado, Boulder, Colo.; June 16–18, 1969; Chairman: Anton Lang, University of Michigan; Sponsor: Society for Developmental Biology and the National Science Foundation.

Gordon Research Conferences:

Lysosomes, II: Cellular Resistance and Intercellular Parasitism.—Andover, N.H.; July 1–5, 1968; Chairman: George Parks, University of Rhode Island; Sponsor: Gordon Research Conference.

Molecular Pharmacology.—Tilton, N.H.; June 16–22, 1969; Chairman: O. Jardetzky, Sharp and Dohme Research Laboratories; Sponsor: Gordon Research Conference.

Nucleic Acids.—New Hampton, N.H.; June 16–22, 1969; Chairmen: Robert Bock, University of Wisconsin, and Jerome Vinograd, California Institute of Technology; Sponsor: Gordon Research Conference.

Cell Structure and Metabolism.—Meriden, N.H.; June 23–27, 1969; Chairman: Dr. Lowell Hokin, University of Wisconsin; Sponsor: Gordon Research Conference.

Proteins.—New Hampton, N.H.; June 23–27, 1969; Chairmen: Dr. Howard Schachman, University of California and Dr. C. H. W. Hirs, Brookhaven National Laboratory; Sponsor: Gordon Research Conference.

Scientific Conferences and Symposia in Computer Science

Conference on Undergraduate Education in Computer Science.—Park City, Utah; Sept. 8–13, 1968; Chairman: William Viavant, University of Utah; Sponsors: Association for Computing Machinery, Commission on Engineering Education, and University of Utah.

Conference on Computer-Assisted Instruction.—University Park, Pa.; Sept. 24–26, 1968; Chairman: Ralph T. Heimer, Pennsylvania State University; Sponsors: National Council of Teachers of Mathematics and Pennsylvania State University.

Special Series of Lectures on Mathematics, Computation, and Computers.—Urbana, Ill.; Oct. 28–Nov. 1, 1968; Chairman: J. Richard Phillips, University of Illinois; Sponsor: University of Illinois.

Second Conference on Computer Graphics.—Urbana, Ill.; Mar. 30–Apr. 2, 1969; Chairman: W. J. Poppelbaum, University of Illinois; Sponsor: University of Illinois.

Fourth Symposium on Numerical Algebra.—Gatlinburg, Tenn.; Apr. 13–18, 1969; Chairman: A. S. Householder, Society for Industrial and Applied Mathematics; Sponsors: Oak Ridge National Laboratory and Society for Industrial and Applied Mathematics.

Conference on Statistical Computation.—Madison, Wis.; Apr. 28–30, 1969; Chairman: Roy C. Milton, University of Wisconsin; Sponsor: University of Wisconsin.

Intensive Summer Course on Digital Computers in Chemical Instrumentation.—Lafayette, Ind.; June 8–27, 1969; Chairman: Samuel P. Perone, Purdue University; Sponsor: Purdue University.

Seminar on Computer-Aided Design in Engineering Education.—Houston, Tex.; June 9–July 31, 1969; Chairman: G. F. Paskusz, University of Houston; Sponsor: University of Houston.

Summer Institute in Computer Applications.—Urbana, Ill.; June 16–July 26, 1969; Chairman: John J. Bateman, University of Illinois; Sponsors: American Philological Association, National Endowment for the Humanities, University of Illinois.

Regional Conference on Automata and Computational Complexity.—Plattsburgh, N.Y.; June 23–27, 1969; Chairman: William E. Hartnett, State University of New York at Plattsburgh; Sponsors: Conference Board of the Mathematical Sciences and State University of New York.

Scientific Conferences and Symposia in the Engineering Sciences

Twelfth International Symposium on Combustion.—Poitiers, France; July 14–20, 1968; Chairman: J. P. Longwell, Combustion Institute; Sponsor: Combustion Institute.

Conference on Biomedical Materials.—Denver, Colo.; July 15–20, 1968; Chairman: David S. Crimmins, University of Denver; Sponsor: University of Denver.

International Conference on Vehicle Mechanics.—Detroit, Mich.; July 16–18, 1968; Chairmen: Herbert K. Sachs, Stephen R. Davis, Lawrence M. Patrick, Wayne State University; Sponsor: Wayne State University.

International Conference on Recent Developments in Ellipsometry.—Lincoln, Nebr.; Aug. 7–9, 1968; Chairman: N. M. Bashara, University of Nebraska; Sponsor: University of Nebraska.

Second International Conference on Thermal Analysis.—Worcester, Mass.; Aug. 18–23, 1968; Chairman: C. B. Murphy, Xerox Corp.; Sponsor: College of the Holy Cross.

Eleventh Midwestern Mechanics Conference.—Ames, Iowa; Aug. 18–20, 1968; Chairman: H. J. Weiss, Iowa State University; Sponsor: Iowa State University.

Twelfth International Congress on Applied Mechanics.—Stanford, Calif.; Aug. 26–31, 1968; Chairman: Nicholas J. Hoff, Stanford University; Sponsor: Stanford University.

International Symposium on Gallium Arsenide.—Dallas, Tex.; Oct. 16–18, 1968; Chairman: William N. Carr, Southern Methodist University; Sponsor: Southern Methodist University.

Conference on Interdisciplinary Aspects of the Application of Engineering Technology to the Industrialization of Developing Countries.—Pittsburgh, Pa.; Oct. 20–25, 1968; Chariman: Harold E. Hoelscher, University of Pittsburgh; Sponsor: University of Pittsburgh.

Symposium on Cybernetics and the Management of Large Systems.—Gaithersburg, Md.; Oct. 23–25, 1968; Chairman: Heinz Von Foerster, University of Illinois; Sponsor: The American Society for Cybernetics and the National Bureau of Standards.

Symposium on Engineering and Medicine.—Washington, D.C.; Oct. 30–31, 1968; Chariman: Edward L. David, Bell Telephone Laboratory; Sponsor: National Academy of Engineering.

Symposium on Nonsteady State Methods of Kinetics Experiments.—Los Angeles, Calif.; December 3, 1968; Chairman: William Manogue, DuPont Co.; Sponsor: American Institute of Chemical Engineers.

Conference on Effects of Temperature and Heat on the Engineering Behavior of Soils.—Washington, D.C.; Jan. 16, 1969; Chairman: James K. Mitchell, University of California, Berkeley; Sponsor: Highway Research Board, National Academy of Sciences.

Conference on Buckling of Space Frames.—New York, N.Y.; Apr. 1–2, 1969; Chairman: Lynn S. Beedle, Lehigh University; Sponsor: Column Research Council.

Symposium on Electron, Ion, and Laser Beam Technology.—Gaithersburg, Md.; May 21–23, 1969; Chairmen: S. K. Poultney and C. O. Alley, University of Maryland; Sponsor: National Bureau of Standards and the University of Maryland.

Conference on the Behavior of Structural Concrete Subjected to Combined Loadings.—Morgantown, W. Va.; June 16–18, 1969; Chairman: Emory L. Kemp, West Virginia University; Sponsor: West Virginia University.

Conference on Current Developments in High Voltage Electron Microscopy.—Monroeville, Pa.; June 17–19, 1969; Chairman: R. M. Fisher, U.S. Steel Corporation; Sponsor: National Institutes of Health and the United States Steel Corp.

Scientific Conferences and Symposia in the Environmental Sciences

Symposium on Theoretical Problems in Turbulence Research.—Pennsylvania State University, University Park, Pa., Sept. 9–13, 1968; Program Director of Symposium: Hendrik Tennekes, Associate Professor of Aerospace Engineering, Department of Aerospace Engineering, Pennsylvania State University; Co-sponsors: Pennsylvania State University; National Science Foundation.

Symposium on the High Pressure Environment.—National Bureau of Standards and Carnegie Institution of Washington, Washington, D.C., Oct. 14–18, 1968; Symposium Organizers: Drs. Charles W. Beckett and Edward C. Lloyd, National Bureau of Standards, and Drs. Peter M. Bell and Francis R. Boyd, Jr., Carnegie Institution of Washington; Co-sponsors: National Bureau of Standards; Carnegie Institution of Washington.

Scientific Conferences and Symposia in the Mathematical and Physical Sciences

Conference on Difference Methods for Initial Boundary Value Problems.—Denver, Colo., June 24–27, 1968; Chairman: Burton Wendroff, Mathematics Department, University of Denver; Co-sponsor: Universtiy of Denver.

Gordon Research Conference on Nuclear Structure Physics.—Tilton, N.H., July 29–Aug. 2, 1968; Chairman: Joseph Weneser, Department of Physics, Brookhaven National Laboratory; Vice-chairman: Linwood L. Lee; Co-sponsor: Gordon Research Conferences, Inc.

Research Seminar and Conference on Orthomodular Theory. — Amherst, Mass., June, July, and August 1968 (conference date, Aug. 3–10, 1968); Chairman: David J. Foulis, Department of Mathematics, University of Massachusetts; Co-sponsor: University of Massachusetts.

International Symposium on High-Speed Computing in Fluid Dynamics.—U.S. Naval Postgraduate School, Monterey, Calif., Aug. 19–24, 1968; Chairman, Scientific Committee: Francois N. Frenkiel, Applied Mathematics Laboratory, Naval Ship Research and Development Center, Washington, D.C.; Co-sponsors: International Union of Theoretical and Applied Mechanics, American Institute of Physics, Office of Naval Research, and Atomic Energy Commission.

Twenty-Third Annual Symposium on Molecular Structure and Spectroscopy.—Columbus, Ohio, Sept. 3–7, 1968; Symposium Co-Directors: K. Narahari Rao and H. H. Nielsen, Ohio State University; Co-sponsors: Ohio State University and Office of Naval Research.

Seventh Annual Eastern Theoretical Physics Conference.—Amherst, Mass. Oct. 18–19, 1968; Conference Chairman: Robert L. Gluckstern, Head, Department of Physics and Astronomy, University of Massachusetts; Co-sponsor: University of Massachusetts.

Seventh Rare-Earth Research Conference.—Coronado, Calif., Oct. 28–30, 1968; Conference Chairman: Joseph F. Nachman, Solar Division, International Harvester Co., San Diego, Calif.; Co-sponsor: Solar Division of International Harvester Co.

Symposium on Dynamics of Liquid Structures.—Cleveland, Ohio, Nov. 19–22, 1968; Chairman, Organizing Committee: Frederick H. Fisher, Scripps Institution of Oceanography, University of California, La Jolla, Calif.; Co-sponsors: Acoustical Society of America and Case Western Reserve University.

Symosium on Wiener-Hopf Equations.—Evanston, Ill., Nov. 29, 1968; Symposium Chairman: Allen Devinatz, Department of Mathematics, Northwestern University; Co-sponsor: Northwestern University.

International Symposium on Relativistic Astrophysics.—Dallas, Tex., Dec. 16–20, 1968; Symposium Organizers: A. G. W. Cameron, Yeshiva University; Istvan Ozsvath and Ivor Robinson, Southwest Center for Advanced Studies; Alfred Schild, E. L. Schucking, and Harlan Smith, University of Texas; Co-sponsors: Southwest Center for Advanced Studies; Belfer Graduate School of Science, Yeshiva University; University of Texas; Office of Naval Research; Air Force Office of Scientific Research; National Aeronautics and Space Administration; Atomic Energy Commission; and private sources.

New Mexico State University Mathematics Symposium.—Las Cruces, N. Mex., Christmas Holidays, December 1968; Co-sponsor: New Mexico State University.

Second Conference on Nuclear Isospin.—Asilomar Conference Grounds, Pacific Grove, Calif., Mar. 13–15, 1969; Conference Chairman: Stewart D. Bloom, Lawrence Radiation Laboratory, Livermore, Calif., and University of California, Davis, Calif.; Co-sponsors: Americal Physical Society, Atomic Energy Commission, and Lawrence Radiation Laboratory.

Conference on Complex Analysis.—Houston, Tex., April 1969; Chairman, Organizing Committee: H. L. Resnikoff, Department of Mathematics, Rice University; Co-sponsor: Rice University.

Midwest Conference on Theoretical Physics.—Iowa City, Iowa, May 9–10, 1969; Chairman: Edward R. McCliment, Department of Physics and Astronomy, University of Iowa; Co-sponsor: University of Iowa.

Status Discussion Meeting on the Concept of Resonance in Subatomic Physics.—Eugene, Oreg., May 15–17, 1969; Organizer and Host for Meeting: Michael J. Moravcsik, Department of Physics and Institute of Theoretical Science, University of Oregon; Co-sponsors: University of Oregon, Atomic Energy Commission, and Willamette Valley Research Council.

Regional Conference on Nilpotent Groups.—Austin, Tex., May 26–30, 1969; Chairman: John R. Durbin, Department of Mathematics, University of Texas at Austin; Co-sponsor: University of Texas at Austin.

Regional Conference on Global Differentiable Dynamics.—Cleveland, Ohio, June 2–6, 1969; Co-Chairmen, Organizing Committee: A. J. Lohwater and Nam P. Bhatia, Department of Mathematics, Case Western Reserve University; Co-sponsor: Case Western Reserve University.

Regional Conference on Algebraic and Analytic Aspects of Operator Algebras.—Honolulu, Hawaii, June 9–13, 1969; Principal Organizer: Adolf Mader, Department of Mathematics, University of Hawaii.

Regional Conference on Boundary Value Problems and Differential Equations.—Knoxville, Tenn., June 9–13, 1969; Conference Director: John S. Bradley, Department of Mathematics, University of Tennessee; Co-sponsor: University of Tennessee.

Symposium on Kinetic Equations.—Ithaca, N.Y., June 12–13, 1969; Chairman of Symposium: Richard L. Liboff, Department of Applied Physics and School of Electrical Engineering, Cornell University; Co-Chairman: Norman Rostoker, IBM; Co-sponsor; Cornell University.

International Conference on Symmetries and Quark Models.—Detroit, Mich. June 18–20, 1969; Conference Chairman: Ramesh Chand, Department of Physics, Wayne State University; Co-sponsors: Wayne State University and Atomic Energy Commission.

Regional Conference on Automata and Computational Complexity.—Plattsburgh, N.Y., June 23–27, 1969; Conference Director: William E. Hartnett, Department of Mathematics, State University of New York at Plattsburgh; Cosponsor: State University of New York at Plattsburgh.

Scientific Conferences and Symposia in the Social Sciences

Research Conference on Comparative State Policies.—Ann Arbor, Mich.; July 28–Aug. 3, 1968; Chairman: Warren E. Miller; Sponsor: Inter-University Consortium for Political Research and University of Michigan.

Conference in Proof Theory and Intuitionism.—Buffalo, N.Y.; Aug. 11–30, 1968; Chairman: John Myhill; Sponsor: State University of New York at Buffalo.

International Symposium on Methodology and Theory in Archaeological Interpretation.—Flagstaff, Ariz.; Sept. 10–26, 1968; Chairman: Robert W. Ehrich; Sponsor: American Anthropological Association.

Conference on Technology and Competition in International Trade.—New York, N.Y.; Oct. 11–12, 1968; Chairman: Raymond Vernon; Sponsor: Universities-National Bureau Committee for Economic Research.

Symposium on Social Behavior.—Oxford, Ohio; Nov. 1–2, 1968; Chairman: G. A. Milton; sponsor: Miami University.

Conference on Education and Income.—Madison, Wis.; Nov. 15–16, 1968; Chairman: W. Lee Hansen; Sponsor: Conference on Research in Income and Wealth, National Bureau of Economic Research.

Symposium on the History of Economic Thought.—Durham, N.C.; Dec. 6–7, 1968; Chairman: Robert S. Smith; Sponsor: Duke University.

Conference on Law and the Social Sciences.—Washington, D.C.; Feb. 10–11, 1969; Chairman: Michael H. Cardozo; Sponsor: Association of American Law Schools.

Conference on Comparative Legislative Behavior Research.—Iowa City, Iowa; May 26–30, 1969; Chairmen: Samuel C. Patterson and John C. Wahlke; Sponsor: University of Iowa.

A Bi-National Program of Geographical Research: Israel and America.—Jerusalem, Israel; June 30–July 12, 1969; Chairman: Saul B. Cohen; Sponsors: Association of American Geographers and Hebrew University.

A Multidisciplinary Symposium on "Global Systems Dynamics".—Charlottesville, Va.; June 17–19, 1969; Chairman: Ernst O. Attinger; Sponsor: University of Virginia.

Advanced Science Seminars

Advanced Science Seminar in Linguistics.—Urbana, Ill.; June 16–Aug. 9, 1969; Director: R. B. Lees, University of Illinois; Grantee: American Council of Learned Societies.

International Field Institute-African Rift Valley System.—East Africa; June 27–Aug. 11, 1969; Director: G. R. Downs, American Geological Institute; Grantee: American Geological Institute.

Regional Conferences in Comparative Endocrinology.—Memphis, Tenn.; Laramie, Wyo.; Greenvale, N.Y.; New Orleans, La; Lincoln, Nebr.; Indiana, Pa.; Seattle, Wash.; Oct. 31, 1968–May 24, 1969; Director: W. Chavin, Wayne State University; Grantee: American Society of Zoologists.

Advanced Seminar in Algebraic Groups.—Brunswick, Maine; July 2–Aug. 22, 1968; Director: D. E. Christie, Bowdoin College; Grantee: Bowdoin College.

Advanced Seminar in Category Theory.—Brunswick, Maine; June 24–Aug. 15, 1969; Director: D. E. Christie, Bowdoin College; Grantee: Bowdoin College.

Institute in Theoretical Physics.—Waltham, Mass.; June 16–July 25, 1969; Director: E. Lipworth, Brandeis University; Grantee: Brandeis University.

Support for U.S. participation in *A Seminar on Global Analysis.*—Montreal, Canada; June 25–July 26, 1969; Director: J. Maranda, University of Montreal; Grantee: Canadian Mathematical Congress.

Summer Seminar for Research Workers in Statistics.—Fort Collins, Colo.; June 16–27, 1969; Director: J. S. Williams, Colorado State University; Grantee: Colorado State University.

Seminar on Comparison of Recent and Ancient Deltaic Sediments.—Baton Rouge, La.; April 1–5, 1969; Director: S. M. Gagliano, Louisiana State University; Grantee: Louisiana State University.

Institute in Dynamical Astronomy.—Cambridge, Mass.; June 16–July 11, 1969; Director: V. Szebehely, University of Texas; Grantee: Massachusetts Institute of Technology.

Summer Institute of Glaciological and Arctic Sciences.—Juneau Icefield, Alaska; July 13–Aug. 30, 1968; Director: M. M. Miller, Michigan State University; Grantee: Michigan State University.

Support for U.S. participation in *The Tenth Latin American School of Physics.*—Mexico City, Mexico; July 1–27, 1968; Director: M. Moshinsky, National Autonomous University of Mexico; Grantee: National Autonomous University of Mexico.

Support for U.S. participation in the *Second Latin American Chemistry Seminar.*—Santiago, Chile; July 8–26, 1968; Director: J. D. Perkinson, Pan American Union; Grantee: Pan American Union.

Institute in Systematics for Zoologists.—Washington, D.C.; June 23–July 12, 1969; Director: P. Illg, University of Washington; Grantee: Society of Systematic Zoology.

Field Training in Cultural Anthropology.—Oaxaca City, Oaxaca, Mexico; June 16–Aug. 22, 1969; Director: B. D. Paul, Stanford University; Grantee: Stanford University.

Advanced Field Training in Archaeology.—Fort Apache, Ariz.; June 13–Aug. 7, 1969; Director: R. H. Thompson, University of Arizona; Grantee: University of Arizona.

Summer Workshop on Molecular Techniques in Developmental Biology.—La Jolla, Calif.; Aug. 3–31, 1968; Director: H. Stern, University of California, San Diego; Grante: University of California, San Diego.

Advanced Graduate Seminar in Electrical Engineering.—Boulder, Colo.; June 16–Aug. 22, 1969; Director: F. S. Barnes, University of Colorado; Grantee: University of Colorado.

1969 Summer Institute for Theoretical Physics.—Boulder, Colo.; June 16–Aug. 22, 1969; Director: W. E. Brittin, University of Colorado; Grantee: University of Colorado.

Summer Colloquium on Solar Magnetohydrodynamics.—Boulder, Colo.; June 16–Aug. 8, 1969; Director: P. A. Gilman, University of Colorado; Grantee: University of Colorado.

Winter Institute in Quantum Chemistry, Solid-State Physics and Quantum Biology.—Gainesville, Fla.; Sanibel Island, Fla.; Dec. 2, 1968–Jan. 18, 1969; Director: P. O. Lowdin, University of Florida; Grantee: University of Florida.

Communication Sciences Seminar on Transformational Grammar as a Model of Language Users.—Gainesville, Fla.; Sept. 2–13, 1968; Director: R. J. Scholes, University of Florida; Grantee: University of Florida.

Seminar on Computer-Aided Design in Engineering Education.—Houston, Tex.; June 9–Aug. 1, 1969; Director: G. F. Paskusz, University of Houston; Grantee: University of Houston.

Seminars in Theoretical and Applied Economics.—St. Louis, Mo.; Lawrence, Kans.; Boulder, Colo.; Ames, Iowa; Oct. 18, 1968—May 6, 1969; Director:

J. P. Quirk, University of Kansas; Grantee: University of Kansas.

Laser Raman Institute and Workshop.—College Park, Md.; June 9–13, 1969; Director: E. R. Lippincott, University of Maryland; Grantee: University of Maryland.

Advanced Science Seminar in Tropical Botany.—Coral Gables, Fla.; June 16–Aug. 2, 1969; Director: H. J. Teas, University of Miami, Grantee: University of Miami.

Conference on Group Theory.—Ann Arbor, Mich.; July 8–19, 1968; Director: R. C. Lyndon, University of Michigan; Grantee: University of Michigan.

Field Training for Anthropoligists.—Western U.S.; June 16–Aug. 22, 1969; Director: W. L. d'Azevedo, University of Nevada; Grantee: University of Nevada.

Advanced Science Seminar on Intertidal Zone Sedimentation.—Parrsboro, Nova Scotia, Canada; July 6–Aug. 11, 1968; Director: G.deV. Klein, University of Pennsylvania; Grantee: University of Pennsylvania.

Field Training in Cultural Anthropology.—Tlaxcala, Puebla, Mexico; June 15–Aug. 22, 1969; Director: D. Landy, University of Pittsburgh; Grantee: University of Pittsburgh.

Symposium on the Foundations of Relativistic and Classical Thermodynamics.—Pittsburgh, Pa.; Apr. 7–8, 1969; Director: E. B. Stuart, University of Pittsburgh; Grantee: University of Pittsburgh.

Electron Microscopy for Molecular Biologists.—Oak Ridge, Tenn.; Sept. 29–Oct. 19, 1968; Director: L. G. Caro, Oak Ridge National Laboratory; Grantee: University of Tennessee.

Symposium on the Evolution of Higher Basidiomycetes.—Knoxville, Tenn.; Aug. 5–15, 1968; Director: R. H. Petersen, University of Tennessee; Grantee: University of Tennessee.

Advanced School for Statistical Mechanics and Thermodynamics.—Lake Travis, Tex.; Mar. 17–28, 1969; Director: R. S. Schechter, University of Texas; Grantee: University of Texas.

Seminar in Theroretical Physics.—Madison, Wis.; Apr. 1–May 10, 1969; Director: V. G. Barger, University of Wisconsin; Grantee: University of Wisconsin.

1969 Summer Institute in Behavioral Science and Law.—Madison, Wis.; June 23–Aug. 16, 1969; Director: S. A. Scheingold, University of Wisconsin; Grantee: University of Wisconsin.

Advanced Seminar in Statistics.—Blacksburg, Va.; June 12–July 23, 1969; Director: B. Harsbarger, Virginia Polytechnic Institute; Grantee: Virginia Polytechnic Institute.

Graduate Student Field Training Program in Anthropology.—Ixmiquilpan, Mexico; June 20–Aug. 21, 1969; Director: H. R. Bernard, Washington State University; Grantee: Washington State University.

Summer Programs in Geophysical Fluid Dynamics.—Woods Hole, Mass.; June 23–Aug. 29, 1969; Director: M. V. Malkus, Woods Hole Oceanographic Institute; Grantee: Woods Hole Oceanographic Institution.

Postdoctoral Research Training Program in Oceanography.—Woods Hole, Mass.; Sept. 1, 1968–Aug. 31, 1969; Director: A. E. Maxwell, Woods Hole Oceanographic Institution; Grantee: Woods Hole Oceanographic Institution.

Postdoctoral Research Training Program in Biological Oceanography.—Woods Hole, Mass.; Sept. 1, 1968–Aug. 31, 1969; Director: J. H. Ryther, Woods Hole Oceanographic Institution; Grantee: Woods Hole Oceanographic Institution.

Appendix E

Publications of the National Science Foundation Fiscal Year 1969

1 GRADUATE STUDENT SUPPORT AND MANPOWER RESOURCES IN GRADUATE SCIENCE EDUCATION (NSF 68–13).
2 REVIEWS OF DATA ON SCIENCE RESOURCES, No. 14, "Scientific and Technical Personnel in the Federal Government, 1966" (NSF 68–16).
3 ORGANIZATIONAL DEVELOPMENT OF THE NATIONAL SCIENCE FOUNDATION (NSF 68–17).
4 HUMAN DIMENSIONS OF THE ATMOSPHERE (NSF 68–18).
5 ENGINEERING RESEARCH INITIATION GRANTS (NSF 68–19).
6 RESEARCH AND DEVELOPMENT IN INDUSTRY, 1966 (NSF 68–20).
7 9TH ANNUAL WEATHER MODIFICATION REPORT (NSF 68–21).
8 SCIENTIFIC ACTIVITIES AT UNIVERSITIES AND COLLEGES, 1964 (NSF 68–22).
9 SCIENTIFIC INFORMATION NOTES, June–July 1968, Vol. 10, No. 3 (NSF 68–23).
10 RELEASED TEXTBOOKS, FILMS, AND OTHER TEACHING MATERIALS (NSF 68–24).
11 SCIENTIFIC INFORMATION NOTES, August–September 1968, Vol. 10, No. 4 (NSF 68–25).
12 NATIONAL SCIENCE FOUNDATION (NSF 68–26).
13 FEDERAL FUNDS FOR RESEARCH, DEVELOPMENT, AND OTHER SCIENTIFIC ACTIVITIES, VOL. XVII (NSF 68–27).
14 TO IMPROVE SECONDARY SCHOOL SCIENCE AND MATHEMATICS TEACHING (NSF 68–28).
15 DEPARTMENTAL SCIENCE DEVELOPMENT PROGRAM (NSF 68–29).
16 EMPLOYMENT OF SCIENTISTS AND ENGINEERS IN THE UNITED STATES (NSF 68–30).
17 SUPPORT AND RESEARCH PARTICIPATION OF YOUNG AND SENIOR ACADEMIC STAFF (NSF 68–31).
18. U.S.-JAPAN COOPERATIVE SCIENCE PROGRAM (NSF 68–32).
19. CURRENT RESEARCH AND DEVELOPMENT IN SCIENTIFIC DOCUMENTATION, No. 15 (NSF 68–33).
20. SCIENTIFIC INFORMATION NOTES, October-December 1968, Vol. 10, Nos. 5 and 6 (NSF 68–34).
21. 18TH ANNUAL REPORT, 1968, NATIONAL SCIENCE FOUNDATION (NSF 69–1).
22. GRANTS AND AWARDS, 1968, NATIONAL SCIENCE FOUNDATION (NSF 69–2).
23. JUNIOR COLLEGE TEACHERS OF SCIENCE, ENGINEERING, AND TECHNOLOGY, 1967 (NSF 69–3).
24. REVIEWS OF DATA ON SCIENCE RESOURCES, No. 15, "Baccalaureate Sources of Science and Engineering Manpower" (NSF 69–4).
25. REVIEWS OF DATA ON SCIENCE RESOURCES, No. 16, "Salaries and Selected Characteristics of U.S. Scientists, 1968" (NSF 69–5).
26. NATIONAL SCIENCE FOUNDATION DATABOOK (NSF 69–6).
27. FEDERAL SUPPORT TO UNIVERSITIES AND COLLEGES, FISCAL YEAR 1967 (NSF 69–7).
28. CURRENT RESEARCH AND DEVELOPMENT IN SCIENTIFIC DOCUMENTATION, No. 15 (NSF 69–8).
29. PUBLICATIONS OF THE NATIONAL SCIENCE FOUNDATION, February 1969 (NSF 69–9).
30. SCIENTISTS, ENGINEERS, AND PHYSICIANS FROM ABROAD, FISCAL YEARS 1966 AND 1967 (NSF 69–10).
31. ANNOUNCEMENT OF INSTITUTIONAL GRANTS FOR SCIENCE, 1969 (NSF 69–11).
32. REVIEWS OF DATA ON SCIENCE RESOURCES, No. 17, "Research and Development in Industry, 1967" (NSF 69–12).
33. NATIONAL SCIENCE FOUNDATION GUIDE TO PROGRAMS (NSF 69–13).
34. R. & D. ACTIVITIES OF LOCAL GOVERNMENTS, FISCAL YEARS 1966 AND 1967 (NSF 69–14).
35. GRANTS FOR EDUCATION IN SCIENCE (NSF 69–19).
36. SUPPLEMENT TO COURSE AND CURRICULUM IMPROVEMENT PROJECTS (NSF 69-21).

Glossary

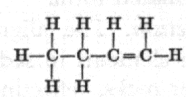
The following list is appended for the convenience of the nonscientist reader. The explanations are not intended as exhaustive definitions, but merely as an aid to better understanding.

algorithm. A step-by-step procedure or method for manipulating data according to predetermined "rules," frequently involving repetinitive operations, in order to arrive at a desired answer.

alpha particle. A subatomic particle consisting of two protons and two neutrons bound tightly together. It is identical with the nucleus of helium and is ejected with high velocity from the nucleus when it collides with some radioactive nuclei.

biostratigraphy. The separation and differentiation of rock units on the basis of assemblages of fossils which they contain.

butene. An "unsaturated" compound consisting of four carbon atoms and eight hydrogen atoms; C_4H_8. In this compound, two of the four carbon atoms are doubly bonded to each other as indicated.



cardiopulmonary bypass. A medical procedure undertaken during surgery when, for various reasons, it is necessary temporarily to oxygenate blood by mechanical means, bypassing the patient's own heart and lungs.

Cassegrain focus. An alternate position of the focus in an astronomical telescope (either optical or radio) in which the light (or radio) waves following reflection from the primary (concave) mirror are reflected a second time back toward the primary mirror.

chert. A form of silica found in sedimentary rocks usually as nodules or irregular lumps. It is very fine grained and exhibits a variety of colors.

chromosphere. The lowest part of the atmosphere of the sun, just above the photosphere. It is thousands of miles thick and is composed chiefly of hydrogen gas.

coherent vibrations. Vibrations in which all waves are in phase and of the same wavelength.

cryogenic. Of or relating to the production of very low temperatures.

deoxyribonucleic acid (DNA). The nucleic acid which normally stores the hereditary information of an organism. A nucleic acid is a macromolecule consisting of nucleotides linked in a chain.

deuterium. A heavy isotope of hydrogen. It is like hydrogen except its mass is very nearly twice the mass of hydrogen.

deuteron. The nucleus of deuterium or heavy hydrogen. It consists of a neutron and a proton bound together with a binding energy of 2.2 million electron volts.

dropsonde. A radio-bearing instrument which is dropped by parachute from an aircraft for the purpose of obtaining soundings (temperature and humidity) of the atmosphere below.

electron. A subatomic particle of negative charge and of small mass. It can be pictured as orbiting the nucleus of an atom. Chemical reactions involve the interactions of electrons.

flux. The rate of transfer of particles or energy through a given surface.

gel electrophoresis. A technique of separating molecules by placing them in a bath with electrodes at each end, towards which different molecules will migrate at characteristic rates. If the bath includes a gel, the molecules will be immobilized at specific positions so that each kind may be isolated for further study.

genetic locus. Position of a gene in the heredity material.

gnotobiotic. Describes experimental animals which are free of germs, having been raised from birth in a totally germ-free environment.

graupel. Small, white, opaque ice pellets.

hemolyze. To cause, by chemical or mechanical means, the release of hemoglobin from red blood cells.

hydrolyze. To undergo a chemical process in which the elements of water are added to the original compound.

hygroscopic. That characteristic of a mineral or chemical compound which causes it to absorb readily large quantities of water.

in situ. Signifying that a measurement or observation is taken of a phenomenon in its original location, or as it naturally occurs, rather than in the more artificial conditions of laboratory measurement.

interferometer. In radio astronomy, an antenna system arranged to make use of the natural interference of radio waves related to their direction of arrival at the system, thereby increasing the apparent resolving power of the antenna.

interstitial water. The water between the grains of a sedimentary deposit.

leukopenia. A physiological condition in which the number of leukocytes, the infection-fighting white cells of the blood, is abnormally low.

macromolecule. A very large molecule usually made up of smaller molecules linked together. Examples are proteins, nucleic acids, and artificial polymers.

magnetopause. The boundary between the earth's magnetic field and the interplanetary magnetic field.

magnetosphere. The region surrounding the earth which totally encloses the magnetic field of the earth.

molecular fluorescence. Radiation emitted from a certain excited quantum state of a molecule (called a singlet state). The excited singlet state loses energy in the form of radiation and decays to the lowest lying stable singlet state of the molecule.

montmorillonite. A group of closely related fine-grained clay minerals, one characteristic of which is a high propensity to absorb water.

neutron. A neutral particle with mass equal to that of 1,838 electrons. Although stable when bound in nuclei, free neutrons are short-lived, decaying into smaller subatomic particles.

nucleotide. A biochemical molecule consisting of a nitrogen-containing base, a 5-carbon sugar, and a phosphate group.

nucleus. In chemistry and physics, the core of an atom, composed of protons and neutrons surrounded by a cloud of electrons. In biology, the nucleus is a body within a living cell which contains the heredity material.

oxidized states. Those states of a substance resulting from the loss of an electron. For example, the ferrous ion (Fe^{++}) is oxidized to the ferric ion (Fe^{+++}). $Fe^{++} \rightarrow Fe^{+++} +$) electron.

oximetry. Any of several methods for the measurement of the proportion of hemoglobin in blood which is in the oxygenated form.

paleomagnetism. The alignment of magnetic elements in sedimentary and other rocks, reflecting the direction of the earth's magnetic field at the time of their deposition.

palygorskite. A group of clay minerals (hydrous magnesium aluminum silicates) characterized by a distinctive rod-like shape.

pheromone. Chemical substances secreted by living organisms, release of which is used as a means of communication among members of a group.

photochemistry. A branch of chemistry emphasizing the transient events and permanent effects produced when a molecule or atom interacts with electromagnetic radiation, chiefly near the visible and the ultraviolet regions of the spectrum.

photoelectron. An electron released from an atom or molecule by the action of light.

photosphere. The visible surface of the sun on which sunspots and other physical markings appear. It is the limit of the distance into the sun that can be seen.

plasma. A gaseous medium composed of ions, electrons as well as neutral atoms and molecules in such proportions that the whole gas is electrically neutral. Unlike an ordinary gas, it is a good electrical conductor and is affected by magnetic fields.

plasmapause. A transition region of the magnetosphere which separates the relatively dense plasma of terrestrial origin from the tenuous plasma of solar origin. It is located at about 1,600 miles from the earth's surface.

plasmasheet. A dynamic region of plasma accumulation between the plasmapause and the nighttime extension of the earth's magnetic field. The energetic particles which cause the aurora are believed to originate in this region of the magnetosphere.

polymer. A molecule formed by linking up a number of simpler molecular units. The repeated units are called monomers.

polypeptide. A macromolecule consisting of, usually, fewer than 100 amino acids linked together in a single chain. Amino acids are the building blocks for proteins.

potential energy. Energy due to the position of one body (atom or molecule) with respect to another or with respect to the relative parts of the same body.

proton. A positively charged, stable nuclear particle with mass equal to that of 1,836 electrons. It is identical with the nucleus of the lightest and most abundant isotope of hydrogen.

quantum states. The discrete energy levels at which a given atom or molecule can exist. The energy gaps between these states are determined by characteristic spectral lines or bands.

reduced states. Those states of a substance resulting from the addition of an electron. For example, the ferric ion (Fe^{+++}) is reduced to the ferrous ion (Fe^{++}). Fe^{+++}+ electron→Fe^{++}.

species. In biology, a category of classification including organisms potentially capable of interbreeding. In physics and chemistry, particular atomic or molecular entities.

stratosphere. The lower part of the outer region of the atmosphere, lying immediately above the troposphere. It extends to a height of 35 to 40 miles above the earth's surface.

synoptic. Pertaining to data obtained simultaneously over a wide area for the purpose of presenting a comprehensive and nearly instantaneous picture of a large-scale phenomenon.

taxonomy. The theoretical study of classification of plants and animals according to their presumed natural relationships.

terrigenous clay. A clay derived from land by erosion processes.

thermoconductivity. The property of a substance by which heat is transferred from molecule to molecule.

thermal asymmetry. A temperature distribution (and the resulting heat transfer) which is not of balanced proportions about a point, line or plane, i.e., has no symmetry.

thermal neutron. A neutron of relatively low kinetic energy, as opposed to a "fast neutron" with high kinetic energy.

tropopause. The boundary between the troposphere and stratosphere.

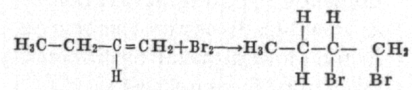
troposphere. The lowest layer of the atmosphere, containing about three-quarters of the total mass of the atmosphere. It varies in height from 4 to 10 miles, depending on the season.

turbidite deposits. Underwater deposits laid down by flows of muddy water.

undecane. A "saturated" compound consisting of 11 carbon atoms and 24 hydrogen atoms,

$$CH_3(CH_2)_9CH_3.$$

unsaturated. The availability or potential for bond formation in a chemical compound. Multiple bonds in compounds are frequently centers for addition reactions such as:



The butene on the left is "unsaturated." However, following addition it is described as "saturated."

vegetative. The growth state of a living cell, as opposed to the dormant state.

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