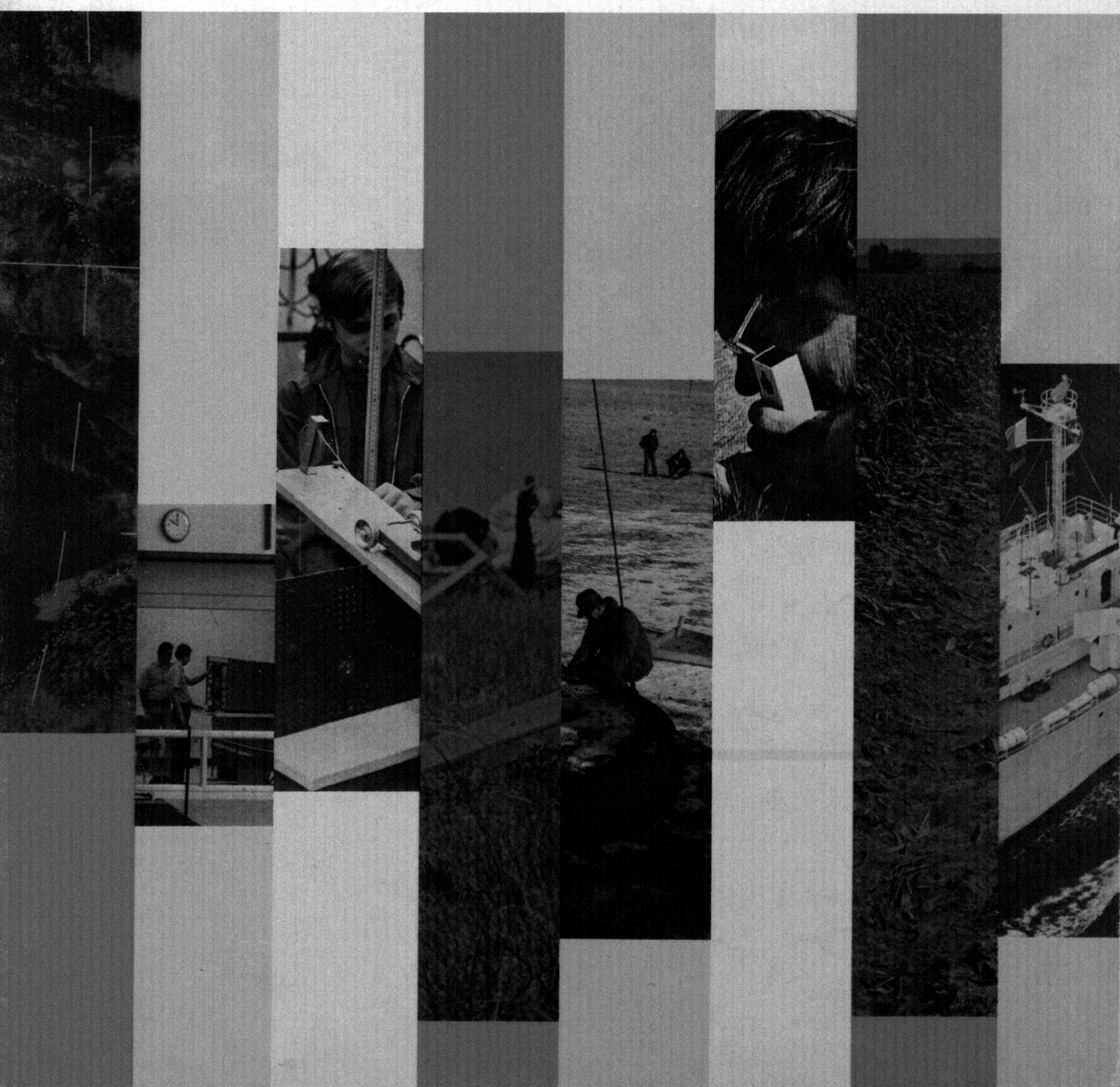
# National Science Foundation Annual Report 1971

NSF 72–1



# National Science Foundation

*Twenty-First Annual Report for the Fiscal Year Ended June 30, 1971*

## *Letter of Transmittal*

Washington, D.C.

DEAR MR. PRESIDENT:

I have the honor to transmit herewith the Annual Report for Fiscal Year 1971 of the National Science Foundation for submission to the Congress as required by the National Science Foundation Act of 1950.

Respectfully,

W. D. MCELROY
*Director, National Science Foundation.*

***The Honorable***
***The President of the United States.***

U.S. GOVERNMENT PRINTING OFFICE
WASHINGTON: 1972

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# *Director's Statement*

## First Step in a Decade of Change

In the last Annual Report, I referred to the 1970's as a transitional decade. Now the opening year of the decade has passed. What is new? What do the changes mean? Are we moving in the right direction —even though our final destination isn't in sight?

In science, which is so critical to the survival of our society, some of the answers to these questions are to be found in the activities of the National Science Foundation during fiscal year 1971.

Most things, as a matter of fact, are still the same. The Foundation's central commitment to progress in fundamental research remains unchanged. We maintain a continuing concern for education in science and those institutions involved in science education. As in the past, the Foundation must continue its leadership role in the Federal support of science.

While holding fast to these well-established themes, changing times and needs require that such themes be carried out differently and with different emphases. This may mean fiscal reductions in some areas, increases in others. At the same time, new initiatives and policies must also be instituted. Both the adaptation of traditional NSF policies and the creation of new policies have indeed changed the status quo.

In our core program of research support (the familiar disciplinary project grant), every discipline has received additional funding in fiscal year 1971 —though some of this increase merely compensated for research support other agencies were forced to drop. The social sciences, engineering, biological

sciences, and oceanography received special emphasis in fiscal year 1971. These areas were selected for emphasis, in large part, because anticipated research results are believed likely to provide options for helping solve some of our urgent problems.

In selecting disciplines for special attention, we are, in effect, engaging only in fine tuning. Fundamental science flourishes best, it seems to me, when scientific inquiry is guided primarily by scientific interest and opportunity. By adhering to this principle, NSF's support of superior research will help maintain the nation's position of scientific leadership.

The most important NSF development in 1971, continuing an effort started last year, was the establishment of a new Research Applications Directorate to provide a single management focus to problem-oriented research. Although problem-oriented research has been supported by the Foundation for more than a decade, the new directorate will concentrate additional resources upon specific problems of national concern. Major programs of the Research Applications Directorate are designed to help scientists increase societal benefits from research, exploit promising scientific and technological opportunities, and provide a base to advance national economic growth and productivity. This new directorate—which comprises about 10 percent of the fiscal year 1972 NSF budget—will support work in four broad areas: environmental systems and resources, social systems and human resources, advanced technology applications, and exploratory research and problem assessment. In addition, the Research Applications Directorate is charged with the strengthening of science resources available to State and local governments, and with encouraging State and local officials to exploit the potential for applying science and technology.

I am keenly aware of the strong interactions between the programs of the Research Applications Directorate and the interests and responsibilities of other Federal agencies, as well as State governments and private industry. Therefore, NSF efforts will be carefully coordinated with these other parties, and it is intended to complement and underpin the existing capabilities of others through cooperative effort.

While NSF efforts are directed both toward the traditional forms of support for fundamental research and in the direction of research applied to national needs, certain problems are—and I suppose always will be—the same. The increasing complexity of scientific investigation, ever more sophisticated equipment, and the growing community of researchers all place heavier fiscal pressures on the Foundation and force greater selectivity on our part. I believe the programs undertaken with the resources available represent a balanced and reasonably comprehensive support of both fundamental research and problem-focused research.

We support efforts at NSF which, in addition to being fundamental or problem-oriented in character, are designated as National and Special Research Programs for purposes of management. These are major undertakings which relate to specific geographic areas or are of such broad scope or magnitude that special efforts in planning, management, funding, and logistic support are essential. Some of these programs have been under way for many years—the U.S. Antarctic Research Program and, more recently, the International Biological Program. Fiscal year 1971 marked the beginning of scientific activities for the International Decade of Ocean Exploration (IDOE), for which NSF has been designated lead agency for the United States. The IDOE will apply the combined resources of many nations to expand our knowledge of the earth's marine environment for mutual benefit.

During fiscal year 1971, plans for the University National Oceanographic Laboratory System (UNOLS) were developed for improved management of ship operations and oceanographic facilities at academic institutions. The objective of UNOLS is to use a systems approach to the sharing of large oceanographic facilities by the academic community.

Changes in the status quo are evidenced in more than just new activities or increased support for existing programs. As needs change, as worthy programs approach the practical fulfillment of their original objectives, priority shifts are forced by limited resources. For this reason, while most NSF programs received increased funding in 1971, several were redirected or phased out. Fiscal reductions have been most pronounced in NSF's institutional and educational support sectors. During fiscal year 1971, a decision was made to assign a higher priority to research support and, as a consequence, the Science Development Program was suspended. The Graduate Science Facilities Program ended the previous year.

Important changes in program emphasis are under way in NSF's science education programs. As in the case of institutional development, certain long-term objectives have been largely achieved or their priorities necessarily reduced. I would stress that the changes, intended to make more efficient use of our resources, were undertaken only after our most intensive consideration. After taking into account such factors as societal needs, program effectiveness, expected program duration, and the minimum levels of support required to keep satisfactory programs operating, we concluded that the new order of emphasis should be curriculum development, teacher improvement, and student support. In practice, this means:

- Curriculum development focused more directly on social and environmental problems, particularly those of a multidisciplinary nature;
- Local school systems helped to augment their own capabilities for science education programs by training science educators as specialists within their own institutions;
- Broadened career alternatives made available in science and engineering at both the graduate and technologist levels. At the technologist level, we are seeking to help fulfill the need for technologists who have received substantial college-level training in specific fields so they can aid senior research and development personnel.

By concentrating more of our resources for science education on these types of activities, we expect to sustain a high-quality science education program which will affect a wide range of students and teachers. To accomplish this goal, however, it was necessary for us to make a significant reorientation in the Foundation's direct support for graduate education. In fiscal year 1971, no new traineeships were granted because the indicated need for special incentives in this area has considerably diminished. The traditional program of NSF graduate fellowships has been continued, however, but at a slightly reduced scale.

Among the ongoing Foundation programs in science education, we expect in the College Science Improvement Program to provide specific opportunities for colleges and universities historically directed toward the education of racial minority groups. We are continuing support training for science teachers and supervisory personnel, together with coordinated State, local, and private efforts for Statewide or regional approaches to improving science education.

My comments cover only the highlights of events during the past fiscal year that indicate how the Foundation has reoriented and redirected its energies at the outset of the transitional decade. During the past year, we have made progress in responding to the needs of the whole of our society, its environment, and the growth of the individuals who make it up. In so doing, we have had to make many hard choices. It is too soon to say that we have delivered what we have promised. But we have begun a period of growth which is dynamic. If it is to continue, this growth must be based on a broader and better informed American public. The informed citizen of the future cannot be indifferent to the impact of science on his life. At the same time, the scientific community must be more sensitive to the spirit of the times. The scientist's faith in knowledge for the sake of understanding must

increasingly include the concept of conscience, which includes and is greater than the word "science." This we have begun in the past year.

I have resigned as Director of the National Science Foundation, effective in February 1972, to become Chancellor of the University of California, San Diego. During my tenure as Director of the National Science Foundation, I have tried to serve the needs of the nation and the scientific community. No man can accept such a task without a keen sense of its importance, nor with any hope of success without the help of dedicated and competent colleagues. I am grateful to the National Science Board for their counsel, and the staff of the National Science Foundation for their effective and loyal support. They have my warmest thanks.

In my relations with the Congress and within the Executive Branch, I have met an openmindedness, sincerity, and cooperation which has made my term memorable for me as an individual—and, I believe, beneficial for science and the nation. In this last Director's Statement that I will make for the Foundation, I express my gratitude and my hope that the forward movement of the National Science Foundation and science will continue to enrich human life in the years ahead.

# *Research Support Activities*

Support of fundamental research in all fields of science is a major function of the National Science Foundation and is the primary responsibility of the Research Directorate. Limited support for projects of an applied nature is also provided through the Research Directorate. These responsibilities are carried out mainly through grants to academic institutions where research also contributes to education in the sciences. Principal mechanisms for research support are as follows:

- Grants to institutions in support of individual scientists or small groups of scientists pursuing scientific investigations deemed to have outstanding potential for the development of new scientific knowledge.
- Grants in support of the International Biological Program and the Global Atmospheric Research Program. (These programs, administered by the Research Directorate, are described with other National and International Programs on pages 38–39 and 43–44.)

Supplementing scientific research project grants through which most of the Directorate's funds are distributed, limited support is also provided to assist in:

- The purchase of specialized research equipment.
- Construction or acquisition of specialized research facilities.
- Defraying the costs of travel of individual scientists to selected scientific conferences.
- Support of dissertation research in the social sciences and certain other sciences involving extensive field work.

In addition, the Foundation supports five National Research Centers for the conduct of research in astronomy and the atmospheric sciences. Administration and funding of these centers are discussed in the chapter on National and International Programs. Scientific aspects of their activities will be found in this chapter under the appropriate discipline.

### Scientific Research Support

The Foundation awarded 4,329 grants for the support of individual research projects in fiscal year 1971 amounting to $174.6 million. Comparable figures for fiscal year 1970 were 3,817 grants for a total of $161.7 million. Table 1 gives the distribution, number, and amount of grants according to field of science for fiscal years 1969, 1970, and 1971. Of all the actions taken by the Foundation on research project proposals in fiscal year 1971, 46 percent were awards as compared to 47 percent in 1970. Grants were awarded to 419 institutions, including 304 colleges and universities, in all 50 States, the District of Columbia, and Puerto Rico. Ninety-four percent of the funds went to academic institutions. Of these, 214 received two or more research grants, and 124 received $200,000 or more. The average distribution for approved cost items on the 4,329 research grants made in fiscal year 1971 is shown in table 2.

It is estimated that NSF support of research that could properly be classified as being applied totaled approximately $42 million in 1971. This was an increase of approximately $10 million over the previous year. Applied research is supported principally under the NSF program of Research Applied to National Needs, which represents a consolidation of NSF's major problem-focused research efforts. These projects include Weather Modification, Earthquake Engineering, Enzyme Technology, and research efforts previously supported in Interdisciplinary Research Relevant to Problems of Our Society. Some applied research is also supported under the Foundation's Scientific Research Project Support and National and International Programs and at the National Center for Atmospheric Research.

## Table 1
## Scientific Research Projects
## Fiscal Years 1969, 1970, and 1971
## (Dollars in millions)

| | Fiscal year 1969 | | Fiscal year 1970 | | Fiscal year 1971 | |
|---|---|---|---|---|---|---|
| | Number | Amount | Number | Amount | Number | Amount |
| **Astronomy:** | | | | | | |
| Solar System Astronomy | | .57 | | .58 | | .45 |
| Stars and Stellar Evolution | | 1.70 | | 1.45 | | 1.59 |
| Stellar Systems and Motions | | .72 | | .77 | | .52 |
| Galactic and Extragalactic Astronomy | | 2.48 | | 1.26 | | 3.17 |
| Astronomical Instrumentation and Development | | 1.35 | | 1.74 | | .69 |
| Subtotal | 125 | 6.82 | 108 | 5.80 | 135 | 6.42 |
| **Atmospheric Sciences:** | | | | | | |
| Aeronomy | | 1.65 | | 1.69 | | 2.21 |
| Meteorology | | 4.30 | | 3.95 | | 4.58 |
| Solar-Terrestrial | | 2.25 | | 2.28 | | 2.37 |
| Subtotal | 116 | 8.20 | 118 | 7.92 | 143 | 9.16 |
| **Biology:** | | | | | | |
| Cellular Biology | | 9.28 | | 8.68 | | 8.89 |
| Ecology and Systematic Biology | | 7.96 | | 8.60 | | 8.50 |
| Molecular Biology | | 9.88 | | 9.76 | | 10.73 |
| Physiological Processes | | 10.04 | | 9.53 | | 9.68 |
| Psychobiology | | 4.02 | | 4.30 | | 5.56 |
| Subtotal | 1,173 | 41.18 | 1,072 | 40.87 | 1,369 | 43.36 |
| **Chemistry:** | | | | | | |
| Chemical Analysis | | 1.48 | | 1.71 | | 2.00 |
| Chemical Dynamics | | 4.16 | | 3.58 | | 3.56 |
| Chemical Thermodynamics | | 1.56 | | 1.86 | | 2.39 |
| Quantum Chemistry | | 3.54 | | 3.40 | | 3.54 |
| Structural Chemistry | | 3.22 | | 2.80 | | 3.11 |
| Synthetic Chemistry | | 3.90 | | 4.05 | | 4.27 |
| Subtotal | 484 | 17.86 | 449 | 17.40 | 488 | 18.87 |
| **Earth Sciences:** | | | | | | |
| Geology | | 1.31 | | 1.42 | | 1.52 |
| Geochemistry | | 3.31 | | 3.07 | | 3.05 |
| Geophysics | | 3.30 | | 3.36 | | 3.43 |
| Subtotal | 200 | 7.92 | 169 | 7.85 | 225 | 8.00 |
| **Engineering:** [4] | | | | | | |
| Engineering Chemistry | | 2.73 | | 2.82 | | 2.92 |
| Engineering Energetics | | 2.94 | | 2.86 | | 2.70 |
| Engineering Materials | | 3.23 | | 3.29 | | 3.88 |
| Engineering Mechanics | | 6.39 | | 6.55 | | 5.57 |
| Engineering Systems | | 3.00 | | [1] | | [1] |
| Special Engineering Programs | | .98 | | 1.17 | | .98 |
| Electrical Science and Analysis | | - 0 - | | - 0 - | | 1.35 |
| Subtotal | 491 | 19.27 | 463 | 16.70 | 425 | 17.40 |
| **Mathematics:** | | | | | | |
| Algebra and Topology | | 4.39 | | 4.49 | | 4.42 |
| Analysis, Foundations, and Geometry | | 4.37 | | 4.34 | | 4.69 |
| Applied Mathematics and Statistics | | 3.94 | | 3.83 | | 3.82 |
| Subtotal | 462 | 12.70 | 489 | 12.66 | 535 | 12.93 |
| **Oceanography:** [2] | | | | | | |
| Biological Oceanography | | 3.13 | | 3.66 | | 3.88 |
| Physical Oceanography | | 2.16 | | 2.07 | | 2.69 |
| Submarine Geology and Geophysics | | 2.55 | | 3.18 | | 3.35 |
| Support, Ship Operations | | 8.64 | | [3] | | [3] |
| Subtotal | 280 | 16.48 | 218 | 8.91 | 235 | 9.92 |
| **Physics:** | | | | | | |
| Atomic, Molecular, and Plasma Physics | | 2.46 | | 2.72 | | 2.75 |
| Elementary Particle Physics | | 11.53 | | 11.24 | | 10.31 |
| Nuclear Physics | | 8.01 | | 6.46 | | 9.26 |
| Solid State and Low Temperature Physics | | 4.61 | | 4.42 | | 4.60 |
| Theoretical Physics | | 3.73 | | 3.34 | | 3.79 |
| National Magnet Laboratory | | - 0 - | | - 0 - | | .40 |
| Subtotal | 283 | 30.35 | 245 | 28.18 | 290 | 31.11 |

## Table 1—Continued
## Scientific Research Projects
## Fiscal Years 1969, 1970, and 1971
## (Dollars in millions)

| | Fiscal year 1969 | | Fiscal year 1970 | | Fiscal year 1971 | |
|---|---|---|---|---|---|---|
| | Number | Amount | Number | Amount | Number | Amount |
| Social Sciences: | | | | | | |
| Anthropology | | 3.42 | | 3.48 | | 3.50 |
| Economics | | 4.29 | | 4.35 | | 4.83 |
| Geography | | .19 | | .48 | | .65 |
| Sociology and Social Psychology | | 3.29 | | 3.35 | | 3.73 |
| Political Science | | 1.28 | | 1.19 | | 1.34 |
| History and Philosophy of Science | | .87 | | .83 | | .76 |
| Special Projects | | 1.90 | | 1.74 | | 2.58 |
| Subtotal | 474 | 15.24 | 459 | 15.42 | 484 | 17.39 |
| Total | 4,088 | 176.02 | 3,817 | 161.71 | 4,329 | 174.56 |

[1] Included in National and Special Research Programs for FY 1970 and 1971
[2] Includes marine biology
[3] Included in National and Special Research Programs for FY 1970 and 1971
[4] Transfer of Program elements to Research Applied to National Needs (RANN) accounts for FY 1971 decrease in funding.

## Table 2
## Scientific Research Projects
## Average Distribution of Funds by Type of Expenditure
## Fiscal Years 1969, 1970, and 1971

| | Fiscal Year 1969 | | Fiscal Year 1970 | | Fiscal Year 1971 | |
|---|---|---|---|---|---|---|
| | Amount | Percent of total | Amount | Percent of total | Amount | Percent of total |
| Professional Personnel | | | | | | |
| Faculty | $ 6,296 | 14.5 | $ 6,758 | 15.4 | $ 6,560 | 15.0 |
| Research Associates | 2,822 | 6.5 | 2,940 | 6.7 | 2,668 | 6.1 |
| Research Assistants | 6,687 | 15.4 | 6,275 | 14.3 | 5,510 | 12.6 |
| Other Professional | 2,345 | 5.4 | 2,150 | 4.9 | 2,274 | 5.2 |
| Total Professional Personnel | 18,150 | 41.8 | 18,123 | 41.3 | 17,012 | 38.9 |
| Other Personnel | 3,039 | 7.0 | 3,467 | 7.9 | 3,499 | 8.0 |
| Fringe Benefits | 1,433 | 3.3 | 1,492 | 3.4 | 1,618 | 3.7 |
| Total Salaries and Wages | 22,622 | 52.1 | 23,082 | 52.6 | 22,129 | 50.6 |
| Permanent Equipment | 3,039 | 7.0 | 2,677 | 6.1 | 2,756 | 6.3 |
| Expendable Equipment and Supplies | 3,300 | 7.6 | 3,028 | 6.9 | 3,149 | 7.2 |
| Travel | 1,216 | 2.8 | 1,273 | 2.9 | 1,356 | 3.1 |
| Publication and Printing | 608 | 1.4 | 658 | 1.5 | 612 | 1.4 |
| Computing Costs | 1,389 | 3.2 | 1,360 | 3.1 | 1,356 | 3.1 |
| Other Costs | 1,738 | 4.0 | 2,019 | 4.6 | 2,536 | 5.8 |
| Total Direct Costs | 33,912 | 78.1 | 34,097 | 77.7 | 33,894 | 77.5 |
| Indirect Costs | 9,509 | 21.9 | 9,786 | 22.3 | 9,840 | 22.5 |
| Total Average Grant | $43,421 | 100.0 | $43,883 | 100.0 | $43,734 | 100.0 |

## Table 3
## Specialized Research Facilities and Equipment
## Fiscal Years 1969, 1970, and 1971
## (Dollars in millions)

| | Fiscal Year 1969 | | Fiscal Year 1970 | | Fiscal Year 1971 | |
|---|---|---|---|---|---|---|
| | Number | Amount | Number | Amount | Number | Amount |
| Astronomy | 5 | $0.324 | 5 | $0.190 | 3 | $0.250 |
| Atmospheric Sciences | 8 | .298 | 4 | .199 | 5 | .290 |
| Biological and Medical Sciences | 34 | .880 | 11 | .918 | 22 | .977 |
| Chemistry | 57 | 1.700 | 63 | 1.697 | 58 | 1.700 |
| Earth Sciences | 0 | 0 | 3 | .103 | 2 | .115 |
| Engineering | 26 | .880 | 28 | .600 | 30 | .696 |
| Oceanography | 1 | 1.397 | | [1] | | [1] |
| Physics | 25 | 1.300 | 12 | 2.499 | 5 | 1.500 |
| Social Sciences | 2 | .438 | 1 | .298 | 6 | .272 |
| Total | 158 | $7.216 | 127 | $6.504 | 131 | $5.800 |

[1] Included in National and Special Research Programs for FY 1970 and FY 1971

### Specialized Research Facilities and Equipment

In fiscal year 1971, $5.8 million was awarded to institutions to assist in the purchase of specialized facilities and equipment in biology, astronomy, earth and atmospheric sciences, physics, chemistry, engineering, and the social sciences. (Computing and oceanographic facilities are discussed in the following chapter under National and International Programs.) Distribution of funds over a 3-year period will be found in table 3. The following examples illustrate the nature of this support.

In fiscal year 1971, approximately $1 million was made available to fund a major expansion of the experimental area at the NSF-supported 10 GeV electron synchrotron at Cornell University. The Cornell electron synchrotron is the highest energy long-duty-cycle electron accelerator in the world, and the many novel types of experiments made possible by this accelerator have led to very heavy demands on the use of the experimental area by scientists at Cornell and other universities. Other university physics projects supported during the past fiscal year include the accelerator laboratories at Stanford University and the Indiana University where major equipment was provided in a continuing buildup of experimental facilities.

A grant to the University of California at Berkeley assisted in the purchase of a radio telescope with high angular resolution to operate at centimeter and millimeter wavelengths. The telescope will be a precise 20-foot antenna, mounted in such a way that it can be used later as part of an interferometer. The telescope will operate from 2 to 16 millimeters and will be equipped with a 128-channel spectrometer. The problems studied with such an instrument range from planetary to galactic and extragalactic research. The facility will be placed at the Hat Creek Observatory in northern California.

In support of social science research, a grant of $181,000 to Haskins Laboratories in New York provided for the assembly of a hardware-plus-software computer system for on-line experimentation with natural speech. The completed system will permit scientists associated with Haskins Laboratories and nearby universities to conduct research on important questions about the perception and comprehension of spoken language and language learning. Practical applications are envisaged to language teaching, man-machine communication, machine control systems, and reading aids for the blind.

The biotron at the University of Wisconsin, constructed with the help of Foundation grants, was dedicated in 1971, consummating an extensive development and construction period. The biotron permits the maintenance of animals and plants under controlled environmental conditions, and provides for programmed changes in environmental parameters. A similar laboratory, also constructed with the help of Foundation grants—but primarily for plant studies—has been in operation in the Research Triangle of North Carolina for a little over 2 years. Both the biotron in Wisconsin and the phytotron in North Carolina operate as regional facilities and are intended to serve the increasing need to validate ecological concepts developed in the field by controlled experiments in the laboratory.

## MATHEMATICAL AND PHYSICAL SCIENCES

Because new knowledge in the mathematical and physical sciences —mathematics, physics, chemistry, and astronomy—is so vital to the continuing progress of science, the Foundation has allocated more than a third of its scientific research project support to these disciplines. Although the NSF has increased its level of support so that its share of university-based research in the mathematical and physical sciences has risen substantially, this has been insufficient to offset the funding decrease from other Federal agencies that have shifted some of their support towards research more closely related to their statutory mission.

In the area of physics during fiscal year 1971, the NSF granted 290 awards totaling $31.1 million as compared to 245 awards for $28.1 million in the previous year. This support can be considered to fall into two major categories. One category, elementary particle and nuclear structure physics, involves major facilities and requires significantly higher support per scientist each year than does the other category, which includes such programs as atomic, molecular and plasma physics, and solid state and low temperature physics.

The elementary particle physics program is affected not only by the costs of facilities, but by their operational status as well. The new National Accelerator Laboratory (NAL) at Batavia, Ill., built with Atomic Energy Commission funds, is becoming operational, and user groups are now turning to the Foundation to support the necessarily larger-scale research projects to be undertaken at NAL. There is also an increased demand for the use of the NSF-supported Cornell Electron Synchrotron. The strong demand for use of the Cornell accelerator arises both from its unique capability to provide high-duty-cycle, high-energy electron beams, and because of the phase-out of other accelerators. In nuclear physics, several new directions of research are emerging. Among the research topics of special interest are the microstructure of the nucleus, possible new super-heavy elements, and the range of new isotopes around stable elements of very high mass.

Because of the high productivity of solid state and low temperature physics, research is being supported on a wide front. In particular, there is a continuing interest in the prospect of wide technological use of low temperature physics phenomena such as superconductivity and superfluidity.

From a scientific point of view, physics is at a most promising point in its history. Over the longer range, it can be expected that new and significant developments will take place in studies of gravitational radiation, ultra-high density matter, cryogenics, and plasma physics.

The NSF has in the past been providing about a quarter of the annual Federal support of chemistry research projects at universities. As in the case of physics, the increased mission orientation and decreased funding by those agencies other than NSF supporting fundamental chemistry research has increased the fraction of the scientific research community looking to NSF for support. During fiscal year 1971, 488 awards in the amount of $18.8 million were provided for research project support in chemistry. This represents an increase of 39 awards and an increase of $1.4 million over the preceding year.

Although chemistry has undergone development in experiment and theory over many years, many fundamental questions remain. Despite substantial progress, we are unable to predict, in general, which atomic or molecular arrangement will produce a desired property. Also lacking is the ability to predict the optimum sequence of reactions to produce a desired molecule. A third fundamental problem of chemistry concerns the rate of chemical reactions. Of major importance to our understanding of chemical reactions are the mechanisms by which catalysts influence the rate of reaction without being permanently changed themselves.

There are many new initiatives in chemistry related to the fundamental problems of chemical structures and reaction sequences and rates alluded to above. Research is also under way on important new classes of substances such as liquid crystals and room-temperature superconductors. Subfields such as surface chemistry and electrochemistry are becoming increasingly important. In electrochemistry, ion-specific electrodes are receiving a great deal of attention. Ten years ago, electrodes which would respond to a particular ion were virtually unknown. Today, electrodes are commercially available for at least 20 ions, and some electrodes have been developed which are sensitive to organic molecules.

Instrumentation plays a central role in chemical research regardless of the problem area under investigation. Adequate instrumentation is a necessity for chemical research, and despite university contributions there remains a continuing need and backlog to be met by NSF, which is the only explicit Federal source of funds for chemistry department instrumentation.

The Foundation is now the most important supporter of ground-based astronomy, furnishing about 70 percent of the total Federal support in this area when research project support, facility and equipment programs, and the four national astronomy centers are considered. During fiscal year 1971, 135 awards in the amount of $6.4 million were awarded for scientific research project support at universities. This was an increase of 27 awards and $.6 million over the previous year. Total obligations for all astronomical observatories increased $6.0 million to a total of $21.7 million in fiscal year 1971.

Astronomical research is characterized by observation instead of experimentation, and its subject matter involves extremes of density, temperature, space, and time which are far greater than those dealt with in the other physical sciences. Among the recent advances in this discipline are the detection of additional molecules in interstellar space and high-resolution spectroscopic studies of a quasi-stellar object receding at more than 80 percent of the speed of light, which reveal fundamental new information about the history of the universe.

There has been a rapid growth in recent years in the mathematical sciences due to the increased numbers of highly qualified mathematicians, the expanding role of mathematics in society at large, and the remarkable changes in teaching of elementary mathematics. The power of recent research is evidenced by the solution of numerous famous problems of mathematics which had defied solution for many years. Also, mathematical methods are increasingly penetrating the biological and social sciences. In large measure, this has been made possible by the computer, itself the offspring of advanced mathematics, the other physical sciences, and their related technologies.

The NSF is now the largest single source of funds for academic basic research in mathematics and, in fact, Foundation funding is slightly more than half of the total available from all sources.

The level of Foundation awards has remained essentially constant over the past 5 years (535 awards in the amount of $12.9 million in fiscal year 1971) so that its position of major support is the result of declines from other sources of support. Despite these factors, the mathematical sciences in the United States are now in a period of scientific growth, utility, and appeal.

## CHEMISTRY

### *Metastable Species*

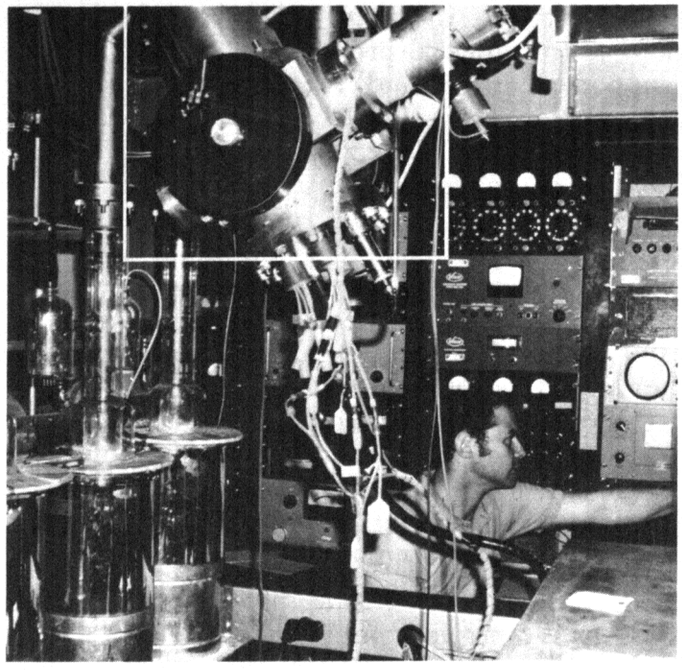
The transformation of energy from one form to another that usually accompanies chemical reactions is often as important as the change in the chemical nature of

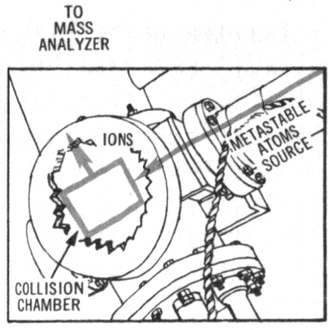
the materials involved. For instance, the products of oxidizing certain mixtures of hydrocarbons are relatively unimportant—except insofar as they may contribute to pollution—compared to the fact that the energy produced in the reaction makes the internal combustion engine possible. In the future, much more complicated chemical reactions, now known to occur in shock waves, flames, and certain types of electrical discharges, may become important as they apply to new techniques for the generation of electrical power or totally new forms of portable engines. In the meantime, detailed knowledge about energy transfer is relevant to understanding and controlling the rates and products of chemical reactions.

As energy is put into a chemical system, atoms and molecules temporarily absorb energy which they then generally lose by emitting light or by colliding with other particles —which is often the driving mechanism behind a chemical reaction. However, there are certain of these temporary levels of energy at which such radiation is relatively unlikely. An atom or molecule which stays in such an energy state for any appreciable length of time is called metastable.

Metastable species are important in reactions between gases because they may remain in an excited state long enough to make a number of collisions and therefore be more likely to become involved in a chemical reaction.

Studies of the properties of metastable atoms and molecules, primarily in electrical discharges, have been hindered by the fact that this is an extraordinarily complex environment. It is a mixture of different kinds of particles, in which a number of different reactions may be occurring simultaneously and consecutively, and in which the energy distribution among the particles is subject to wide variation.






Beam of excited, metastable atoms, generated by bombarding gas with electrons of controlled energy, reacts with atoms and molecules of low pressure gas in collision chamber. The resulting ions and their energies can then be identified and analyzed.

Earle Muschlitz, Jr. at the University of Florida has overcome many of the difficulties of the electrical discharge environment by using a molecular beam technique to study energy transfer and reactions involving metastable species. Dr. Muschlitz produces a molecular beam of helium, part of which he excites to metastable states by bombarding it with electrons of controlled energy. This impact produces two different metastable states which differ only slightly in energy but which have different magnetic properties. By using a magnetic field which is not uniform, Dr. Muschlitz is able to deflect a selected state out of the beam and determine how the proportions of the two are determined by the energy of the electrons producing them. He is then able to pass the beam through a gas at low pressure and, because he knows its composition, determine the relative likelihood of interactions of the two metastable states with the molecules of the gas.

In principle, this experiment is relatively simple, yet it provides answers to some rather subtle questions, some of long standing. Furthermore, in some instances the results have been contrary to what had been predicted theoretically and have therefore provided a basis for a revision of some thoroughly basic theories about chemical reactions.

These studies both provide very basic insights into the nature of a class of chemical reactions and move ever closer to possible practical preparative techniques.

## *Catalysts*

Many important industrial-chemical processes, especially those dealing with refining crude petroleum into fuel, lubricants, and other useful chemicals, are made economically feasible by the use of catalytic materials. A catalyst is a material which "helps out" in a chemical reaction without itself being consumed in the process. In the field of petroleum chemistry, two general forms of catalysts have been known. The first and most commonly used form is the solid or heterogeneous catalyst, often comprised of tiny metallic particles bound to clays and other insoluble supports. The other

form, not as commonly used, consists of soluble complexes of metals belonging to what chemists call the transition groups, which include platinum, rhodium, and palladium.

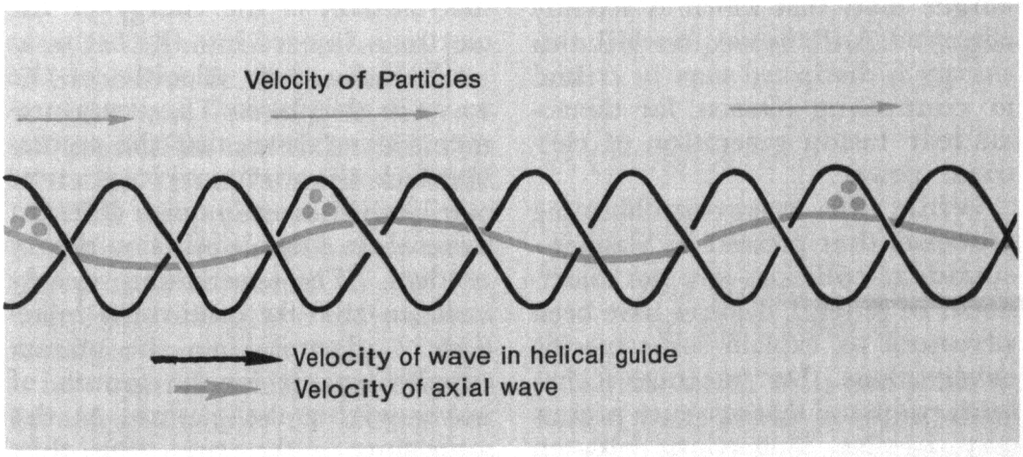
The insoluble catalysts have been the subject of intensive research during the past 3 decades, but their exact structures and the mechanisms by which they work are still largely unknown. On the other hand, the more recently discovered soluble catalysts have better understood mechanisms which chemists can alter minutely to do highly specific tasks and minimize the production of undesired byproducts.

Unfortunately, the use of the soluble catalysts is accompanied by a number of problems. In the first place, they are not particularly durable catalysts. Furthermore, industry is hesitant to employ these expensive noble metals in solution because of the difficulties of recovering the catalysts from the product in which they are dissolved. Finally, there are a number of important reactions which these soluble materials do not catalyze and which the insoluble catalysts do.

The best aspects of both systems have been combined in recent experiments by James Collman at Stanford University. Soluble compounds consisting of several of the transition metal atoms joined in a cluster by metal-to-metal bonds have been chemically fastened to porous, insoluble plastic supports. When Dr. Collman activates these clusters by removing carbon monoxide groups, he obtains an insoluble material with the same catalytic specificity as the soluble transition metal catalyst.

For example, a catalyst composed of tetrameric (four-atom) rhodium units will catalyze the hydrogenation of benzene and other similar compounds—converting them into useful intermediates for chemical synthesis—at room temperature and atmospheric pressure, rather than the high temperatures and pressures hitherto required. His preliminary experiments suggest that the rhodium clusters remain intact and can be recovered unchanged. The exact nature of this new class of catalysts is not yet fully resolved, but Dr. Collman's experiments show the possibility of preparing specific well-defined insoluble catalysts which can be "tailored" like soluble catalysts to perform desired reactions efficiently.

This system also offers an opportunity for chemists to study the detailed mechanisms by which the much used but poorly understood insoluble catalysts perform their tasks. The disadvantages associated with the use of soluble catalysts can be circumvented without losing many of their advantages by using this new type of system.




Ions of heavy elements are introduced in front of slow-moving wave crest in axis of double-helical wave guide. "Surfing" effect causes particles first to slip to rear of wave, focusing them. Wave accelerates particles until they are again in front of wave crest, and accelerator section terminates. Pitch of helix determines velocity of axial accelerating wave—successive sections have lower pitches and faster axial waves.

## PHYSICS

### *High Speed Particle Control*

Most high energy particle accelerators—linacs, cyclotrons, synchrocyclotrons—operate successfully by application of a "phase stability" principle, somewhat equivalent to "particle surfing." The accelerated particles ride on the forward side of the wave, near the crest. If a particle is moving too slowly, it slips backwards towards the crest and is speeded up; if it is moving too fast, it moves down towards the trough and slows down. The particles, like the surfer, are forced back toward their original position on the wave, and the system is said to be stable. The velocity of the wave, of course, must be continuously increased to match that of the accelerating particles.

When these phase stability conditions apply, the particles unavoidably are able to slide to and fro parallel to the wave crest. For a surfer, this is of little importance, but in an accelerator it means that the diameter of the beam grows with time and quickly would become too large and diffuse to be useful if other lens-like devices were not added to keep the beam focused.

If the particles were forced to ride on the rear of the wave crest, the beam would automatically be focused. However, in this position, the particles would fall out of phase with the wave and not be accelerated properly. If it were possible to force the group of particles being accelerated to periodically alternate their position from the front to the rear of the wave crest, both acceleration and focusing could be achieved without the need for additional lenses.

Thomas Tombrello at the California Institute of Technology has proposed a method for accomplishing this automatic focusing and phase stability at the same time. Dr. Tombrello proposes that particles to be accelerated should be introduced into a section of the accelerator just in front of a wave moving at a fixed speed, slightly higher than that of the particles. The group of particles would "slip" with respect to the crest until it was on the wave's rear side, thereby being stable with respect to focusing. However, the motion of the wave would be causing the particles to accelerate, and if the relative velocity of wave and particles were correctly chosen, the particle velocity would equal and finally exceed that of the wave. Thus, the group of particles would automatically advance again to the forward side of the wave. At this point, the acceleration would be terminated so that the particles would not move further into the trough of the wave and be slowed down. In this "slingshot" operation, the particle group is focused and accelerated. Further acceleration may be achieved by introducing the particles into a series of further "slingshot" sections with correspondingly higher wave velocities.

This effect may be very useful in the acceleration of very heavy elements like uranium for the production of new transuranic elements. The difficulty of using a linear accelerator for this purpose has been that the accelerating waves have been too fast for those of the slow-moving low-energy uranium ion—an effect similar to stepping onto a too-fast moving platform.

At the same time, it is known that a wave traveling along a helical conductor, or wave guide, can produce a field velocity along the axis of the helix, or an axial velocity, equal to about 2 percent of the speed of light. It has recently been found that if a second helix, wound the opposite way, is placed concentrically with the first, an axial wave velocity of less than 1 percent of the speed of light can be produced.

Combining the double-helical wave guide and the "slingshot" effect would allow physicists to start off with a "slowed-down" accelerating wave which is more nearly the speed even of the low-energy heavy uranium ions. A succession of accelerating sections of ever-faster waves can then be used to achieve the desired acceleration.

## *Equilibrium Processes in Plasmas*

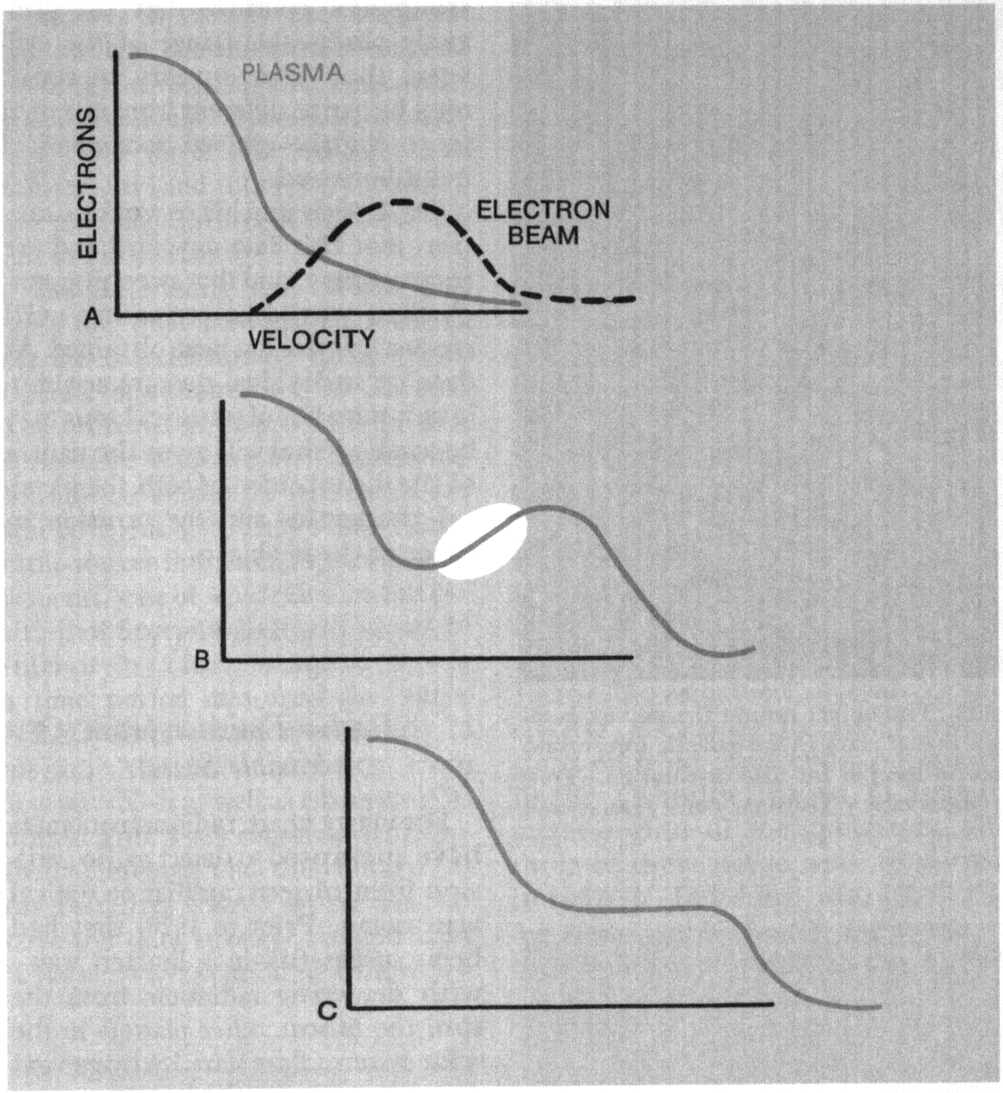
One of the fundamental physical facts of the universe is that a system in which energy is unevenly distributed will eventually achieve thermodynamic equilibrium (the even distribution of energy throughout the system). In nearly all physical systems, this thermodynamic equilibrium is reached by a process of simple collisions between the particles of the system which distribute the energy evenly. This process is well understood and quite predictable.

A plasma—a "gas" of ions and electrons—however, is an exception. Collisions between the ions and electrons in a plasma are rare, and do not explain the rate at which equilibrium is reached: The equilibration time predicted from collision theory may be hundreds of times longer than that which is actually observed. And the way in which this energy is dissipated may be crucial to controlling plasmas for themonuclear fusion generation of electrical power.

While the energy-equilibrating processes that proceed in plasmas—outside of collisions—are not understood in general, theories have been advanced to explain some specific observations. For instance, it has been proposed that one such process may involve interactions between the individual particles of a plasma and the wave motions set up by the oscillations of the particles as a whole. Kenneth Gentle and his colleagues at the University of Texas at Austin have confirmed the existence of several such types of interactions, and have shown that they may, indeed, lead a system of initial energy unbalance to equilibrium.

Dr. Gentle's first experiment demonstrated the existence of an effect termed "nonlinear Landau damping." Many waves may propagate through a plasma without apparent absorption. A system in which such waves were excited would not, because of the waves alone, relax to a uniform equilibrium. Theoretically, however, it was predicted that an interaction between different waves propagated through the plasma at the same time would lead to a nonlinear interference between the waves and the subsequent "damping" would result in wave energy going into heating the particles. In a set of experiments using pairs of waves propagated through the plasma simultaneously, Dr. Gentle and his co-workers demonstrated that the interaction was completely in accord with theoretical predictions.

One of the simplest and most basic forms of instability in a plasma arises from the injection of a beam of electrons into a plasma which was initially at equilibrium, thereby modifying the distribution of the electrons' velocities. Dr. Gentle's group has been able to measure, in a second experiment, the statistical distribution of the energy of the electrons injected into the beam, as well as the phase velocities of the waves in the plasma. These measurements have shown that the process by which the plasma arrives at a new equilibrium is again quite different from what a simple collision theory predicts. The experiments clearly indicate that the continuing injection of electrons into the plasma supplies energy for the growth of waves within the plasma. At the same time, as the waves grow, they begin to interact with the particles and cause them to diffuse to a lower velocity. This effect produces, both mathematically and in the physical system, a new equilibrium distribu-




Electron beam injected into stable plasma (A) adds an unstable "bump" to high-velocity region of graph of electron velocity distribution (B). Plasma waves with phase velocities corresponding to electrons in the shaded portion grow, interact in turn with particles in the plasma and push them into lower-energy regions, producing new equilibrium (C).

tion. In this second experiment, just as in the first, Dr. Gentle and his coworkers have learned that theoretical predictions match the behavior of the real system in complete detail.

While the problem of energy distribution in the equilibrium-forming process in plasmas is not yet completely solved, it is fully understood for some cases. The problem is now open to careful experimental investigation, since the theory has been shown, so far at least, to live up to expectations. Physicists reasonably expect that these processes will be virtually completely understood within a few years, thereby providing a stronger basis for the understanding of plasma physics in general.

## ASTRONOMY

### Kitt Peak National Observatory

### *The Optical Edge of the Universe*

In 1969, Derek Wills and John G. Bolton made precise position measurements of a radio source known as 4C 05.34. Using the Parkes, Australia, 210-foot radio telescope, Drs. Wills and Bolton tentatively identified this source as a quasistellar object, or quasar. The radio position was subsequently confirmed as being identical with that of a very faint blue, star-like image, and identified as having the largest red shift yet observed. The red shift phenomenon occurs when an object is receding from the viewer, apparently stretching out the wavelength of the light by which it is seen. This stretching-out effect causes the light to appear redder (hence, the name) and the more rapid the recession, the redder the light. Using the 84-inch reflector at Kitt Peak, Dr. Wills and C. Roger Lynds made image tube spectrograms to obtain preliminary measures of the amount of the red shift, which indicated that it corresponds to a relative velocity in excess of 80 percent of the speed of light. (See NSF 20th Annual Report, p. 19.)

During 1971, Dr. Lynds continued his spectrographic studies of 4C 05.34 using new techniques with the image tube (an electronic device which multiplies the light received from a very faint object). He obtained observational material with unprecedentedly high spectral resolution and discrimination against contaminating sky light, revealing complex systems of absorption lines. Measurements and analysis of 93 of these lines have led astronomers to conclude that the absorption lines are caused by several gas clouds located along the line of sight between earth and the quasar. Because the red shift values derived for the absorption lines are themselves high, it is apparent that the gas clouds are at great distances, although not receding as rapidly as the original source. Furthermore, the absorption line profiles are unresolved, and indicate that the velocity dispersion (variations in velocity around some average value) along the line of sight of the gas in these discrete clouds is relatively small, signifying that there is little internal turbulence.

Dr. Lynds and others at Kitt Peak also studied the absorption line systems in a number of spectra of other quasars having large red shifts. The

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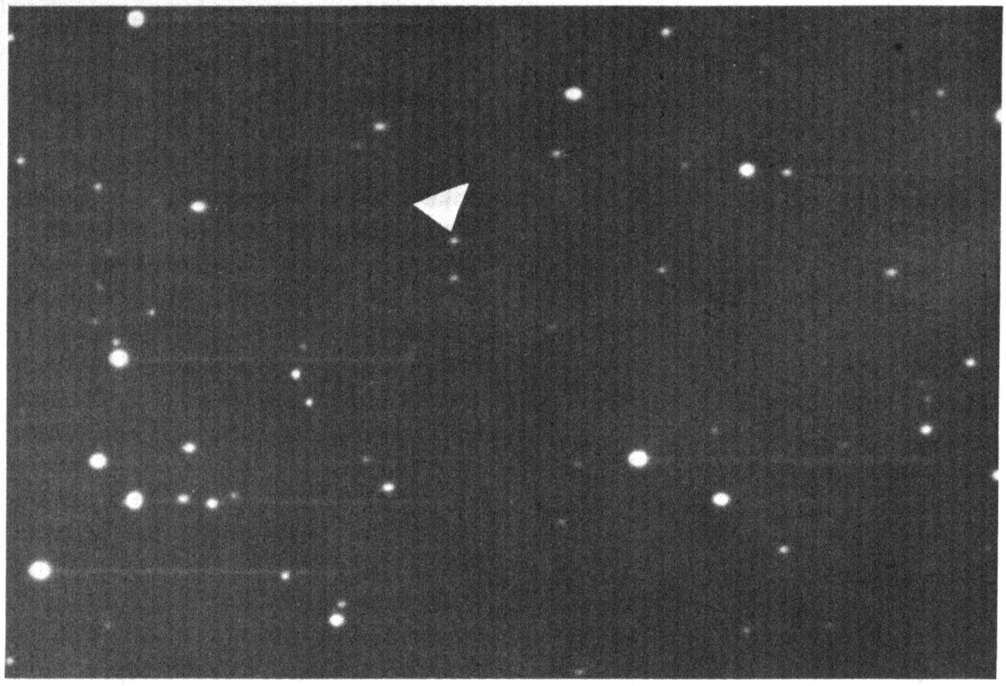
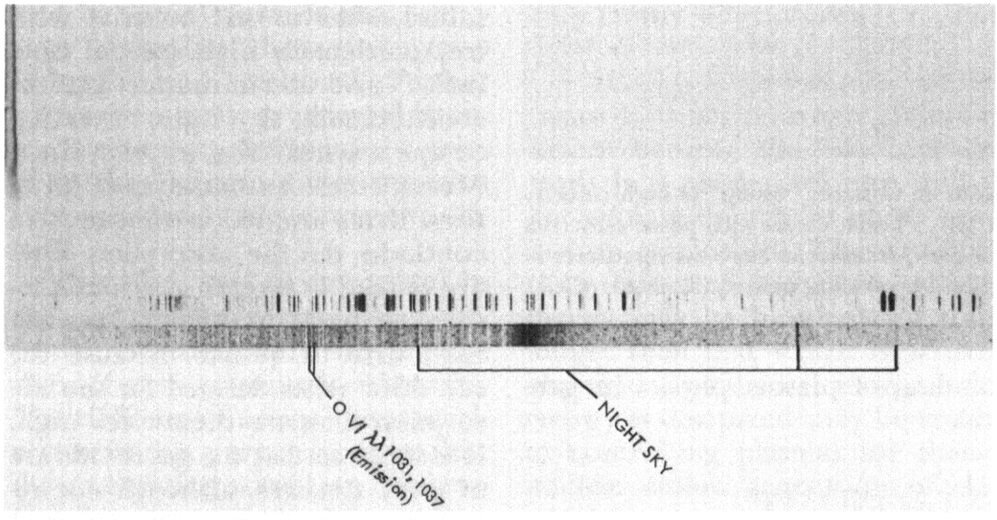


Quasi-stellar source with largest measured redshift. The object nearest the pointer is the 18th magnitude quasar 4C 05.34; all other images are of stars in the galactic foreground, with the brighter ones showing trails from telescope motion for field orientation. (From plate taken with 107-inch reflector of McDonald Observatory, University of Texas, Austin, by Dr. D. Wills.)




A 5Å resolution image tube spectrogram of the most distant optical source 4C 05.34 taken by C. R. Lynds. The redshift measured from the position of the emission lines (dark on this negative illustration) is $Z = 2.877$, which means the object may be receding at more than 80 percent of the velocity of light. (Photo KPNO)

general picture emerging is one of very luminous distant objects, which are at a relatively early stage of evolution with respect to the age of the universe, representing a state of matter and an association with gas that is not characteristic of similar volumes near our own galaxy. (The quasars being studied are said to be at an early stage of evolution because they are so far from earth that the light now being received from them left them when the universe was a tenth of its present age.) Astronomers conclude that the presently observable fringe of the universe that these quasars represent may be quite different from our own more highly evolved astronomical neighborhood.

Dr. Lynds and his co-workers caution that the data now on hand are fragmentary, and that sweeping conclusions would be premature until more evidence has been obtained. As data on individual quasars accumulate, a number of statistical tests may be applied that will assess the nature of the distribution of both the physical properties and the position in space of these objects.

## National Radio Astronomy Observatory

### *Radio Emission from Visible Stars*

For many years, radio astronomers have attempted to detect radio emission from objects familiar to optical astronomy. Prior to 1970, they had been successful—in a limited way—with detecting radiation from the sun, the moon, other planets in the solar system, flare stars, hydrogen gas clouds, remnants of supernovae, quasars, and a few galaxies. During the past year R. M. Hjellming and Cameron Wade of the National Radio Astronomy Observatory (NRAO) have succeeded in conclusively detecting radio emission from three new classes of objects: a normal red supergiant star; a strong X-ray emitting star; and a group of ordinary novae.

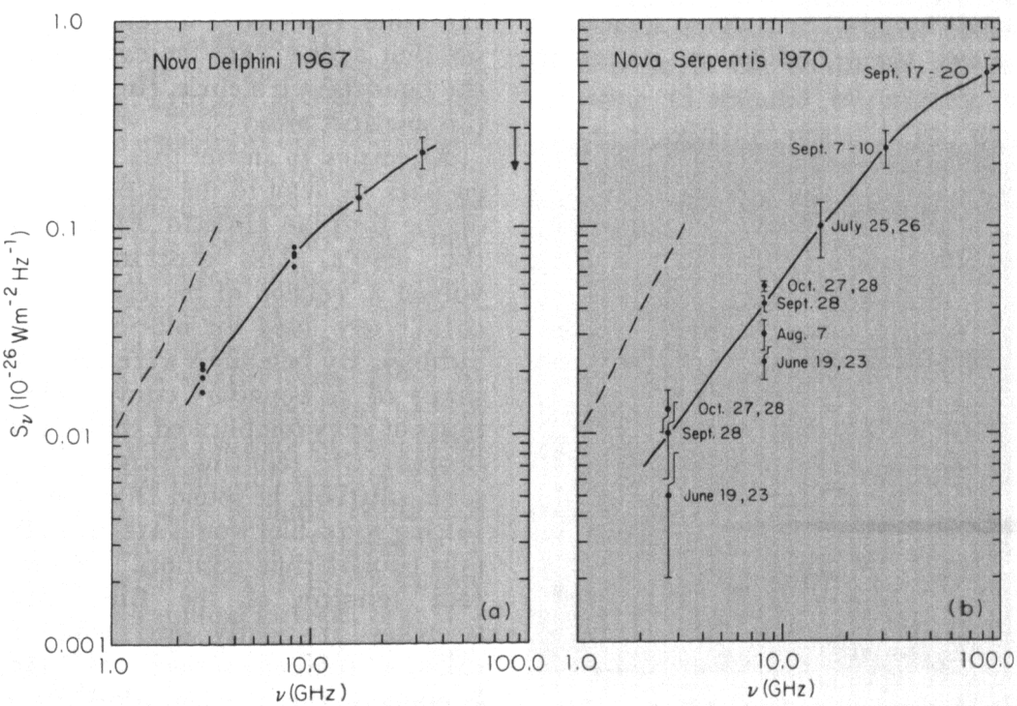
Within a few days after the installation of a new receiver system on the NRAO interferometer, Drs. Hjellming and Wade detected radiation at a wavelength of 11 centimeters from the red supergiant star Antares. Although one or two NRAO observers had suspected the presence of radio emission from supergiants previously, this was the first positive evidence for detection, opening up the field of stellar astrophysics to radio astronomy.

Antares is visually the brightest star in the constellation Scorpius. With better receivers and larger telescopes, it should be possible to measure radio waves from smaller and fainter stars and ultimately to measure the temperatures of the individual stellar surfaces.

Drs. Hjellming and Wade also used the dual wavelength receiver on the interferometer, designed to operate simultaneously at 3.7 and 11.1 centimeters, to provide the first conclusive evidence of variable radio emission from the intense X-ray star Scorpius X–1. They resolved the radio source into three separate components, one of which lies in the position of Scorpius X–1 and varies in intensity by a factor of up to 50 over a time period measured in hours. NRAO observers are continuing to monitor the radio emission from Scorpius X–1, as well as observing its optical and X-ray emission with optical telescopes and the Uhuru X-ray satellite. NRAO observers believe the data strongly suggest that X-ray activity occurs first, followed a few days later by optical activity and, after a few more days, by radio variations. By thorough analysis of data from all three sources, astronomers will be able to determine the radius of the active region.

Because X-ray detectors still have relatively poor resolution, it is often difficult to "find" X-ray stars optically, particularly in crowded regions of the sky. However, now that astronomers know that these peculiar variable sources can be detected by radio emission as well, they can measure their positions sufficiently accurately to make positive optical identification—which will help to solve the enigma of the nature of these X-ray sources.

Drs. Hjellming and Wade and Victor Herrero used several of the NRAO telescopes to study radio emission from three ordinary novae in the 3.5 millimeter to 11.1-centimeter region of the spectrum. All three of these novae were observed in 1967 (N. Delphini) and 1970 (N. Serpentis and N. Scuti) and were, at their brightest, visible to the naked eye. Astronomers suspect that their radio emission is probably of thermal origin. It is optically "thick," or opaque, in the initial stages of the explosion and becomes thin as the nova expands with time. Optically, N. Delphini was one of the slowest, yet most spectacular novae on record. It experienced at least six distinct shell ejections or explosions. Correlations between the optical and radio variations in novae will provide clues that will lead to more complete understanding of how these star explosions occur.




Spectral data for Nova Delphini 1967 and Nova Serpentis 1970. Because of the rapid radio brightening of Nova Serpentis 1970, each data point for this object is accompanied by the date of measurement. Dashed lines, spectral slope expected for an optically thick thermal source with a uniform emission measure. (Photo NRAO)

## University Research

### *New Windows on a Chemical Universe*

Astronomers have been tremendously stimulated in recent years by both the extension of the observational spectrum available to them and the development of a field which might be called "astro-chemistry."

University research in astronomy has used the surface of the earth, balloons, rockets, and even satellites as platforms from which to collect and study electromagnetic radiation in the radio, infrared, ultraviolet, X-ray, and gamma ray portions of the spectrum. There are recent indications that the observable spectrum has been extended to include the measurement of gravitational radiation as well (see NSF 19th Annual Report, p. 18). It is now becoming possible to correlate observations made in different regions of the spectrum by entirely different groups. For example, two recently discovered galaxies, Maffei I and II, just barely visible on the photographic plates in the visual light portion of the spectrum, show up more clearly when photographed by infrared light. These two galaxies are of special interest because they are very near our own galaxy by astronomical standards (approximately 6 million light-years away). Although these two galaxies are in our local

group and are of respectable size, they have eluded study until just a few months ago, because they lie in such a direction that their light must pass through the greater thickness of our own galaxy before it reaches us. Our galaxy contains a great deal of interstellar dust, which scatters blue light more than red. Consequently, most of the light that "survives" to reach the earth appears reddened, much as the light from the setting sun is reddened by dust in the earth's atmosphere. Infrared photographs had hinted previously that these two galaxies were present. These more recent plates have proved conclusively that these galaxies are part of our local group. Furthermore, measurements of these galaxies in the infrared now show that they are approximately normal galaxies. Astronomers are now looking toward further research in the visible and radio wavelengths to provide more information; one of the Maffei galaxies is a known radio source.

In the last few years, the number of different molecules proven to exist in interstellar space in our galaxy has grown phenomenally. These molecules have been detected by radio astronomy groups both at the National Radio Astronomy Observatory and at various university installations. For the first time, however, simple molecules have been detected in galaxies outside our own. L. N. Weliachew, a visiting astronomer at the California Institute of Technology, has discovered such molecules in at least two galaxies.

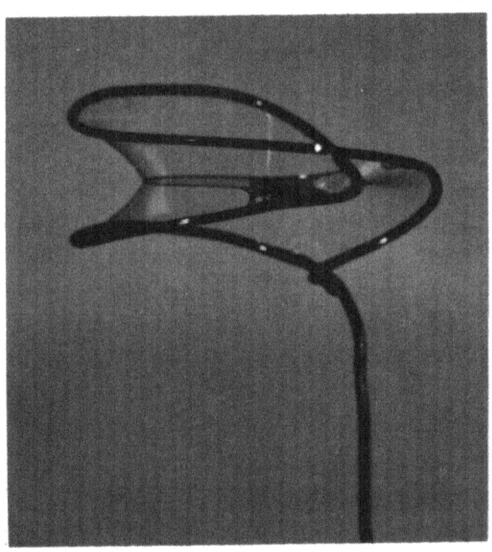
The question as to whether there are even more complicated molecules elsewhere in the universe may be soon answered. There is no reason, in principle, that organic and other molecules in other galaxies cannot be detected. This, of course, raises questions bearing on the possibility of extraterrestrial and extragalactic life which can perhaps be answered by the techniques of radio and other types of astronomy. The discovery of these molecules has now prompted much research in physics and chemistry to find out what processes take place in interstellar space that can produce and preserve these molecules for long periods of time.

Eight new molecules were observed between January and June of 1971—the most recent being methyl alcohol, methyl cyanide, and silicon oxide. There seems to be almost no end to the types of molecules that can be discovered. The identification of the molecules themselves is now a real part of the problem. As soon as other scientists can find and identify the lines of various molecules accurately in the laboratory, radio astronomers can search for the spectra of these molecules in interstellar space.

## MATHEMATICS

### *Branch Points of Minimal Surfaces*

When a mathematician says, "Among all one-dimensional configurations or paths, with the same zero-dimensional boundary, the straight line path has a unique minimal length," he is doing something more than finding an extremely complex way of saying, "The shortest distance between two points is a straight line."



Surface tension stretches fluid soap film across wire-frame boundary curve into a "minimal surface." Same boundary curve may give rise to several different surfaces, each behaving like a minimal surface.

The advantage of the mathematician's roundabout approach is that it is phrased entirely in terms that have counterparts in higher dimensions. For instance, the basic two-dimensional configuration, a surface, has a boundary which is a one-dimensional curve. (In each case, the boundary has one less dimension than the configuration it bounds.)

Just as there are many paths that may join two points—and only one, the straight one, is the shortest—many surfaces may have the same boundary curve. For instance, a rubber ball is made up of two hemispheres, each of which has a circle for a boundary. The same circle may be a boundary for a globular surface like a fish bowl, a bottle, a shallow bowl, or a disc.

But not all boundaries are as simple as a circle, or surfaces as simple as half a rubber ball. Mathematicians have for some time been working on the next higher dimension of the "shortest path" question and asking, "Of all surfaces which have the same boundary, which has the smallest area?" (For the case where the boundary is a circle, the disc has the smallest area.)

Attempts to answer this question go back at least to the experiments of the Belgian physicist Plateau in the 1840's. This experiment involved a version of the traditional child's toy used for blowing soap bubbles. By bending a wire into the shape of a boundary curve, sometimes of very complicated shape, and dipping the resulting frame into a soap solution, he found that the resulting soap film would attain a certain equilibrium position. The surface tension of the fluid film stretches it tightly into what is called a "minimal surface." Strangely enough, the same boundary curve —or frame—may give rise to several different surfaces, each of which behaves as though it were a minimal surface.

In the early 1930's, the first formal mathematical proof was established, showing that a large class of boundary curves do indeed have minimal surfaces associated with them. Since there is an infinite number of possible boundary curves, it would be impossible to examine every curve and surface individually. The actual formulation of the minimal surface problem involves a set of complicated mathematical functions.

Robert Osserman at Stanford University has been trying to find out whether there are minimal surfaces which possess a type of deficiency called a "branch point." A branch point—a difficult phenomenon to visualize—involves a series of rays stretching out from a point along which the surface intersects itself, and in the vicinity of which the surface understandably becomes quite complex. It was not known whether a minimal surface was necessarily free of such points.

Dr. Osserman has recently shown that this is indeed the case. His proof consists of two basic steps. First, he identifies mathematically the nature of a surface in the neighborhood of a branch point on a minimal surface. In the formal proof, he establishes that the surface would have to pass through itself in a well-defined number of self-intersections. His second and more difficult step involves a slight mathematical modification of the surface—without changing the boundary—to one with a smaller area. Since he assumed at the outset that he was working with a surface of minimum area, a contradiction results: a surface with such a point could not have been minimal. Therefore, a surface with a branch point cannot also be a minimal surface, that is, a minimal surface is free of such points.

Dr. Osserman's proof involved some delicate geometric arguments which he supported with careful analysis. Since he resolved this question in 1970, still another proof has been discovered which reinforces and extends his fundamental result.

## BIOLOGICAL AND MEDICAL SCIENCES

Foundation programs in the life sciences are being challenged by the unusual opportunities for the development of new knowledge and changes in the organization of research activity. Through 1,369 awards totaling $43.4 million in fiscal year 1971, new information is being developed about the molecules that make up biological systems and the way in which they organize themselves into functional systems, giving rise to the tremendous range of anatomical forms which have led some observers to characterize biology as the study of diversity. The scope of problems which can now be addressed in quantitative terms rather than in an exploratory or qualitative way has grown far beyond the Foundation's capacity to pursue all of these problems in a vigorous way.

In addition to the challenge of much more difficult choices in priorities, there is the challenge of attempting to respond effectively to moves to organize research in substantial team efforts. The integrated research programs of the International Biological Program (see p. 38 for discussion of research results) are a prime example of the development of such collaborative research teams now attempting to address problems of a magnitude that could not be undertaken by a few investigators and supporting personnel. Experience to date has demonstrated that integrated team research in biology is quite feasible when proper attention is paid to the new managerial problems presented by this approach. It is our hope that it will be possible to demonstrate both a new capacity for dealing with complex problems and the ability to make progress more rapidly and economically.

The Foundation's program of biological and medical sciences is so diverse that it is impossible to characterize it briefly. The twin themes of recognition and regulation, however, run through essentially the full range of biological research.

At the molecular level, the fidelity with which genetic information is copied and passed on to new generations depends on chemical recognition which can be largely identified with bonding between specific pairs of molecules. Research supported by NSF is adding to the evidence that chemical "recognition" between component molecules also determines the organization of viruses, membranes, and other complex biological structures.

The molecular basis of gene expression and its regulation continue to attract substantial NSF support. Precisely how are the plans, which are stored in a finite number of DNA molecules in a fertilized ovum, translated into the complex structures found in an adult organism? If, as now seems clear, the cells in different parts of an individual may have identical complements of this genetic information, why do they differ so greatly in form and function? One hypothesis developed to explain this was that there is a class of regulator genes which has the function of making repressors, each of which functions to prevent a structural gene from making its product. After a decade of research, such a repressor was isolated in purified form, and it was shown (see 17th NSF Annual Report, 1967, pp. 34–35) to exert its regulatory action by combining with the specific gene which it controls (regulation through chemical recognition). Although repressor genes and their products have been demonstrated only in bacterial and viral systems, higher organisms probably operate in a similar way. A major and as yet relatively undeveloped line of research will extend these same approaches to higher organisms and provide a better basis for dealing

with genetic diseases and abnormalities of development.

Recognition and regulation are, again, central themes in studies of immunity. How do organisms or cells recognize that bacteria, viruses, or other foreign substances are different, and initiate a complex of responses to dispose of them? What goes wrong with the regulation of this process when an organism begins to treat cells of some of its tissues as foreign, and an autoimmune disease develops? Although much progress has been made in understanding the molecular basis of the antigen-antibody reaction—again, chemical recognition of one molecule by another—much remains to be learned about the cellular basis of immunity.

The whole range of behavioral problems may be put in the same framework of recognition of particular sensory stimuli in a discriminating way, and the steps by which these sensory inputs are processed to regulate the behavior of an organism. In what cases can the regulatory processes be modified by learning, and in what cases are these processes fixed? For example, research on depth perception has shown that in some animal species this kind of visual discrimination must be learned, while in others it appears to be an innate response. The study of the ability of prior sensory experiences to modify behavior and the mechanisms by which this is accomplished is, of course, the study of learning. Such research is an area of increasing emphasis in the NSF life sciences program.

The chemical regulation of behavior has become a particularly lively area of research. Some studies deal with the behavior of very primitive organisms. One such case is the behavior of the slime molds. At one stage in its life, the mold consists of individual, motile cells. At the proper stage of development these individual cells "swarm," and as they meet each other, fuse to form a multicellular organism. It has been clear for some time that the motile cells must be signalling each other with a chemical attractant, and more recent research has shown that this attractant is cyclic adenosine monophosphate (cyclic AMP) (see 19th NSF Annual Report, pp. 37–38). This was particularly exciting because cyclic AMP has been known to play a role as a chemical messenger, or intracellular hormone, in several important processes in higher organisms, and more recently it has been shown to play a role in regulation of enzyme synthesis. These observations further emphasize the fact that, though the way in which a variety of options may be utilized gives rise to an almost infinite diversity of forms and specialized behavior, these are, to a considerable extent, variations upon common themes which pervade all of biology.

## *The Genetic Origins of Behavior*

It has long been known that both genetic and nongenetic factors affect an individual's behavior, but attempts to separate the two are extremely difficult.

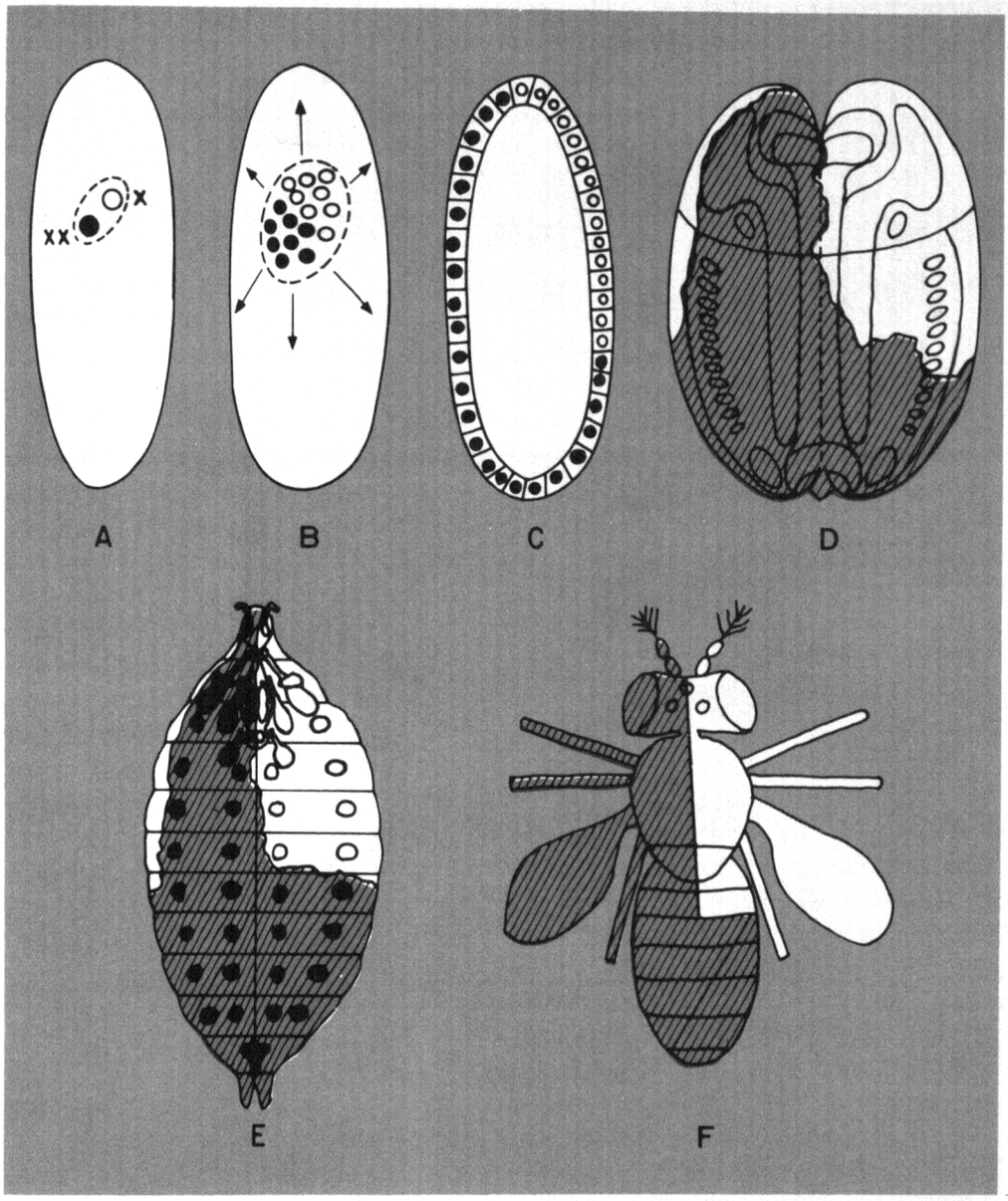
One particularly promising line of investigation of the genetic influence on behavior is being taken by a group at the California Institute of Technology. The group is under the direction of Seymour Benzer, a molecular biologist, who in the 1950's conceived a method for detailed mapping of genes using a virus.

Dr. Benzer has taken an approach to the study of behavior that is based more or less on classical genetics. He is trying to bridge the gap between geneticists, who have almost completely ignored the nervous system, and neurophysiologists, who have virtually neglected genetics. He chose to work with the fruit fly, *Drosophila melanogaster,* whose genetics was amply known from decades of study. His approach to investigating the genes and behavior is to start with a pure strain and see what changes in nervous system and behavior result from changing the genes one at a time.

Simple as it is compared to humans, *Drosophila* has a rich repertoire of behavior of genetic origin. From among those, Dr. Benzer's group decided to begin its work in a study of visual behavior. Normal flies exhibit a consistent response to light—they move towards it. At least two mutants that did not move towards light have been known for many years. Dr. Benzer's group isolated many more by adding a chemical to the sugar-water fed to male flies that greatly increases mutation rates. Dr. Benzer's group separates the mutants from the "normals" by an adaptation of the "countercurrent distribution" procedure used in biochemistry to separate molecules from a mixture.

After the flies are identified by their visual responses, they can be studied in more detail. The eye can actually be used as a photoelectric cell by means of an electroretinogram, a standard measurement used in diagnosing visual abnormalities in humans. To study visual mutants, the team puts electrodes on the eye and in the body itself. They then flash a short-duration light at the eye and measure the electrical response. The response of a normal eye follows a standard pattern, corresponding to the steps in the visual message towards the brain. An abnormal electrical response may give an indication of where a defect occurs in the visual sequence. The group has so far identified seven different genes that can undergo mutations that show up in both the electroretinogram and some aspect of behavior. For several of those mutants, they have also identified specific anatomical abnormalities in the visual system.

But a real question frequently exists as to where in the body the focus of the defect lies. If an eye of a fly with some visual defect is re-




Development of a Mosaic Fly—Fertilized egg (A) is female (XX), but one of the X chromosomes is unstable. In A, the unstable chromosome is lost during the first division so that one daughter nucleus is female (Black, XX) and the other male (White, X). The resulting male and female cells migrate during early stages of development (B, C), and tissues descending from them are either male (white) or female (shaded) during all successive stages of development (D, E) to produce the part-male, part-female adult gynandromorph or mosaic fly. (Diagram courtesy of Seymour Benzer, California Institute of Technology.)

placed with a normal eye, vision may be restored. Of course, transplanting an eye or a part of an eye in a fly is not practical surgically. But it is quite possible genetically.

The technique takes advantage of a rare strain of fly whose offspring are sometimes composites of male and female—a gynandromorph or mosaic fly. Such offspring can be part normal-female and part mutant-male—and the pattern is random, providing a range of combinations. It is easy to determine if a part is normal or mutant, because the male portions of the composite display masculine secondary sexual characteristics, and the female portions, female.

Dr. Benzer and Yoshiki Hotta on his research team used this in studying visual behavior. They tested 44 different normal/vision-mutant mosaics and made electroretinograms from both eyes in each, checking the results against those of a normal fly. In each case, if an eye was of the normal genotype, it behaved normally; if it was mutant, even if the rest of the head and body were normal, the eye was defective. For this particular mutant, the visual defect is clearly autonomous in the eye or in very closely associated tissues. While this is not a surprising finding, it could not be assumed without this kind of proof. But the neurological sites of other kinds of behavioral mutations are less obvious, and the technique will be an increasingly useful tool in localizing the site of the defect, at which point anatomical and physiological methods can be used to study it in greater detail.

While the male/female dividing line can be easily perceived on the outside of the fly's body, it does not necessarily follow the same pattern inside the fly. Moreover, the male/female internal tissues are essentially the same. What is needed is some way to distinguish between normal and mutant tissues, particularly in the brain.

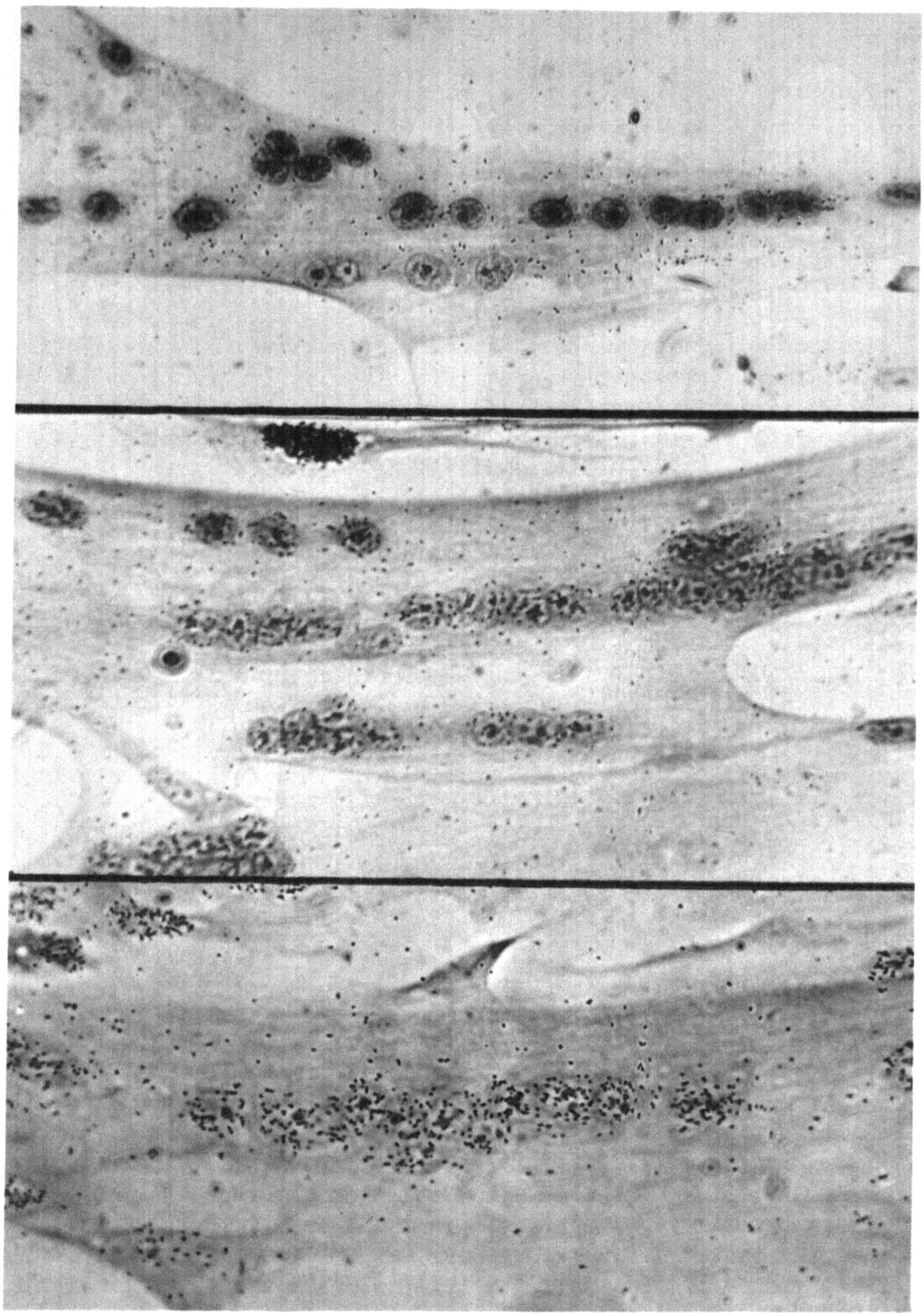
The team started off by looking for a gene on the X chromosome (the chromosome that determines sex and which undergoes an abnormal division to make a gynandromorph) that controls production of an enzyme that could be identified by staining. They could then take a section of brain, stain it, and the male part would turn one color and the female another.

They found an enzyme that exists normally in the brain and a corresponding mutant lacking it, but the controlling gene was on the third chromosome, not on the X. So they had first to "move" that gene to the X chromosome by irradiating chromosomes with X-rays and getting the proper broken section on the third chromosome to reattach to the X—a possible, but very tedious task.

Another way to distinguish between normal and mutant parts of the brain is to start with something known to be in the brain and then mutate the gene that controls it. Members of the group decided to look at an enzyme called acetylcholinesterase, in which the fly's brain is rich, and which is vitally linked to normal brain function. A fly lacking acetylcholinesterase would probably never survive, but it might be possible to find a mutant in which the enzyme would be temperature-sensitive. Below a certain temperature, the fly would act normally; above that temperature it would be mutant and "drop dead." The researchers would let the flies develop normally, then raise the room temperature: brain sections of those that died would be stained for the enzyme to see where it was deficient, and therefore what parts of the brain were mutant. Surprisingly, they found some mutant flies that dropped dead regardless of temperature.

To begin to find out why this happened, the team took a close look at the brains of the "drop dead" flies, and discovered them to be full of holes, like Swiss cheese. Among those with heads divided externally half and half, 80 percent lived normally and 20 percent died as if the entire head was mutant. Drs. Hotta and Benzer interpret that to mean that there are two sites, one on each side of the brain, and both must be mutant for the defect to occur. If the split is through the center, the one normal site is able to supply what is necessary to keep the brain intact. Only if the internal dividing line swings out around in such a way that both centers are mutant will the brain degenerate. This suggests some kind of interaction between the two sides of the brain, perhaps some neuro-circulatory substance. Now the group would like to find out what that substance is, perhaps by injecting extracts from the brains of normal flies into the mutant flies to see what substance protects the "drop dead" mutant.

Dr. Benzer is cautious about drawing too exact a parallel, but points out that the behavior of his "drop-dead" fruit flies is very similar to the phenomena of Huntington's chorea, a human disease. In a way, his team's model system–the fly–may give some relevant answers in spite of its distance from the human system.



In top micrograph, black grains of radioactively "tagged" thymidine–one of the constituent parts of DNA–are scattered randomly throughout multinucleated cell tissue. Below, after tissue has been exposed to damaging ultraviolet radiation, concentration of grains in nuclei is evidence that damaged DNA has undergone repair. (Photo, Frank Stockdale, Stanford University Medical Center)

### *Multinucleated Cell Tissue*

How the body regulates or paces the rate of cell division is one of the most pervasive questions of biology. On the mechanisms of cell division rest all of the questions of how cells differentiate to form different types of tissue as an embryo develops into an adult individual, and also how normal replacement of cells sometimes goes awry to produce biologically defective cells including those of cancer. A classical area for research on the development of tissues has been the long-known fact that the multinucleated muscle cells of higher vertebrates–including man–arise from the fusion of many primordial cells, each with a single nucleus. Detailed studies of these tissues showed that the primitive, single-nucleus muscle cells divide at regular intervals, but once they have united to form the fused multinucleated muscle cells, all nuclear and cell divisions are abruptly halted.

In 1970, Frank Stockdale at Stanford University School of Medicine showed that when the mononucleated primitive cells fuse to form muscle tissue, they lose all but 15 percent of their original amount of an enzyme called DNA polymerase, which is known to be one of the ingredients required for the replication of chromosomes and the ensuing business of cell division.

This discovery raised a number of new problems, including the important one of whether cells lacking the bulk of the enzymes necessary for duplicating chromosomes can repair accidental damage to them. The integrity of chromosomes is important not only for duplication of the cell, but also for the regulation of the cell's activity during its lifetime.

Dr. Stockdale drew on the work of others showing that when DNA is artificially damaged (such as by exposure to ultraviolet light) the abnormal segment of the macromolecule is snipped out and the resulting gap is filled in by a newly synthesized stretch of the proper material. Dr. Stockdale experimentally exposed multinucleated muscle cells –from a tissue culture of the pectoral muscle of embryonic chicks– to ultraviolet light. He then "fed" the tissue culture with radioactively labeled DNA-precursor material. When, after an appropriate period of time, he separated the DNA from the cells, he discovered that the radioactively labeled material had been incorporated in the DNA, and that the DNA had therefore been repaired.

The fact that these repairs were indeed made leads Dr. Stockdale to the conclusion that while muscle cells cannot divide because they do not have enough of the enzyme needed to double DNA, they can nevertheless synthesize short segments of the material for repair purposes.

Of course, these results do not conclusively show that the 15 percent remaining amount of the enzyme is responsible for the repair function. It may indicate that there is a special DNA synthesizing system in higher vertebrates which is set into action by damage to the chromosomes of a specialized body cell. The data can also be interpreted as suggesting the existence of two different DNA-synthesizing enzyme systems in vertebrates.

### *Tropical Ecology*

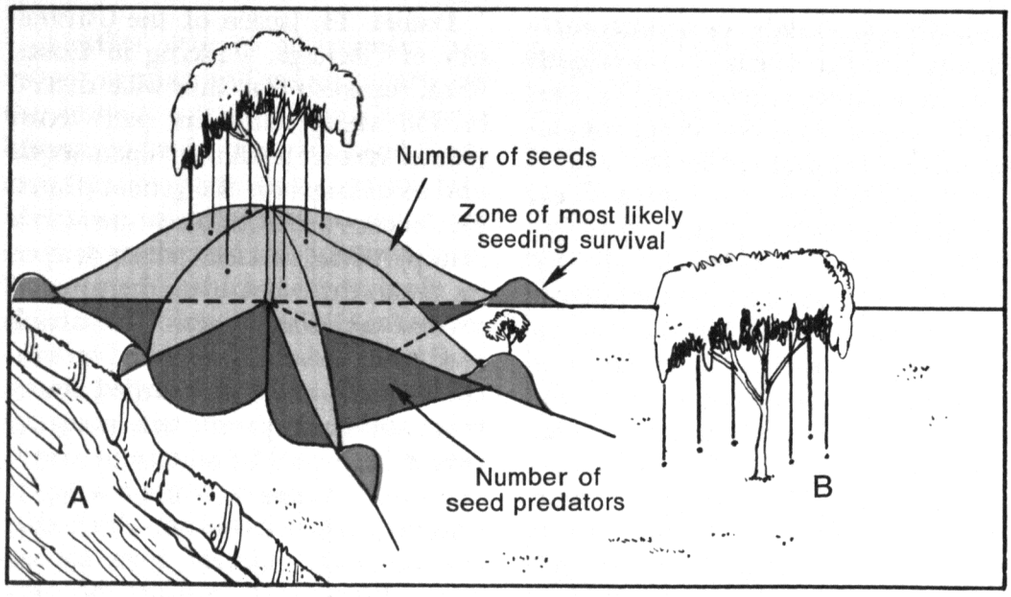
One of the great differences between the ecology of the temperate zone—such as the United States—and that of the tropics is that in the former a given unit of ground is dominated by a few plant species. In the tropics, a similar area has many species, each represented by only a few individuals. Temperate zone agriculture–the familiar field of grain–depends upon this phenomenon. If a tropical food-crop agriculture is ever to be attained, it will have to take into account the nature of the interactions between plant and animal life that generate this diversity of the naturally occurring system.

Daniel H. Janzen of the University of Chicago, working in Costa Rica, suggests that this wide distribution may result in part from greater insect predation upon seeds and seedlings near the parent plant. His most recent studies are of a canopy vine, *Dioclea,* which drapes its flowered crown over the tops of several adjacent trees. The thick seed pods drop to the ground on maturity and many are carried away from under the parent tree by squirrels as a would-be source of food. However, the seeds contain a toxic amino acid, canavanine, which discourages the animals from eating them. These seeds produce the new crop of vines, because most of the seeds left behind are eaten by a species of beetle able to cope with the canavanine and which lives almost exclusively on *Dioclea* seeds. The few surviving seedlings are destroyed by caterpillars that drop to the ground from the parent vine, on whose tender shoot tips the adult moth primarily lives. Only those seedlings that germinate far from an established vine have a reasonable chance of surviving. Inevitably, the vines therefore become widely spaced through the forest.

Larry L. Wolf of Syracuse University is studying the two distinct patterns of distribution of several species of a relative of the banana tree, called *Heliconia.* In one species, the individual trees are scattered through the tropical forest like *Dioclea.* Other species do not depend on seed for reproduction at all –possibly an evolutionary response to heavy seed predation–but reproduce vegetatively and grow in large clumps.

Each *Heliconia* flower lasts for less than a day, and produces nectar only from early morning until shortly after noon. The two types of *Heliconia* therefore provide distinct patterns of nectar distribution for the various species of hummingbird that feed from them.

Dr. Wolf has determined that the long-tailed Hermit Hummingbird,




The number of seeds of the tropical canopy vine, *Dioclea,* that fall to the ground per unit area decreases sharply with increasing distance from the parent vine (light-colored zone). Predators on seeds and seedlings (caterpillars and weevils) are similarly distributed (dark-colored zone). There is therefore an area, ringing the parent vine at a distance, in which a seedling is most likely to survive (Hatched zone). The possibility of survival is influenced by topographic features such as rivers (A), which inhibit the spread of both seeds and predators, and other adult vines of the same species (B).

which feeds from the dispersed *Heliconia,* differs in both its mating behavior and its food-gathering habits from those species that depend on the clumped plants. Each breeding male of the species feeding from *Heliconia* clumps maintains a flower-centered territory in which he feeds and from which he drives all other males of the same species. On the other hand, the male Hermit Hummingbird does not maintain a flower-centered territory, but flies a "trapline" over an extensive area, collecting the nectar as it is produced by the ephemeral flowers. During the breeding season, males congregate in groups called "leks" to call and display. The female Hermit is drawn to the group of males which attract her attention as she flies her own "trapline."

Dr. Wolf concludes that the breeding system with flower-centered territories is more primitive within the hummingbird family. The evolution of "traplining" for nectar by males and their formation of leks have been determined by the dispersed nature of the specialized energy source that they exploit.

Drs. Wolf and Janzen's studies provide another step towards the understanding of these mechanisms and, potentially, how they might apply to agriculture and man.

## ENVIRONMENTAL SCIENCES

Man's surroundings—the earth which he inhabits and the envelope which surrounds it—are the concern of the environmental sciences. The scientists conducting atmospheric, earth, and oceanographic science research supported by NSF are primarily based at universities, oceanographic institutions, or at the National Center for Atmospheric Research at Boulder, Colo. In some cases, environmental studies are large-scale field operations, require the use of ships, aircraft, satellites, rockets, and other facilities, and involve scientists from many disciplines and many nations. Because of their complexity and the sheer physical size of many of the problems which must be investigated, the NSF has established several National Research Programs to bring to bear the diversity of talents needed. (Details of these programs are presented on pages 39 through 44.)

In the atmospheric sciences, 143 grants were made for $9.2 million, an increase of 25 grants and $1.2 million over the previous year. Continuing emphasis is placed on problems of atmospheric chemistry and the production, behavior, and fate of atmospheric constituents, whether occurring naturally or added inadvertently. Increased effort is being focused on the interactions between the lower and upper atmosphere and between global-scale and medium-scale weather. In part, these investigations—which require extensive field measurements using radar techniques and highly instrumented aircraft—are concerned with the behavior of the atmosphere which leads to severe storms.

Through a broad program of solar-terrestrial research, involving both theory and observations, substantial increases in knowledge have been obtained concerning the outer atmospheres of the sun and the earth. In this connection, NSF coordinated all U.S. research programs for study of the total solar eclipse on March 7, 1970. Those investigations covered such diverse topics as stellar occultations, spectrophotometry of the distant solar corona, and ionospheric waves. The findings of these investigations are under review and study. Scientifically, the eclipse research program was a great success, and preliminary planning is under way for an extraordinarily long-duration eclipse predicted for Central Africa on June 30, 1973.

In other studies of the ionosphere, there is a rapidly growing recognition of the power of the incoherent-scatter radar technique to provide a great deal of valuable information about the upper atmosphere. The dominant scientific problem in the outermost atmosphere is the magnetospheric substorm, which produces

brilliant auroras, radio blackouts, and large fluxes of electrons. Because of its pervasive effects, it can be expected to attract particular attention in the future.

As compared to 1970, the earth sciences program remained comparatively stable, awarding 225 grants in the amount of $8.0 million during fiscal year 1971. This level represents 30 to 40 percent of funds for geological research going to the nation's universities. Because the Foundation is the major supporter of geologic research in academic institutions, the effect of the change in the pattern of support by other agencies has been smaller in the earth sciences than in some of the other disciplines. Other programs which make important contributions to our earth science understanding include the Ocean Sediment Coring Program (page 42) and portions of the International Decade of Ocean Exploration (page 39).

The past decade has witnessed remarkable advances in the science of geology. Most significantly, the concept of seafloor spreading and plate tectonics provides, for the first time, a theoretical framework for viewing major tectonic processes on a global basis. With this unifying concept it is possible to explain a wide range of diverse observations on earthquakes, volcanism, faulting, mountain building, and the basic processes that shape the surface of our planet. As is often the case when a new theory of wide scope emerges, further research is required to test the main line of the theory more fully and to extend it so as to integrate it with other observations. Although seafloor spreading and plate tectonics has been most successful in dealing with the oceanic areas, its pertinence to continental deformation is not clearly demonstrated in all cases.

Oceanographic research project support is related to and coordinated with the Ocean Sediment Coring Program, the International Decade of Ocean Exploration, and the Arctic and Antarctic Research Programs. The oceanography research project support concentrates on studies of organisms living in the ocean, the origin and structure of ocean basins, energy interactions between the sea and the land and the atmosphere, and above all, the physical processes that keep the global sea in motion. In pursuit of these objectives, grants for $9.9 million were awarded in fiscal year 1971—which is $1.0 million more than the support of the year before.

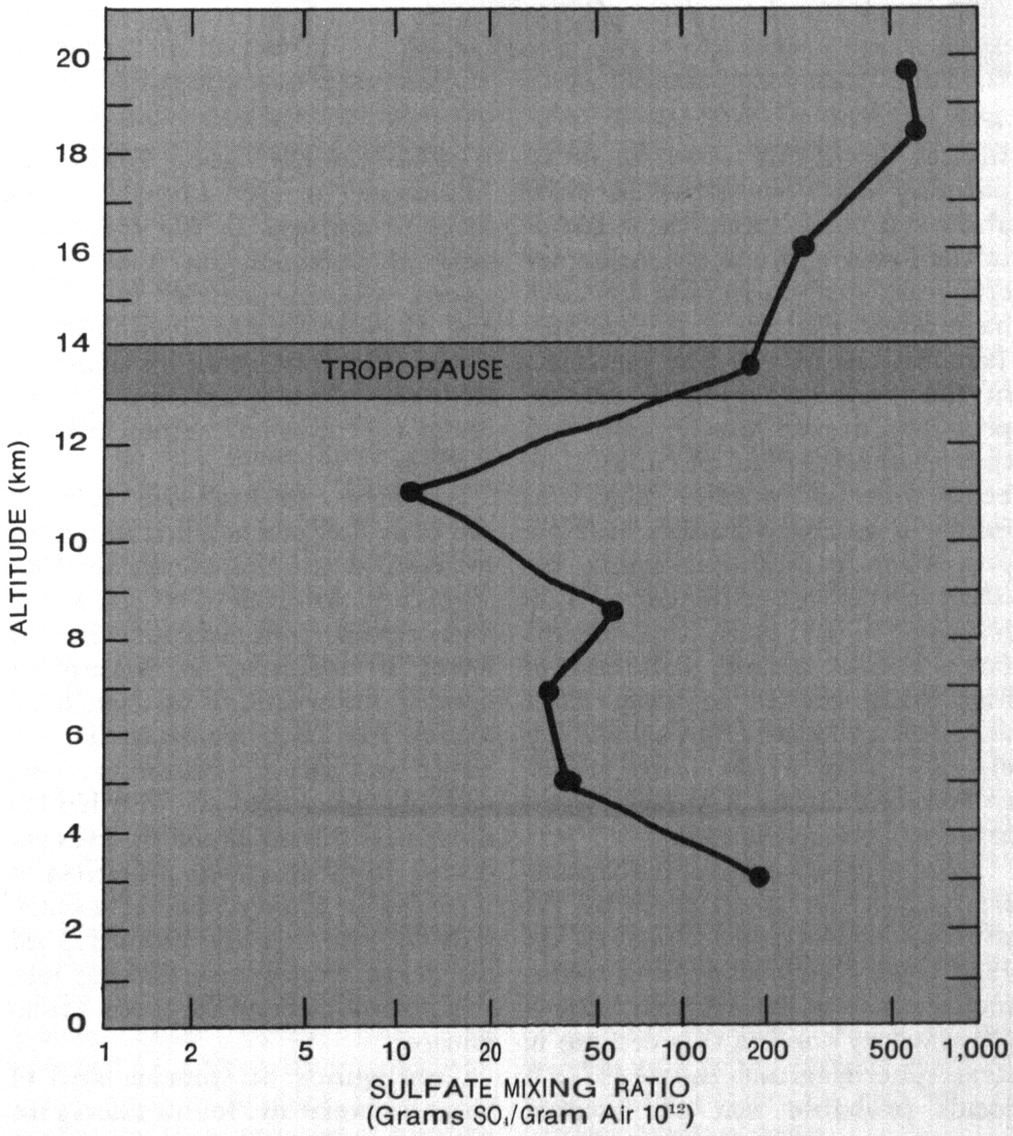
From these kinds of studies it is hoped, among other things, to learn more about the dynamic processes controlling the deep circulation and turnover of ocean waters, sediment concentration, replenishment of surface nutrients, and energy exchanges. Concern with dynamic functioning of ocean systems is also reflected in marine ecological studies. A great deal of emphasis is also being placed on the effect of higher nutrient concentrations, insecticides, and trace metals on marine bacteria and microorganisms. With this increase in our understanding of the oceans and the objects and phenomena associated with them, it is anticipated that the United States can move forward in its efforts to develop and use the vast resources of the sea.

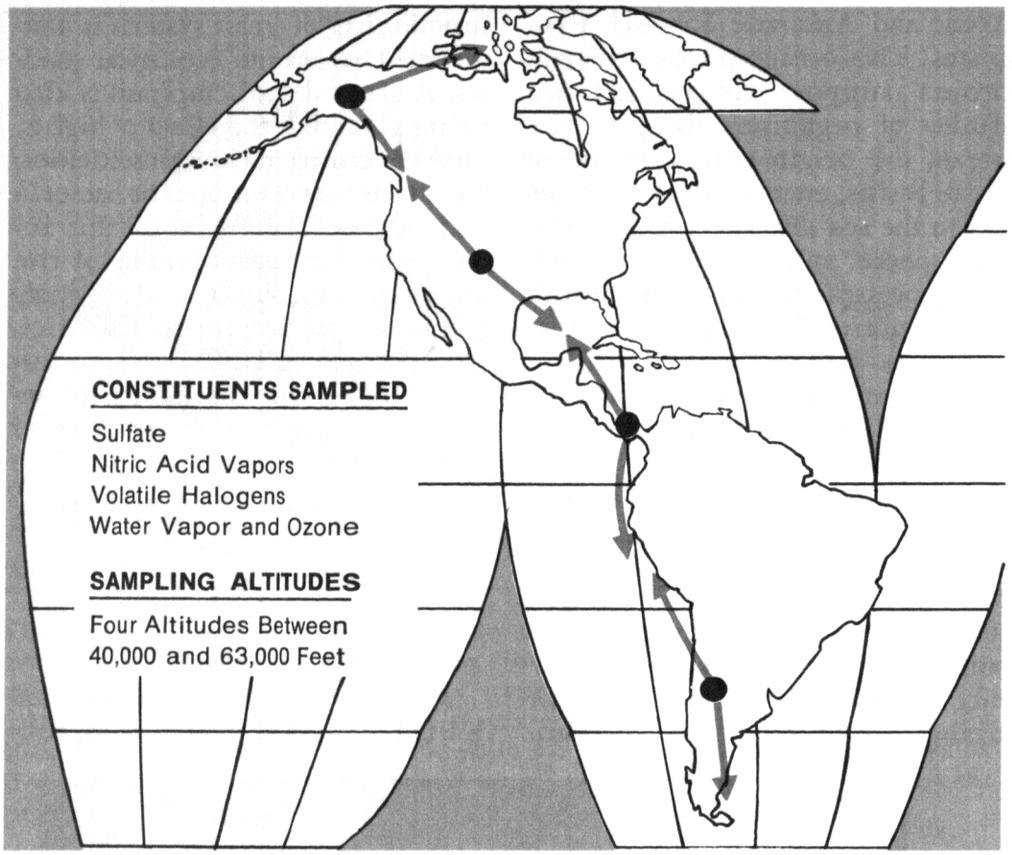
## ATMOSPHERIC SCIENCES

### NATIONAL CENTER FOR ATMOSPHERIC RESEARCH

### *Stratospheric Aerosols*

Although man must take responsibility for much of the polluting sub-






stances in the air today, he is apparently not responsible for some abnormal constituents being found in the lower stratosphere. After several years' study, scientists at NCAR have found that the major aerosols (suspensions of very fine particles) in the lower stratosphere, sulfates, probably derive mostly from volcanic fumes. Sulfate particles have been collected directly from the fumes of several volcanoes, and the proportion of different sulfur isotopes in volcanic sulfur compounds is similar to that of stratospheric sulfate. Aerosol samples collected by high-flying aircraft in 1966, 1969, and early 1970 show that sulfate levels in a layer in the lower stratosphere were almost 10 times as great as were measured in 1961.

Late in 1970, however, the concentrations in the lowest levels of the stratosphere decreased almost to the 1961 level. Other kinds of measurements made at NCAR and Lowell Observatory confirm this decline in stratospheric aerosols in late 1970. It seems probable that the violent eruption of the Agung Volcano in Indonesia in 1963 brought about marked changes in the concentration of particles, and that subsequent volcanic activity in Alaska and elsewhere maintained the high levels. The concentrations measured most recently may represent a return toward a "normal" aerosol concentration.

Another stratospheric aerosol, nitric acid vapor, was first identified by optical studies of the twilight spectrum. Analyses of NCAR's samples reveal concentrations in the lower stratosphere, confirming the optical observations. Although no source has been identified for the nitric acid vapor, preliminary data on its geographical distribution show that it, too, probably does not derive from manmade pollution; it is found in almost equal concentration in the heavily industrialized Northern Hemisphere and the relatively unpopulated Southern Hemisphere.

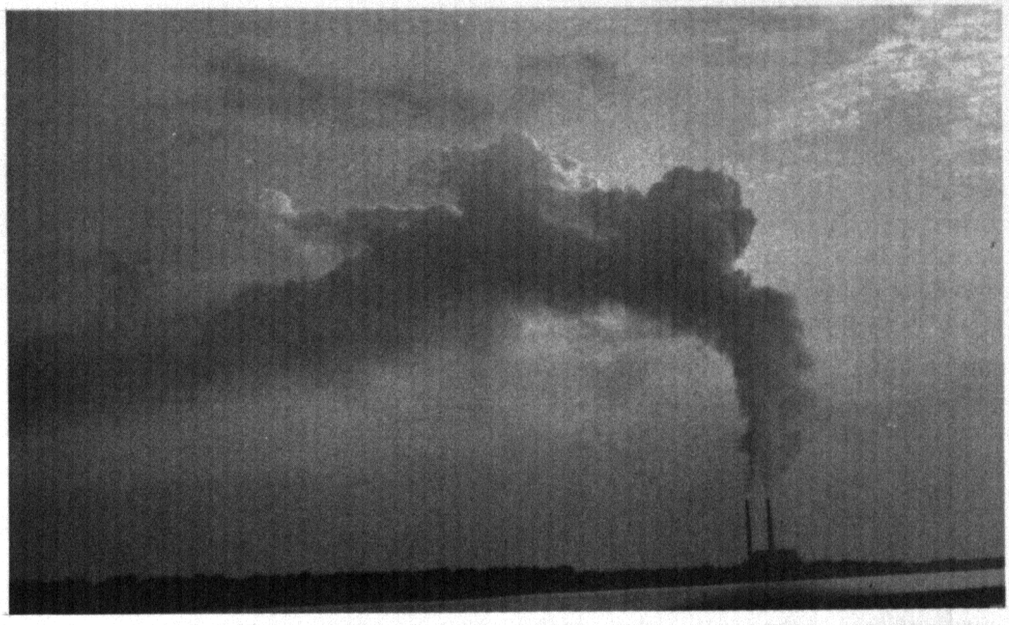
Compounds of chlorine and of bromine were also found among the aerosols collected, with the average chlorine-to-bromine ratio (by mass) about 20 to 1. Since the corresponding ratio in sea salt is about 300 to 1 and that in crustal rocks and soil is about 70 to 1, stratospheric chlorine and bromine probably do not originate from either sea salt or continental dust. They may, however, come from manmade pollutants (especially automobile exhausts) or from volcanic fumes.

## *Solar Wind*

Interplanetary space, far from the complete void it was once thought to be, is filled with ionized gas known as the solar wind. This wind, which consists mainly of protons and electrons emitted from the sun, is the result of continuous expansion of the solar corona. When scientists at NCAR's High Altitude Observatory used satellite observations to study variations in the speed of the solar wind—which ranges from 250 to 850 kilometers per second—they found that, unlike most other solar phenomena, the solar wind speed is nearly independent of the 11-year cycle of solar activity. The yearly average speed is close to 400 kilometers per second whether the year is near solar minimum or solar maximum activity. These findings suggest that solar activity in general, and increases in the density and temperature of the corona in particular, do not grossly affect the overall rate of emission of material.

Although the yearly average is nearly constant, the solar wind speed can vary considerably from one day to the next. Rotation of the sun provides one source of variation at the earth, even when solar conditions are steady; the general evolution of the solar atmosphere provides another source. The NCAR studies have shown that the solar wind emission from the sun typically remains about the same over some 35° in solar longitude. Because the sun rotates at an average rate of 13.3° per earth day, the solar wind speed ob-

served at the earth's orbit is reasonably steady for about 2.6 days. The studies also suggest that the speed of the wind emanating from a particular solar region usually changes significantly within 4 earth days, so specific speed patterns are usually not observed when that portion of the sun eventually rotates back into view. When the patterns do recur on successive rotations, they are more likely to include lower speeds (less than 400 kilometers per second) than higher, implying that the regions of quiet coronal expansion can persist considerably longer than other regions.



An effect of urban activities on weather phenomena is visible at this major power plant along the Mississippi River near St. Louis, where cumulus have been frequently observed growing out of the plant's effluent. (Photo Illinois State Water Survey)

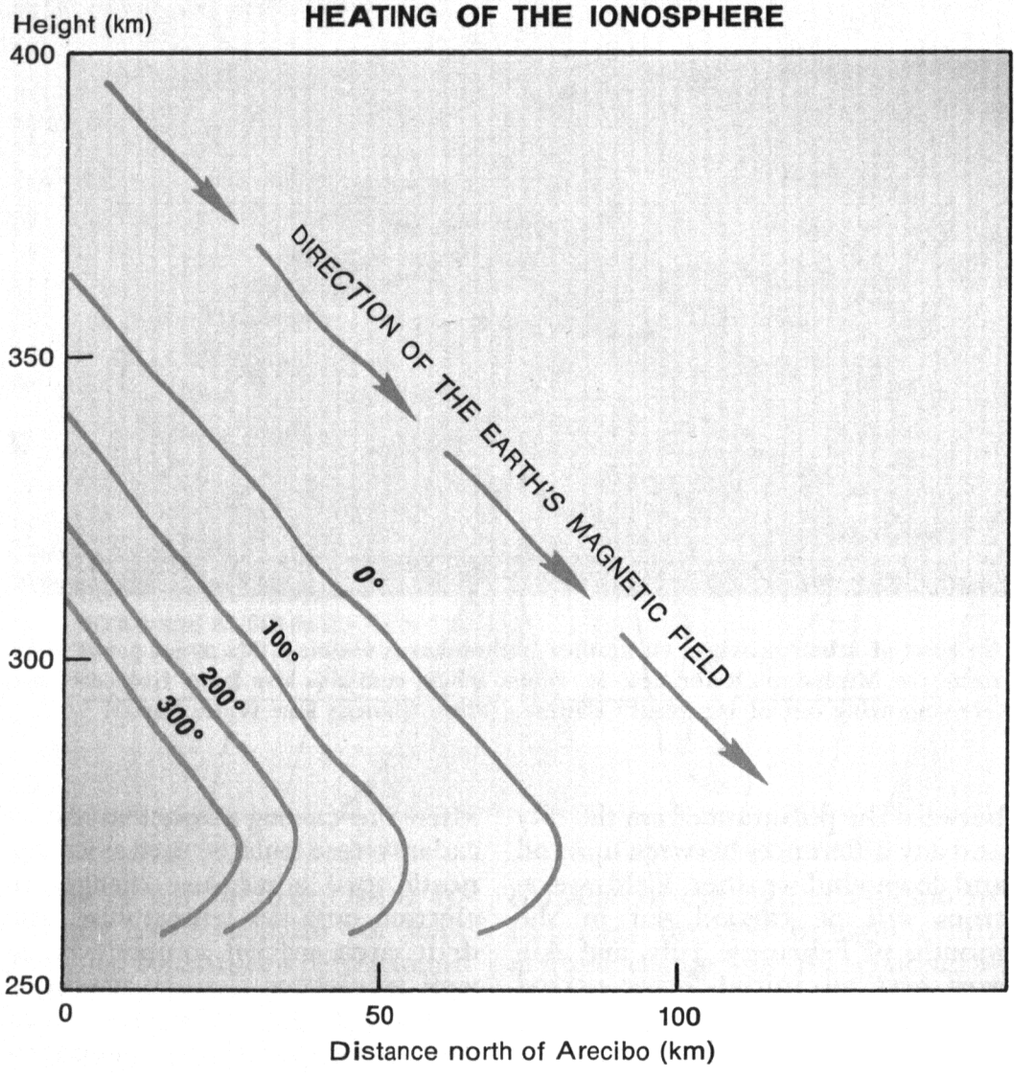
## University Research

### *Modifications of the Atmosphere*

Several projects aimed at discovering the causative factors of inadvertent weather modification—the necessary first steps towards solving the associated social, economic, and ecological problems—have moved into the field experiment stage in the St. Louis urban area. Scientists from the University of Illinois are examining summer precipitation and related severe weather events there, and they will evaluate rainfall and radar data to determine the magnitude of urban-related precipitation changes under different weather situations. A group from the University of Chicago will study the same urban area by measuring and studying the internal structure of clouds and precipitation regions upwind versus downwind of St. Louis. Data on cloud condensation nuclei, cloud particle spectra, cloud water content, precipitation particle spectra, ice crystal nuclei, ice crystal content, meteorological state parameters, solar radiation, and surface albedo will be obtained from an instrumented airplane. These will be compared with ground-based radar measurements of the location and intensity of precipitation regions in an effort to pin down cause-and-effect relationships between the pollutants from the city and any differences between upwind and downwind weather. Field operations will be carried out in the months of February, July, and August over an initial 2-year period that began in 1971.

Inadvertent modification of the atmosphere in and around St. Louis may be contrasted to the deliberate but short-lived and harmless modification of the ionosphere above Arecibo, Puerto Rico. There, the ionosphere (the region of the atmosphere above about 70 kilometers which contains free ions) is heated by a high-power radio pulse. The heated region is then probed by sending a radar pulse into the region of interest and measuring intensity and spectral shape of the weak return as a function of time (the technique of incoherent radar backscatter). NSF grantees have made substantial contributions to the development of this technique.

Substantial heating of the ionosphere by absorption of high-frequency radio waves was first achieved by a Department of Commerce group in Boulder, Colo.; the heating was then repeated at Arecibo where the existing incoherent scatter radar system could be used as a diagnostic tool to measure changes in electron and ion temperature, ion drift rates and ion composition, as well as electron density associated with the heating. The radar measurements indicated that ionospheric plasma waves at the plasma frequency were increased by two orders of magnitude during the heating, and that while the change in ion temperature was small, the maximum increase in electron temperature was from 1,100° to 1,400°, or almost 30 percent. It was concluded that the heating of the electron gas was not due to electron collisions with ions and uncharged particles as originally expected, but that a two-stage process was involved. First, the radio-frequency wave produced amplification of plasma waves in the medium, then the amplified waves interacted with the ambient electrons to transfer energy to them. This heating experiment demonstrates the utility of the incoherent backscatter technique as a powerful tool for measuring a large number of ionospheric parameters over an extended region of space.




On October 22, 1970, at Arecibo Observatory, high-frequency radio waves transmitted from the ground and absorbed in the ionosphere produced the increases in electron temperature shown by the contours. The maximum rise of 300° K. represents a 30 percent increase in temperature. Maximum absorption (and, hence, maximum heating) occurred vertically above Arecibo at a height of 300 kilometers, where the input was strongest. Because heat is conducted rapidly in the direction of the earth's magnetic field, the temperature remains essentially constant along the field down to about 270 kilometers. Below that altitude, rapid cooling takes place as a result of increasing density of the neutral atmosphere.

## EARTH SCIENCES

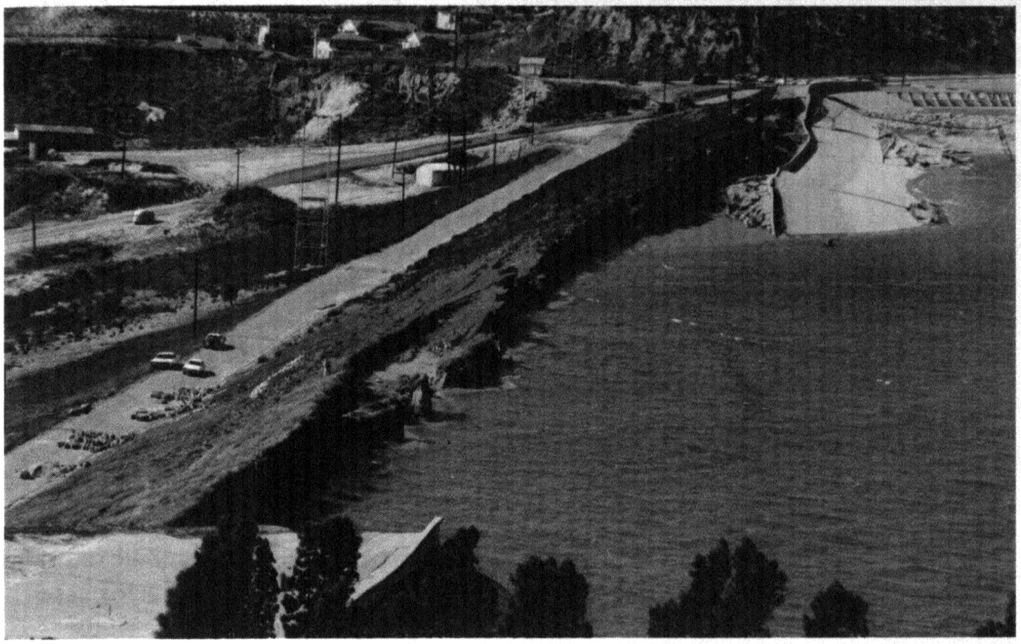
### *Earthquake Studies*

The importance of the earth sciences to man was brought out dramatically during the past year with the occurrence of California's San Fernando earthquake on February 9, 1971. This earthquake, with a Richter magnitude of 6.6—a modest event by seismological standards—was nonetheless a great disaster, with nearly a billion dollars in damage. The loss of 64 lives, the sixth highest in the United States' earthquake history, could easily have been multiplied many times because 80,000 people were threatened by the near-failure of the Van Norman Dam.

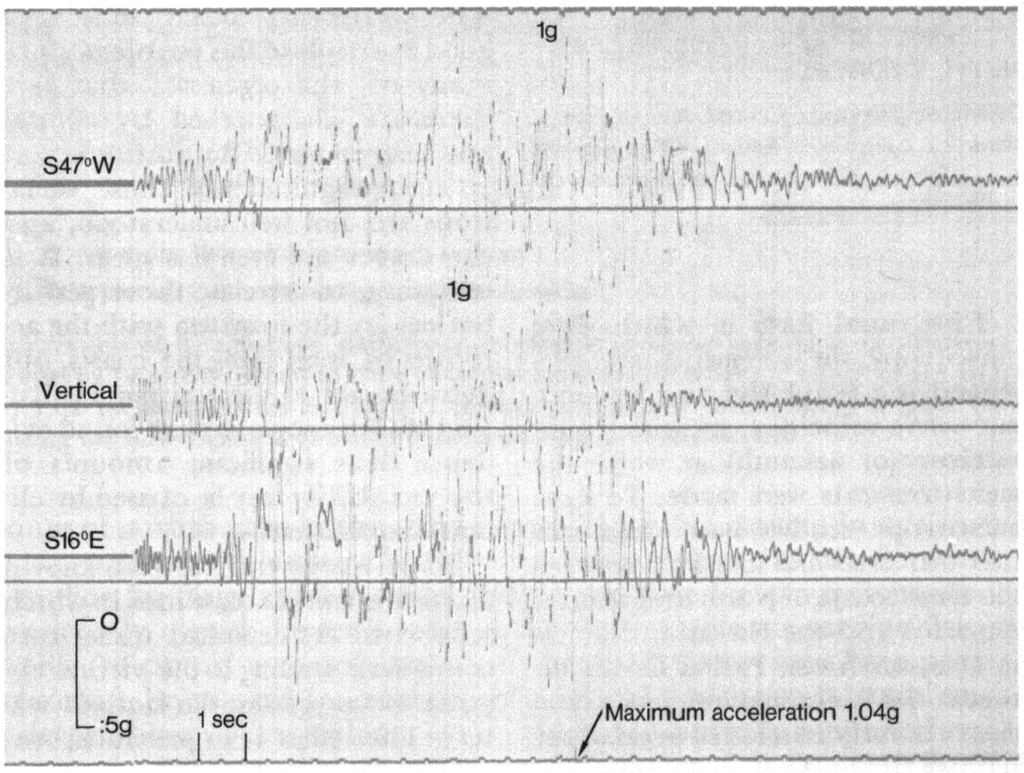
This earthquake has extreme importance for seismology and for earthquake engineering because it occurred in an area that was comparatively instrumented with accelerographs, strain meters, tiltmeters, and other geophysical instruments. It provided unusual opportunities for obtaining information of immense practical as well as scientific value. For example, the greatest ground acceleration ever recorded was reported from the epicentral region, with some high-frequency vibrations exceeding that of gravity. Ground accelerations that great were unknown from previous California earthquake records, and the knowledge that such extreme acceleration can occur is forcing major reevaluations of earthquake hazards and engineering design.

Geophysicists at the California Institute of Technology's Seismological Laboratory, which operates the main seismograph network in southern California, responded quickly to this earthquake. Not only were they able to pinpoint the epicenter immediately because data from some of the key stations were telemetered to the Laboratory in Pasadena, but also within 3 hours of the main shocks they had mobilized portable geophysical equipment and installed it in critical field locations. Caltech geologists were also in the field within 3 hours of the earthquake to assist in obtaining critical aftershock and other data needed for complete geological and geophysical analysis of this earthquake event. The immediate attention of Caltech staff and students to the San Fernando earthquake resulted in the collection of significant data and publication of reports by April 1971, covering the seismological environment, preliminary seismological and geological studies, main shock and aftershocks, patterns of faulting, precise locations of aftershocks, orientation of the fault planes, and strains and tilts of the earth.

An unusual aspect of the earthquake was the extent and complexity of surface faulting which shattered the area, inflicting abnormal amounts of damage to buildings, highways, power lines, and other



The badly damaged Lower Van Norman Dam shortly after the San Fernando earthquake of February 9, 1971. (Los Angeles Water and Power Department photo by Max Gould)




This February 9, 1971, accelerograph record from the abutment of Pacoima Dam shows the greatest earthquake strong motion (1.04 g) ever recorded. Evidence of such large acceleration from a moderate earthquake has important implications for protection against future earthquake hazards.

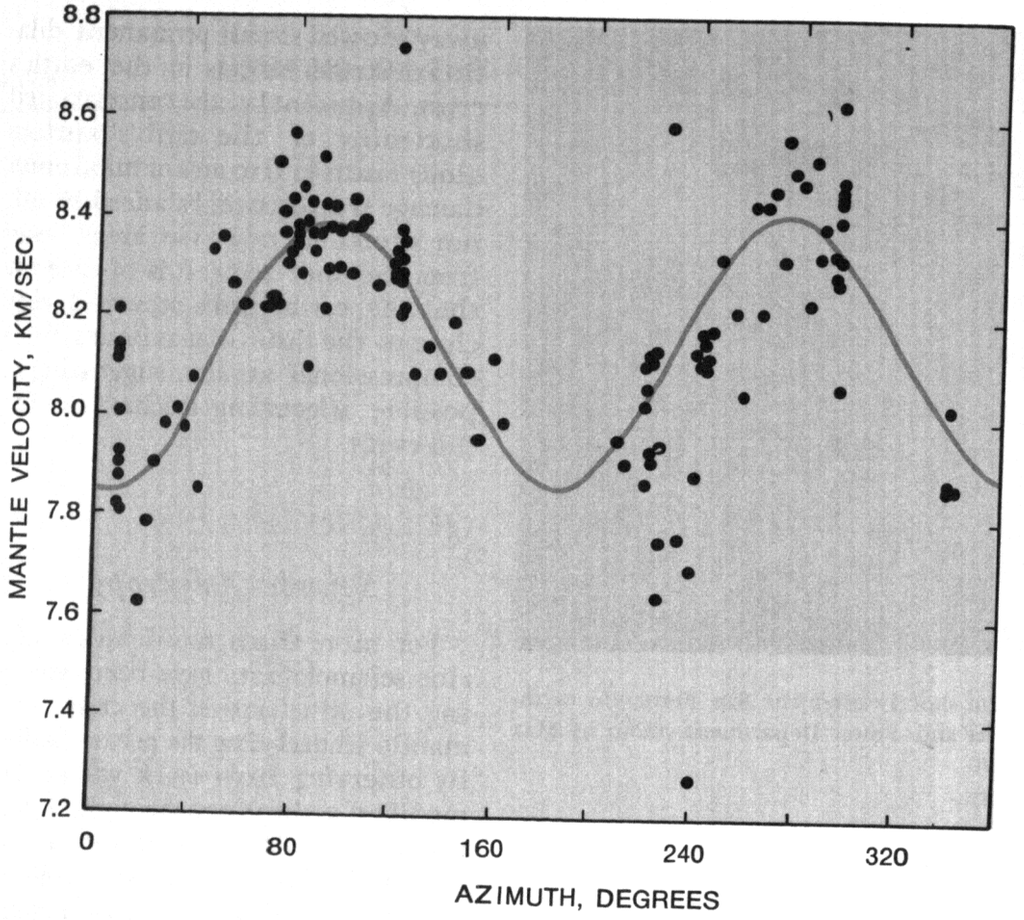
structures built in the path of the faults. In some places the vertical offset on faults was as much as 35 inches, horizontal offset along the trend or strike of the fault as much as 64 inches, and compression of land area across faults as much as 42 inches. Stations as far as 250 miles away showed small permanent dilational strain effects in the earth's crust. Apparently, the concentrated shortening of the earth's surface along faults in the area of maximum damage was counter-balanced by minor stretching over vast areas away from the fault zone. It is of interest that the earthquake occurred very close to the time of maximum tidal compressional strains, suggesting a possible triggering mechanism for this event.

## OCEANOGRAPHY

### *Seismic Anisotropy*

For more than two decades, marine seismologists have been studying the structure of the crust and mantle underlying the ocean basins by observing how shock waves are modified as they pass through. A significant part of the information obtained has involved the determination of the velocity at which compressional waves travel through the rock material forming the outermost part of the earth's mantle. As these data accumulated, it became apparent that there were substantial variations in the magnitude of this mantle velocity from place to place. For many years, these variations were attributed to presumed differences in rock materials from one area to another because there seemed no other reasonable explanation.

In the mid-1960's, with the introduction of the concept of seafloor spreading, it was pointed out by the late Harry Hess of Princeton that a significant part of the variability in mantle velocities might be explained if the rock material in the upper mantle were anisotropic (having different physical properties in different directions) in a regular sense over widespread regions of the ocean basins. Dr. Hess also suggested that this anisotropy might be directly related to large convective cells in the mantle, which many earth scientists believe to be the driving mechanism




Anisotropy measurements from one Pacific Ocean region near Central America show the seismic wave velocity variations as functions of compass direction. (The greatest variations recorded to date are near Hawaii—a high of 8.45 km/sec nearly east-west and a north-south low of 7.85 km/sec.)

for seafloor spreading, and which could reasonably provide a widespread mechanism for the flow-induced alignment of anisotropic crystal grains such as olivine. This crystal alignment would in turn produce an observed whole-rock anisotropy.

Since this hypothesis was suggested, Russell Raitt and George Shor and their associates at the Scripps Institution of Oceanography have been developing and testing the necessary techniques for acquiring and analyzing seismic anisotropy data with the required accuracy. These developments have evolved to the point where adequate anisotropy measurements can be made using one ship and sonobuoys rather than the two ships required before, and where data analyses, though time consuming, have become standardized.

The usual form in which these anisotropy measurements are presented is a graph showing how seismic wave velocities vary with the direction (or azimuth) at which the measurements were made. To date, anisotropy studies have been carried out at several locations between the west coasts of North and Central America and the Hawaiian Islands, in the northwest Pacific Ocean between the Aleutians and Japan, and most recently in selected areas of the Indian Ocean. In all of these studies, the anisotropy observations are consistent with the hypothesis that the maximum velocity is in the direction of seafloor spreading. The magnitude of the anisotropy observed has been variable.

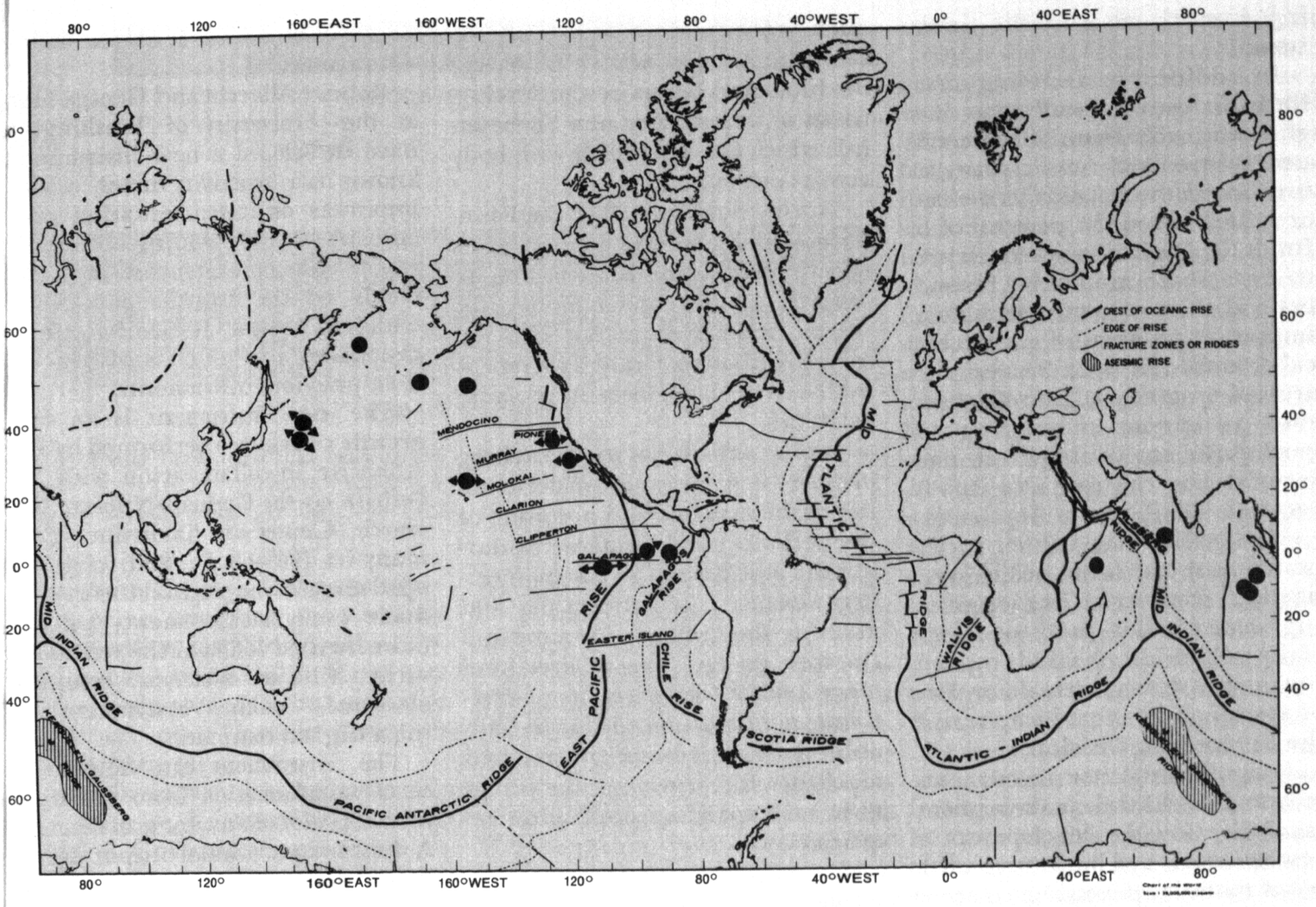
The potential significance of an anisotropic mantle is considerable. It holds the promise of providing independent and quite valuable information and constraints on the directions of seafloor spreading and the mechanism by which crustal plates are moved about. In addition, quantitative information on mantle anisotropy and its variability would contribute substantially to the accurate prediction of the rock densities used in gravimetric analysis of structural models of the earth's crust and upper mantle.

## *Natural Variability of Coastal Resources*

Commercial fisheries, which are important regional industries as well as large producers of food for human and animal consumption, are particularly vulnerable to the variability of coastal ecosystems. The amounts and distributions of species of sea life differ from year to year. The California coastal zone is a good example of this problem, since many of the organisms that live there are characterized by annual and longer-period fluctuations.

The magnitudes of these variations are not well understood, and the causes are even less clear. It is tempting to correlate these perturbations in the ecosystem with the activities of man along the coasts, but John Isaacs at the Scripps Institution of Oceanography has found evidence that significant amounts of the variability may be caused by climatic conditions.

There are several locations known along the world's coastlines in which sediments are deposited under rare conditions leading to the virtual absence of oxygen in the bottom waters. The effect is to preclude burrowing and bottom animals from disturbing the fresh sediments, and also to inhibit the decomposition of any organic remains. One of these unusual offshore basins is at Santa Barbara, and there Dr. Isaacs has been studying the remains of organisms preserved in the annually layered sediments for evidence of past abundances. He found that the




● Anisotropy Stations (data reduction in process)

● Anisotropy Stations with resultant high-velocity vector

Measurements of the anisotropy (differences in physical properties depending on direction) of the upper mantle were made at 16 oceanic sites by June 1971. Results to date show that maximum seismic wave velocities are in the directions of the spreading of the seafloor away from the oceanic ridges and rises. This is in agreement with the concept of giant convective cells within the earth, which may be inducing the flow-alignment of anisotropic crystal grains in the mantle.

amount of sardine scales in the sediments correlated with historical data on sardine landings, and by studying specially "quick frozen" core samples (to protect unconsolidated near-surface layers) and by analyzing deeper, hence older, portions of the cores, he has been able to estimate probable sardine abundances in the past. Sardines, he finds, were extremely abundant during the 1860's and 1890's, and each peak was followed by a drastic reduction. Moreover, these peaks occurred during periods of high rainfall, which is recorded in annual growth rings of trees of the immediate area. It now seems likely that changes in sardine abundance reflect climatic fluctuations and that the precipitous decline of the California sardine fishery in the 1930's may have been part of a natural population fluctuation.

Dr. Isaacs' currently supported research is designed to elucidate fluctuations in other organisms off California and to evaluate fluctuations of commercially important species in other areas. The techniques developed for studying the layered sediments and correlating them with various climatic measures in addition to rainfall should be useful in the study of other regions—such as Peru, India, or southern Africa—that contain important fisheries. Determination of the natural fluctuations of the fish may lead to greatly improved scientific management of these ocean resources.

## ENGINEERING

During fiscal year 1971, the NSF awarded 425 grants, totaling $17.4 million for engineering research. This represents a level of effort similar to that of the preceding year, and accounts for about 15 percent of the direct Federal support for engineer-

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ing research at academic institutions.

In addition to awarding grants for basic research in all areas of engineering, the Foundation continued its trend of recent years and broadened the scope of its research activities. About 30 percent of the funds for engineering were devoted to areas where engineering researchers and their students can have an impact on problems of great technical or social relevance. Some of these areas of programmatic investigation, such as enzyme engineering and earthquake engineering, were transferred during the year to the new Directorate of Research Applications (see page 57), while others, such as materials research, biomedical engineering, communications engineering, construction methods (especially tall buildings), wind engineering, and hydrology, remain as areas of special and enlarged emphasis in the Engineering Division.

A significant factor in our economy and world trade is the national capability for the development of new materials and innovative methods of material processing. In recent years, dominance in materials processing has been severely eroded by technological advances by foreign competitors. Of particular importance is machining of superalloys using superhard materials—an area which requires much research in the development of new materials and improved understanding of existing materials. For some uses it has been found that the durability of tungsten carbide tools can be improved drastically by coating the surface with a 0.0002-inch layer of titanium carbide. It can be expected that coated tools will be used more and more in the future, but their full potential could be better exploited if it was known why a minute coating makes tools more effective.

Biomedical engineering attempts to contribute to the solution of health problems through the interplay of engineering with biology and medicine. It concerns itself with such problems as the effects of electromagnetic and ultrasonic energy on biological tissues or the development of improved or new biomaterials which are compatible with body tissues or fluids.

During fiscal year 1971, the Foundation used about 10 percent of its engineering funds to continue to provide special opportunities for young graduate engineers. This Research Initiation Grant Program is included in all engineering program activities.

Just as science has made exciting progress in gaining new understanding of the structure and operation of the technical and social world during the past 20 years, so has engineering advanced in anticipating and meeting the demands for more and cheaper energy, longer lived and more reliable materials, more effective communication, and more suitable and efficient techniques and machines for providing the things that an expanding population requires.

## *Measurements in Reactors*

A nuclear reactor, more than any other powerful machine, is one whose internal activity must be known from moment to moment. However, the problems are different from checking the oil pressure or rate of fuel flow into a diesel engine or the rate of water flow through a hydroelectric turbine. A nuclear reactor operates silently and behind heavy shielding. Its direct output, heat, is actually a secondary product of the nuclear fission process taking place in its radioactive core. Measuring the heat produced, or the electrical current produced by the heat, is a secondary measure which actually amounts to a reading of what happened earlier in the nuclear reaction. It is important for reactor safety engineers and operating personnel to know from moment to moment exactly how the nuclear reaction—the production of thermal neutrons as a result of atomic fission—is proceeding.

Robert Albrecht and George Hess at the University of Washington have developed a new instrument, known as a "reactivity meter," which improves on instrumentation presently in use by providing both more rapid and more accurate measurements of the neutron population within a reactor. It also has applications to a larger class of reactors than previous instruments.

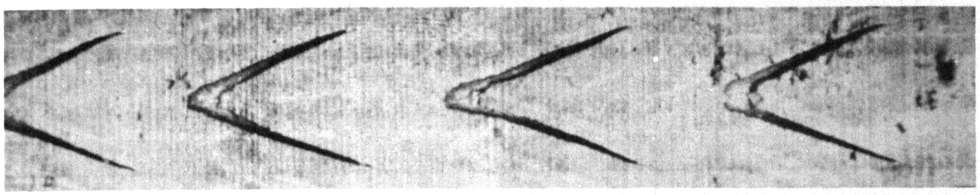
The new instrument is an outgrowth of research performed by Dr. Albrecht in collaboration with W. Seifritz of the German Nuclear Research Center in Karlsruhe, Germany in 1967–68. Dr. Seifritz developed some of the original theory and made early measurements with a more limited design of the reactivity meter. The new meter is a complex electronic "on-line" instrument using a digital computer.

The instrument can determine certain information from the neutron activity of any nuclear reactor. A detector provides an output signal which fluctuates depending on the number of neutrons within its sensitive region. The number and velocity of these neutrons provide information from which the computer can calculate the instantaneous reactivity (i.e., neutron population), the statistical standard deviation (a measure of the accuracy of the measurement), and other values. In effect, the computer and the detector count variations of the neutron population within the reactor and apply standard statistical concepts to these variations.

Dr. Albrecht's new and more advanced instrument was developed at the University of Washington, and has been tested on a number of experimental reactors.

An even more advanced version of the new meter has been tested in the University of Washington nuclear reactor by a group of engineering graduate students in the nuclear engineering department as part of their laboratory experience. These

LABORATORY SCALE



INDUSTRIAL SCALE

The "center burst defect" has been shown to be caused by the conditions under which metal is worked, or "deformed," rather than a pre-existing defect in the material. (Photo by Dr. Betzalel Avitzur, Lehigh University)

tests form the basis of the construction of an instrument that will be permanently installed for the UW nuclear reactor, as well as for meters to be made part of the instrumentation of other nuclear reactors throughout the country.

The instrument is being patented, with title to the invention vested in the U.S. Government, and rights are being transferred by the National Science Foundation to the Atomic Energy Commission.

## *Metal Processing*

The conversion of an ingot of cast metal into useful intermediate products such as sheet, plate, bar, and wire involves a capital investment by American industry of tens of billions of dollars and operating expenses of several billion dollars annually. Despite the large investment and cost involved, the behavior of metals and alloys during the rolling and drawing processes is not well enough understood to permit improving either the process or the product in other than an empirical way. The engineering science traditionally involved has been limited to the design of equipment capable of the required dimensional change. No consideration of the behavior of the material itself was attempted. Thus, to a large extent, the development of most industrial metallurgical processes has been by the costly method of trial and error.

However, as knowledge of the behavior of materials and techniques for the analysis of plastic deformation processes have deepened, a more systematic approach has become possible. Betzalel Avitzur of Lehigh University has been working for some years developing a more rigorous analysis of some of the primary metal fabrication processes. In this analysis, Dr. Avitzur has been correlating known facts of the behavior of metals with the mechanical engineering processes being used. Dr. Avitzur's investigation has been primarily one of matching a theoretical analysis of the axisymmetric flow of materials (the plastic flow of a material which is symmetrical with respect to the direction in which it is moving) with experimental verification. The treatment resulting from Dr. Avitzur's investigation permits, for the first time, the reliable measurement and prediction of such variables in industrial processing as the forces required, the maximum possible reduction in size per processing step, optimum design of dies, flow patterns and strain rates, and the causes for some of the defects encountered in practice.

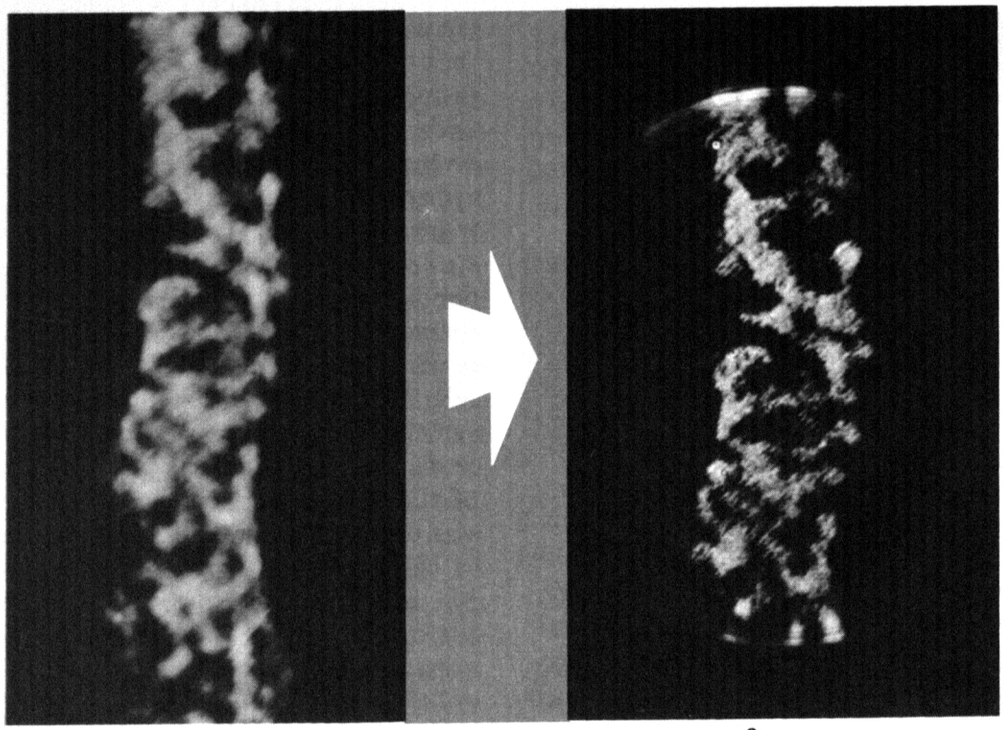
A specific achievement of Dr. Avitzur's analysis has been the determination of the cause for the "center burst defect," traditionally thought to be a problem associated with the material in question. Dr. Avitzur's theoretical analysis first suggested, and his experimental work confirmed, that this defect occurs because of the conditions under which metal is worked, or "deformed," rather than to any specific, preexisting defect in the material itself. As a result, a criterion has been developed for the process which essentially eliminates the probability of the center burst occurring in the standard extrusion process. The use of this criterion has resulted in major improvements in both the quality of the product and in the economics of cold-extruded steel.

Dr. Avitzur's analysis is also being currently applied in the aluminum industry, a major user of extrusion technology; in the optimization of tungsten wire drawing techniques in the electronic industry; and in various special metal forming processes being developed by the Air Force.

Dr. Avitzur's work is fundamentally significant in its contribution to our understanding of the behavior of materials under conditions of axisymmetric flow. Such conditions are and will continue to be of major importance in many metal fabrication processes. The application of this new knowledge offers an opportunity of improving these processes, an opportunity which is being rapidly recognized by the metal extrusion industry.

## *Holographic Image Sharpening*

The electron microscope has brought man's ability to see the very small almost to the point where he can photograph the details of large molecules—but not quite. Unfortunately, virtually all optical systems, from the largest astronomical telescope to the most powerful electron microscope, are barred from reaching their theoretical limits of resolution (the smallest detail they can pick up) by motion, imperfect fo-




Electron microphotograph of fd filamentous virus shows highest degree of resolution—detail to 5 Ångstrom units. Following image enhancement by holographic techniques, resolution is improved by factor of two to show detail of 2.5 Ångstroms. (Micrograph by A. V. Crewe, University of Chicago. Enhancement photo by G. Stroke, State University of New York at Stony Brook)

cus, atmospheric turbulence, or instrumental defects.

This limit on resolution means that the smallest object that a biologist, using an electron microscope, can visualize is approximately the size of the amount of space taken up by two atoms. In order to visualize useful structural details of biological molecules, it would be necessary to improve this resolution by a factor of two. (This does not mean that an electron microscope with a resolution on the order of 2 Angstroms would be able to photograph an atom. The "diameter" of an atom measures a space which is effectively empty, just as the effective volume of the solar system is primarily empty space.)

George Stroke at the State University of New York at Stony Brook reasoned that the electron beam that originally produces the imperfectly resolved image in the electron microscope contains all of the information about the object that is theoretically possible. Further, he reasoned the way the information in the imperfect image is blurred by the system can be predicted mathematically. If this were true, it would be possible to "decode" the blurring by reversing the mathematics.

Accordingly, Dr. Stroke used the mathematics that describe the image-forming mechanism and the principles of holography (laser-produced three-dimensional "lensless" photography) to produce an optical filter which is essentially an analog of the reverse mathematical process. The "key" to decoding the blurring of an entire photograph is contained in the defective image of a single point. In the case of the electron microscope, a point is imaged in the form of an almost uniform circular "patch," rather than like a sharp point. The holographic "filter," if carefully manipulated, can reverse the mathematical function which describes the blurred photo, thereby shifting the image back to its unblurred state.

The most recent and dramatic example of the ability of Dr. Stroke's system to clarify electron micrographs is shown in the illustration. The photographs show a portion of the structure of the fd filamentous bacterial virus, a bacteriophage that infects the common intestinal bacterium *E. coli*. The original photograph was obtained by Albert Crewe at the University of Chicago, using a specially designed transmission scanning electron microscope with a resolution of 5 Ångstrom units. Dr. Crewe's photograph, treated by Dr. Stroke's image sharpening, achieves a resolution of 2.5 Ångstroms.

This degree of detail provides biologists with a hitherto unobtainable ability to see the details of the molecules of life in a fairly direct and simple way. Beyond this, the ability to improve resolution will have applications wherever man's instruments attempt to enlarge the scope of his eyes.

## SOCIAL SCIENCES

Research in the social sciences received increased impetus by NSF during fiscal year 1971. This research covers a wide range of disciplines involving methodological, theoretical, and problem-focused work. All of it is designed to further scientific knowledge of human beings in their interaction with one another, and their customs, institutions, and organizations.

At present, the NSF provides about one-fifth of the total Federal support of social science research. In some fields, such as econometrics and anthropology, the NSF is the principal source of support. A number of factors are currently operating to increase both total Federal support for social science research and the NSF portion.

Solutions for pressing social problems require more complete and accurate knowledge of human behavior and of institutions. Fortunately, productive new research techniques in social sciences are increasingly

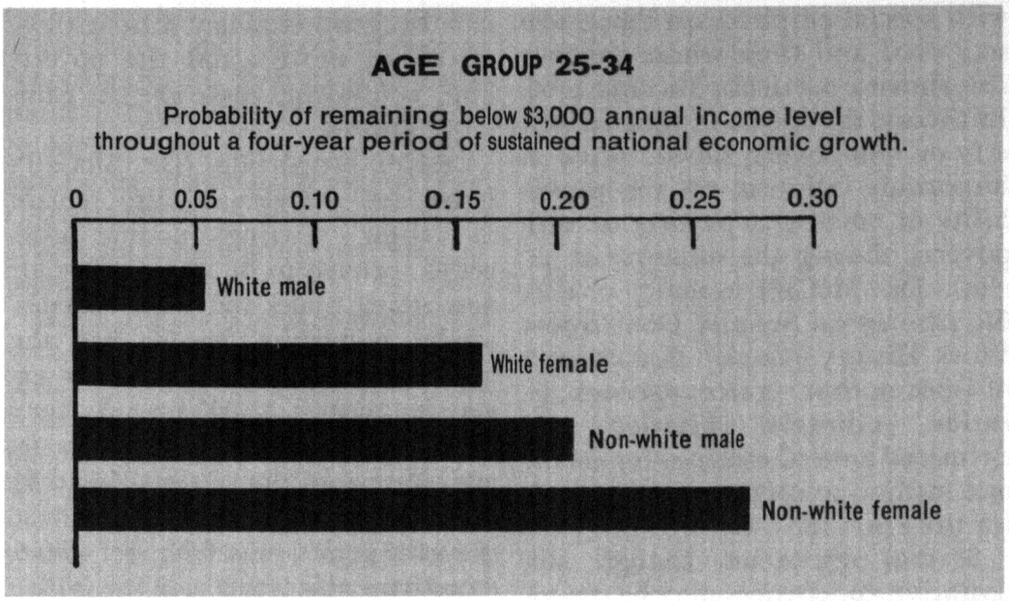
able to help in forming workable responses to current problems.

As a result of these converging trends, the broadened scope of NSF authority, and increasing awareness of the NSF's social science commitment, requests to the Foundation for support of social science have increased markedly in the past fiscal year. In fiscal year 1971 the NSF received 1,281 proposals as compared to 1,087 proposals in fiscal year 1970. A total of 484 grants, in the amount of $17.4 million, was awarded.

With this funding, a wide variety of research in the social sciences was undertaken. One important area of emphasis was the improvement of mathematical methods applicable to social science problems. For example, studies have been and are being funded to investigate the inverse relationship noted between the rate of change in wages, or prices, and unemployment. Economists are trying to improve their understanding of the trade-off between inflation and unemployment so that Government policies can be fashioned to obtain a more favorable long-term relationship, or even decrease unemployment and inflation at the same time.

Improved evaluation of experimental programs is a significant aspect of methodological advances. In the case of the Head Start Program, the Office of Economic Opportunity had supported a large-scale evaluation study by Westinghouse and Ohio State University. Later studies supported by NSF indicate that this evaluation inadvertently used methods containing biases in the direction of making Head Start look useless or even harmful. The Westinghouse-Ohio State University evaluation was most influential in determining the character of Head Start, thus demonstrating the importance of developing a better methodology for evaluations in innovative social programs.

Another area which is receiving special attention is fundamental research in "social indicators." These indicators are data series that allow comparisons of socially important conditions and identification of long-term trends. Although the underlying work has been a part of social science concerns for several years, there is new emphasis on the identification of critical series. A landmark volume on social indicators has been published by the American Academy of Political and Social Science in its series known as *The Annals.* More than half the studies featured in this volume credit NSF with support of research. These studies were also the prototype for many larger-scale, more systematic investigations currently planned. It is expected that this research will rely in part on special computer-readable printouts from resource data centers which can be useful both in connection with the collection of social indicator data and for other research purposes as well.




With NSF support, social scientists are also studying such diverse problems as the reaction to industrialization of contemporary groups in different parts of the world, factors affecting the balance of payments in international trade, crime, and how real estate values are affected in changing neighborhoods.

The results of these and other investigations in the social sciences are expected to be useful in many ways, but two cautions need to be stated. First, social behavior is extremely complex, and spectacular breakthroughs for the solution of critical social problems are unlikely. Instead, it is more reasonable to expect a steady, incremental growth in techniques and methodology. This growth, even when impressive achievements occur, leads to the second caution. The contribution of the social scientist is to provide individuals and political groups with new options and help them to know the probable consequences of choosing any of these options. Science can raise the level of general knowledge in our society and make social processes and interactions more understandable, but it does not, of course, eliminate the need for personal choice and group decision-making.

## *The Persistence of Poverty*

The way poor people's incomes respond to changes in the general economy is of critical importance in formulating programs to deal with problems of poverty. John McCall of the University of California at Los Angeles is trying to measure this income mobility with the use of economic models of the incidence, persistence, and control of poverty—

with special emphasis on those who stay poor and those whose incomes rise above a particular income level. In theory, the length of time in poverty or non-poverty should have an important influence on the probability of moving to poverty or non-poverty during the subsequent period. Dr. McCall is using a data file (the Social Security Continuous Work History Sample) that consists of information on race, age, sex, location, industrial affiliation, and estimated annual earnings for nearly one million anonymous individuals for the years 1957–66.

Several important, though still tentative, conclusions may be drawn from his preliminary results. The first is that a significant proportion of individuals remained in poverty throughout a 4-year period of substantial growth, even using the lowest of the three poverty lines considered (i.e., $1,500 instead of $3,000 or $4,500). This tends to substantiate the "backwash thesis" which states that certain subgroups in poverty are so isolated from society that they are unaffected by economic growth. If so, sustained economic growth may not be sufficient for the elimination of low earnings, and other policies, perhaps investments in human capital, such as health and training programs or income maintenance, may be needed.

The probability of remaining in a low-earnings category all 10 years, given low earnings in 1957, was significantly larger for non-white males than for white males. This was true for all age groups and all three poverty levels. For a $3,000 poverty line, the probability of a non-white male between the ages of 25 and 34 remaining in poverty for the entire 4-year economic growth period was 0.20; for a white male in the same age group it was 0.05. It would appear that to raise the non-white male's economic level will require much more intensive programs than generally stimulating the growth of the whole economy. However, Dr. McCall's evidence does indicate that in a buoyant economy, among those who *can* move across the poverty line, non-whites make greater gains than whites.

Stayer proportions (Dr. McCall's term for individuals who remain in their starting income category) proved to be very similar for non-white males and white females, while non-white females had the highest stayer proportions. For example, with a $3,000 poverty line, the probability of a non-white female between the ages of 25 and 34 remaining in poverty for the 4-year growth period was 0.27; for corresponding white females it was 0.16.

The most obvious explanation for the inferior economic performance of females is job market discrimination. In addition, because of their role in our society, many of the skills developed by females either are not or cannot be converted into their income equivalents. Also, since female participation in the labor force is less stable than that of males, employers are less willing to invest in female human capital, which further lowers their productivity and wages relative to males. All the differences Dr. McCall observed between white and non-white females were much less than the correspond- differences for males.

## *The Use of Violence*

One out of every five American men questioned in a nationwide survey said he believed some degree of violence was necessary to produce needed social change in this country. An even larger proportion, nearly one third, were willing to tolerate substantial police force, including shooting to kill, to control student or black uprising.

The questionnaires were administered in 1969 by a research team headed by Monica Blumenthal from the University of Michigan. The sample of 1,374 was selected to represent all men in the United States between the ages of 16 and 54 and to represent all races, regions, economic classes, and social statuses.

The research was particularly concerned with two types of violence: that used for social control (force or shooting by police) and that involved in social change (such as that occurring in ghetto disturbances or during protests). The study began by asking the men to name the things going on within the country that worried them. Some 65 percent cited activities of violence, usually civil disturbances and political protests. Only 25 percent mentioned traditional forms of crime. Although most agreed that violence has its roots in social problems, many looked to punitive legislation and bolstered police forces as means of prevention. For example, 61 percent said that in ghetto riots, police should shoot but not to kill, while 30 percent felt that police should shoot to kill at least sometimes. When asked whether it was justified to kill another person, 89 percent answered that it was permissible in self-defense, 93 percent said it was right in defense of one's family, and 58 percent said it was right in defense of one's own house. This, the researchers felt, was consistent with the traditional male role in America.

If a person considered a certain act to be violent, the study finds that he was likely to condone substantial police force to control it. However, he did not consider the use of force by police to constitute violence in these cases. For example, while 85 percent thought looting to be violent, only 35 percent considered the police shooting of looters to be violent.

Dr. Blumenthal compared those men who favored strong police action in cases of civil disturbances with the smaller grouping who believed at least some violence was necessary to bring about improvement in society in a reasonable time. Those who favored violence for social control tended to be older, less well educated, and white. More important factors differentiating the

two categories were found to be attitudes toward the persons exercising the violence. Those who rate students or blacks as untrustworthy tend to condone police violence, while those who see the police as untrustworthy tend to condone violence on the part of blacks and students.

These results, based on a study of men only, are the first to come out of a series of studies that will also explore the attitudes of women.

## *High School Athletics and Social Mobility*

One of the arguments often advanced on behalf of extracurricular athletic programs is that they encourage upward social mobility. Unfortunately, much of the discussion hinges on anecdotal information. Now, Richard Rehberg of the State University of New York-Binghamton is systematically studying the social mobility of successful athletes over time as compared to nonathletes. The data consist of questionnaire responses of 1,208 10th-grade boys from various school systems in the southern region of New York State.

Although athletic participation might facilitate upward mobility in different ways, the researchers chose to study a mechanism that is very important at the high school level—the relationship between sports and the enhancement of educational attainment. Better grades, graduation from high school, and attendance in college served as indicators of this process.

Dr. Rehberg found that high school senior athletes had higher expectations for attending college than comparable nonathletes. This raised the question of what intervened between athletic participation and that college expectation. Further investigation suggested that the visibility of athletes increases the attention they receive from school personnel, especially in regard to career counseling and encouragement. School staffs are likely to give more status to the athlete. This might lead to higher expectations for current and future achievement and greater encouragement in areas other than sports, such as in academics and attending college.

Realizing that a certain amount of such expectation and encouragement occurs in the home and is related to a family's socioeconomic status, the researchers investigated the relationship between athletic performance and educational aspirations within each economic class. For each class, the athletes showed higher aspirations than the nonathletes, but the differences were greatest among boys from low status-income homes who received little parental encouragement, and who had accumulated low grades.

Dr. Rehberg concludes that the apparent gains from participating in athletics are greatest among those students less disposed by other factors toward educational attainment. Apparently, success in sports affects expectations and behavior of teachers and school officials, which may be particularly significant for the careers and life chances of student athletes in the lower socioeconomic levels.

This study illustrates an important part of research in the social sciences, a part that can be called the evaluation of conventional wisdom. The fact that findings of an individual research project may seem obvious—as perhaps they do in this case of upward mobility for athletes—masks the fact that conventional wisdom commonly accommodates individually reasonable but conflicting conclusions from the same premises. Social science refines what we know, identifies the significant mechanisms that control social processes, and develops a more rigorous causal pattern that goes beyond common lore.

# *National and International Programs*

Programs administered by the Directorate for National and International Programs cover a diversity of activities in support of science and science education. Some, the National and Special Research Programs, are major research efforts which relate to specific geographic areas or are of such a broad scope or magnitude that intensive efforts in planning, management, funding, and logistic support are essential to ensure maximum effectiveness and efficiency in program performance. Many of these programs involve extensive international cooperation in the planning for and the conduct of the research, as well as coordination and cooperation with other U.S. governmental agencies.

Other National and International Programs incorporate an international component or involve support of scientists from several institutions collaborating in research or sharing facilities. In some cases—in addition to a programmatic support function—organizational elements of the directorate fill a coordinating role with respect to related activities throughout the Foundation.

Following is a list of major program activities administered by the directorate* and discussed in greater detail in subsequent pages.

## National and Special Research Programs

*International Biological Program*** (IBP). U.S. participation in IBP has taken the form of integrated research projects involving many investigators which include intensive studies of ecosystems in six distinct life zones or biomes. Intensive study of the grasslands biome is in full operation, and expanded field research in the desert biome is well under way. In addition to the biome studies, IBP includes a wide range of other environmental research such as biological control of insect pests and human adaptability to harsh climates.

*International Decade of Ocean Exploration (IDOE).* Fiscal year 1971 marked initial implementation of IDOE as a framework for research activity and data collection that will contribute eventually to preservation of the ocean environment, improvement of environmental forecasting, and establishment of a sound basis for seabed assessment.

*Ocean Sediment Coring Program.* The principal component activity of the Ocean Sediment Coring Program is the Deep Sea Drilling Project, which utilizes the drilling ship *Glomar Challenger* to acquire samples from the sedimentary layers of the deep-ocean basins for research in marine geology and related geological and geophysical sciences. Each 2-month cruise—planned by advisory groups of geologists and geophysicists—includes a scientific party of 10 or more scientists selected from U.S. and foreign institutions.

*Oceanographic Facilities and Support.* During fiscal year 1971, the staff and functions of the Oceanographic Facilities Program in the Research Directorate were transferred to the National and International Programs Directorate and integrated into a new Office for Oceanographic Facilities and Support. Besides continuing the support of 32 oceanographic ships operated by 18 academic institutions, the office was responsible for a grant for conversion of the 208-foot Navy ship R/V *Gilliss,* to be operated by the University of Miami. The new office is developing a systems approach to shared use of large oceanographic research facilities by the academic community.

*U.S. Antarctic Research Program.* The Foundation has been active in support of research in Antarctica since 1957. In fiscal year 1971, the President charged the Foundation,

*In October 1970, the National Sea Grant Program, originally assigned by statute to the Foundation, was transferred to the newly activated National Oceanic and Atmospheric Administration of the Department of Commerce.

**Although administered by the Research Directorate, IBP is included in this list because of its identification as one of the Foundation's National and Special Research Programs.

Leaving the harbor at Jacksonville, Fla., the renovated R/V *Gilliss* glides down to sea on a shakedown cruise to Bermuda. (Photo University of Miami)

effective in fiscal year 1972, with responsibility for planning and funding the total U.S. antarctic effort, including the logistic operations conducted by the Department of Defence. June 1971 marked the 10th anniversary of the Antarctic Treaty as scientists from 12 signatory nations continued to pursue a number of joint projects.

*Arctic Research Program.* The Foundation has been designated lead agency for the extension of scientific research in the Arctic and coordinates the arctic research efforts of all Federal agencies through the Interagency Arctic Research Coordinating Committee. Large-scale projects under development emphasize environmental problems and include elements of international cooperation.

*Global Atmospheric Research Program** (GARP). The Global Atmospheric Research Program is an international cooperative research effort aimed at increasing our understanding of the general circulation of the atmosphere and providing a mathematical and physical basis for long-range prediction, for determination of the feasibility of large-scale climatic modification, and for assessment of the consequences to global environmental quality of man's pollution of the atmosphere. Several GARP-related programs have been under way at the National Center for Atmospheric Research during the past several years, including development of a General Circulation Model of the Global Atmosphere. This mathematical model, a realistic representation of the earth's atmosphere, is now being used with real meteorological data to test its reliability as a tool for large-scale weather prediction.

*Although administered by the Research Directorate, GARP is included in this list because of its identification as one of the Foundation's National and Special Research Programs.

### National Research Centers

Five National Research Centers funded by the Foundation were established to meet national needs for facilities, equipment, and operational support for research in astronomy and the atmospheric sciences. Each center is operated under contract by a single university or a university consortium which provides technical and administrative staff (see Appendix F). Both resident scientists and visitors using the advanced equipment and facilities contribute to the preeminence of the centers as research establishments.

### Computing Activities in Education and Research

Administered by the Office of Computing Activities (OCA), the programs of Computing Activities in Education and Research are the focal point for Foundation support of activities designed to meet growing national computer requirements and to develop applications of computer technology for the classroom and laboratory. OCA also coordinates computer-related activities of other programmatic elements of the Foundation.

### Science Information Service

The program of Science Information Service provides assistance to scientists and engineers by increasing the accessibility of information and assuring the adaptability of information services to the changing needs of the user community. Activities supported include development of information systems, support of selected publications and translations, and research on the science information process.

### International Cooperative Scientific Activities

In addition to the international aspects of many other Foundation programs, direct support for cooperative and collaborative projects is provided through the program of International Cooperative Scientific Activities. The cognizant program office—Office of International Programs—along with the Office of Science Information Service (see above) administers the Foundation appropriation of excess foreign currencies (Public Law 480 funds).

**Table 4**
**National and Special Research Programs Awards**
**Fiscal Years 1969, 1970, and 1971**
**(Dollars in millions)**

| | Fiscal Year 1969 | | Fiscal Year 1970 | | Fiscal Year 1971 | |
|---|---|---|---|---|---|---|
| | Number | Amount | Number | Amount | Number | Amount |
| Arctic Research Program | 0 | 0 | 0 | 0 | 32 | $ 2.00 |
| Ocean Sediment Coring Program | 5 | $2.43 | 25 | $ 6.55 | 8 | 7.13 |
| Global Atmospheric Research Program | 9 | .54 | 19 | 1.49 | 31 | 1.90 |
| Research Applied to National Needs | 24 | 2.43[1] | 140 | 12.01[2] | 213 | 33.96[2] |
| International Biological Program | 16 | 1.22 | 24 | 4.00 | 37 | 7.50 |
| U.S. Antarctic Research Program | 145 | 6.86 | 128 | 7.41 | 121 | 7.76 |
| Oceanographic Facilities and Support | 0 | 0 | 31 | 7.60 | 21 | 8.57 |
| International Decade for Ocean Exploration | 0 | 0 | 0 | 0 | 44 | 15.00 |
| Total | 199 | $13.48 | 367 | $39.06 | 513 | $83.82 |

[1] FY 1969 includes Weather Modification Program only.
[2] FY 1970 and FY 1971 include Weather Modification, Earthquake Engineering, and Interdisciplinary Research Relevant to Problems of Our Society. See pages 59–63 for details.

# NATIONAL AND SPECIAL RESEARCH PROGRAMS

## INTERNATIONAL BIOLOGICAL PROGRAM

The International Biological Program (IBP) in the United States, for which NSF has lead agency responsibility within the Federal Government and which is administered by the Research Directorate, is primarily directed towards understanding ecosystems. Studies of man in relation to his environment and of how he adapts to it are specifically included in this research. The ultimate objective of the program is to be able to predict the consequences of man-induced or natural perturbations of ecological systems and thereby to improve our capability for rational management of the ecosystems upon which man depends for food, fiber, water, and the amenities of life.

Ecosystems are complex, and their components are intimately interrelated in ways that are still largely unknown. Perturbations in remote and seemingly unimportant parts of a system can trigger a chain of cause-effect relations which multiply to produce profound consequences throughout the system. On the other hand, ecosystems often display extraordinary stability in the face of environmental stress. Because of their complexity, the most logical route to understanding the functioning of ecosystems is an integrated research program involving many scientists in which all aspects of the system are treated simultaneously.

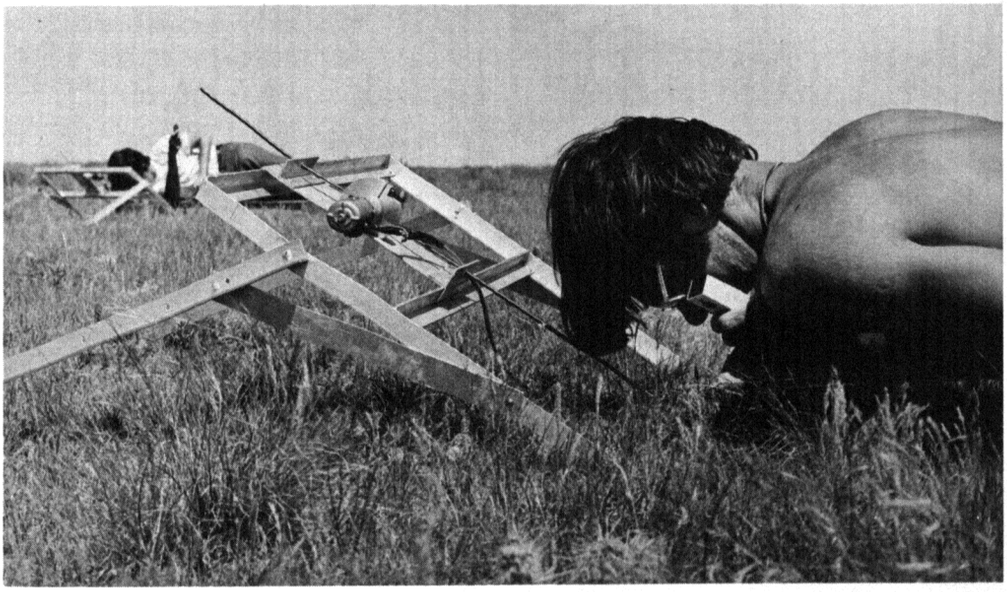
Integrated ecosystem studies of this sort are now in progress in the grasslands region, the deserts and coniferous forests of the western United States, the eastern deciduous forest region, the arctic tundra, and the upwelling regions in the marine environment. These research programs rely heavily on a systems analysis approach and the use of computer modeling. The new and essential aspect of the U.S. approach to the IBP is that as many as possible of the processes taking place in ecosystems are simultaneously evaluated in such a way that they can be linked into a single computer model which simulates the behavior of the entire system.

No operational computer model of a whole ecosystem, usable for testing hypotheses or making predictions, yet exists, although substantial progress toward this goal has been achieved in the past year. Two preliminary computer models of the grassland ecosystem have been developed. When they are operated, their output results indicate appreciable inadequacies in the present state of the models. However, their development and implementation has focused the researchers' attention on those mechanisms of the grassland to which the system as a whole is especially sensitive. The lessons learned in the development of these initial models will be applied during the coming year to provide more directly useful and realistic output. A high degree of linkage and communication among the various IBP studies prevents duplication of effort in model development and in other research, and facilitates exchange of concepts.

Other aspects of the U.S. IBP program are at various stages of development. Field research on isolated tribes of South American Indians has led to development of models of human genetic response and of gene flow within primitive populations. This information will be of significant value in providing a norm against which genetic changes in more urbanized populations can be assessed. Research is underway on human physiological responses to cold and high altitudes and to global nutritional variation. Studies of biosocial adaptations and responses to major migration trends were initiated during the past year. All these studies of human adaptability to the stresses of the physical environment are closely linked to similar research being conducted by scientists from other nations participating in IBP. Sharing of the data and the emerging concepts promotes research efficiency, and makes the progress of American research directly available to scientists elsewhere at an early date.

Research began during the past year on significant aspects of the origin and structure of ecosystems. This research is intended to delve into the processes by which organisms of diverse genetic composition organize themselves when confronted by similar climates. Parallel studies are being made of shrub communities in very similar Mediterranean-type climates in California and in Chile,

Lysimeter is large core of several tons of prairie soil and sod which can be weighed accurately to measure uptake and loss of water. In place, the core is not separated from surrounding plant life. (Photo Colorado State University)



IBP research technician observes motor-driven probe (running diagonally from upper left to lower right), and records all the plants that it touches in its journey to the ground. Resulting data, which reveal utilization of sunlight, are used in computer model of grasslands.

and in desert communities of equally similar climate in Argentina and Arizona. Scientists from both the Latin countries and from the United States are working collaboratively at all the sites, with each country's research funded from its own national sources. Although it is too early for this program yet to have achieved appreciable results, it has already emerged as a model of international cooperation in basic research on ecological processes. Research of this type could ultimately have significant implications for rational use of land and water resources.

## INTERNATIONAL DECADE OF OCEAN EXPLORATION

Fiscal year 1971, the first year of the International Decade of Ocean Exploration (IDOE), was devoted to establishing the guiding philosophy for the program, generating research plans, and setting into motion efforts to meet the long-term goals.

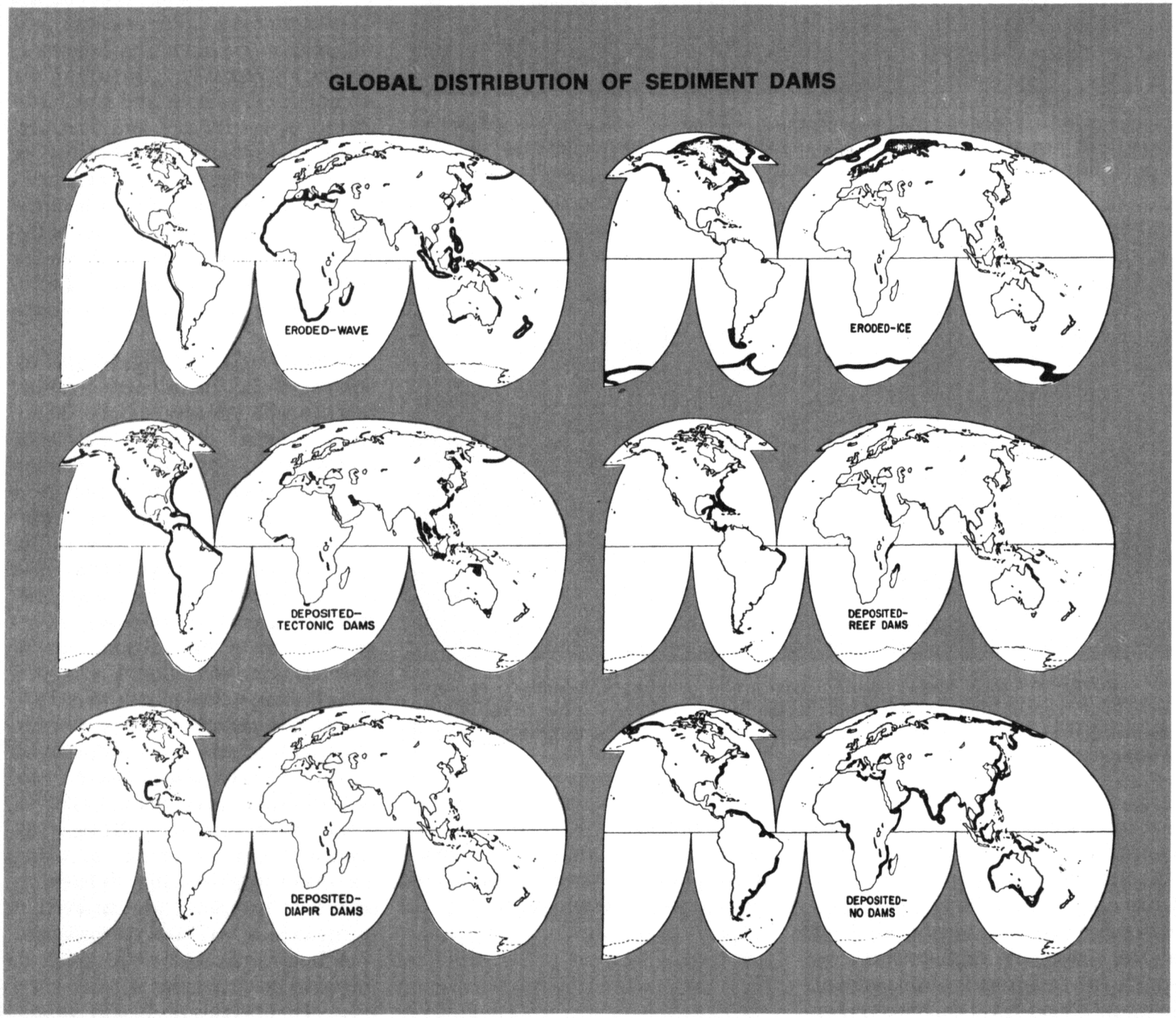
As a first step toward the goal of preserving the ocean environment, investigations were begun to determine the present concentrations (baselines) of pollutants in the North Atlantic, the northeastern Pacific, the Gulf of Mexico, and the Caribbean Sea. In each oceanic area the several participating laboratories are giving close attention to the exchange of samples and standardization of techniques and measurements to ensure comparability of results. Samples of biological materials, sediments, and water from areas adjacent to and remote from pollution sources are being analyzed for concentrations of pesticides, herbicides, heavy metals, and petroleum chemicals.

Special scientific workshops involving U.S. and foreign oceanographers will identify present knowledge, crucial scientific problems, and a set of priorities for a long-term research program on pollution in each of five major problem areas: sources and input rates of pollutants; dispersal by physical motions; transfer among chemical, biological, and geological phases; effects on organisms; and the ultimate fate of pollutants in the oceans. Envisioned benefits from these programs include establishment of safe rates of waste disposal into the oceans, techniques for monitoring the degree of oceanic pollution by man, identification of situations exceeding pollution tolerance levels, protection of living marine resources from deleterious manmade materials, and protection of man from toxic marine products.

A long-term research program to improve environmental forecasting has been formulated. It will emphasize studies in ocean-atmosphere coupling mechanisms in the North Pacific; the role of large-scale dynamic processes in ocean circulation

and global climate; the physical, chemical, and biological dynamics of upwelling processes; and the formation and circulation of water masses in the depths of the oceans. The program is expected to contribute to the improvement of extended weather forecasts, with attendant benefits to farming, construction, transportation, water resource management, and recreation; more accurate fisheries prediction; improved understanding of the oceans as a food source and as a heat sink for industrial activities; and enhanced ability to calculate water renewal rates in the deep ocean as they affect disposal of waste, dispersal of nutrients and pollutants, and improved global circulation forecasting models.

The environmental forecasting program was begun in 1971 with a study of medium-scale geostrophic eddies in the North Atlantic and their role in the general ocean circulation. This Mid-Ocean Dynamics Experiment, involving nine institutions—eight U.S. and one foreign—requires a melding of theory, numerical modeling, and field experiments. The schedule calls for 18 months of hardware development




The continental shelves are formed by a variety of processes throughout geologic time, including erosion by waves and ice, and deposition of sediments often behind "dams" caused by ancient coral reefs, protrusion of salt domes, and crustal folding. The generalized map shows the distribution of the types of shelves which are being studied as part of IDOE's program of seabed assessment to improve our understanding of the processes responsible for the occurrence of natural resources beneath the sea.

and testing, a 6-month field program, and a year of data analysis and interpretation.

The program for expanding seabed assessment activities emphasizes studies of the geophysical and geological structure of the major unsurveyed, wide continental shelves; correlation of onshore and offshore geology through the use of fine-grain surveys in selected areas; and geophysical, geological, and geochemical studies of mid-ocean rift valleys and deep-ocean trenches. It is expected that these studies will provide regional data for the assessment of seabed areas involved in future law-of-the-sea discussions, the determination of economic potentials of mineral deposits, and the evaluation of ocean trenches as possible sites for waste disposal.

One seabed assessment project initiated in the past year is a geophysical survey of the entire continental margin of the west coast of Africa. The project involves investigators from the Woods Hole Oceanographic Institution, the University of Rhode Island, and the University of Capetown (South Africa), and participants from France, the Federal Republic of Germany, the U.S.S.R., and countries along the African coast. The 4-year survey will require a year for hardware development, 2 years of field work, and a final year of data analysis and interpretation.

The data management and instrument development aspects of the IDOE program are receiving special emphasis. On behalf of IDOE, the Environmental Data Service and the National Oceanographic Instrumentation Center of the National Oceanic and Atmospheric Administration are working directly with the institutions and agencies responsible for conducting the scientific research. In addition, it is expected that the major IDOE programs will involve development of many new sensors and measurement techniques.

Cooperative arrangements are being pursued with institutions and scientists of other nations. The broader scale involvement of foreign governments is being developed through the Intergovernmental Oceanographic Commission of UNESCO.

The $15 million allocated to the IDOE program in fiscal year 1971 was distributed approximately as follows: 15 percent to studies of environmental quality, 50 percent to environmental forecasting, and 35 percent to seabed assessment. During this initial period, Government agencies are performing 40 percent of the research, and 60 percent is being carried out by academic and nonprofit institutions and industry.

## POLAR PROGRAMS

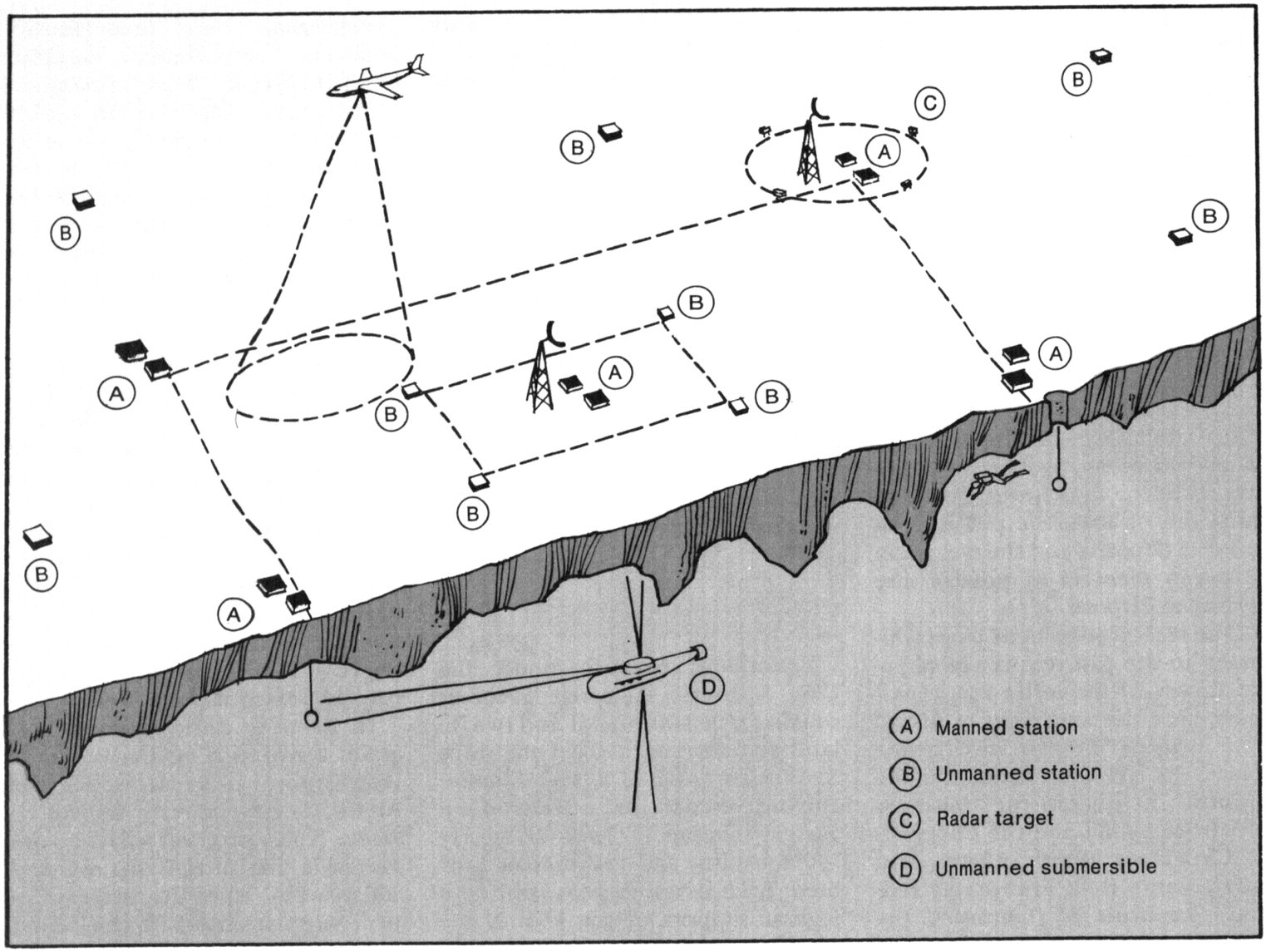
Year-round research under the U.S. Antarctic Research Program continued at two coastal and two inland stations and aboard the ships R/V *Hero* and U.S.N.S. *Eltanin*. During the increased activity of the austral summer of 1970–71, nearly 150 scientists and technicians pursued field investigations with the logistic support of the U.S. Naval Support Force, Antarctica, and icebreaker support by the U.S. Coast Guard. Research spanned many disciplines, with major participation by biologists, earth scientists, oceanographers, and atmospheric scientists.

One of these investigations was conducted by atmospheric physicists from the University of Maryland and Stanford University. Data collected earlier in Antarctica suggested that energy transfer takes place between atomic particles and electromagnetic waves in the plasmapause (the outer boundary of a densely ionized layer around the earth), much as is observed in cyclotrons. On January 2, 1971, this cyclotron resonance was confirmed by simultaneous air and ground measurements at Siple Station, which at 76°S. 84°W. is ideally located for observing magnetospheric phenomena. Using instrumented balloons, the scientists detected bremsstrahlung (the electromagnetic radiation produced by the sudden retardation of charged particles in an intense electric field) that showed remarkable correlation with X-ray bursts and very low frequency waves known as risers. This coincidence occurred several hundred times in a 1-hour period.

Following up on these investigations, the scientists intend to use an antenna array at Siple in February 1972 to create artificially stimulated risers in the ionosphere. If these experiments are successful, it would be the first known positive control of precipitation of trapped energetic electrons in the upper atmosphere. A potential application of the technique would be to modify the reflective properties of the ionosphere to improve radio communication capability along magnetic field lines.

In the new Arctic Research Program, a group at the University of Washington is preparing for the Arctic Ice Dynamics Joint Experiment. This program will be conducted in the Arctic Basin over several years by university and government scientists from both the United States and Canada, and will be funded by both nations. Measurements will be made at a grid of stations on sea ice to determine its influence on global atmospheric and oceanic circulation and to improve ice forecasting techniques.

A study of the tundra ecosystem, coordinated by scientists from the University of Alaska and the U.S. Army Cold Regions Research and Engineering Laboratory, began in the summer of 1970. In 1971, scientists from 43 institutions were engaged in projects supported by Federal agencies and industry. One group, comparing natural and disturbed tundra areas, is attempting to establish the sensitivity of the ecosystem to various types of stress and determine the potential mechanisms for aiding recovery of damaged areas.




Array of instrumentation for the Arctic Ice Dynamics joint Experiment.

United States and Danish scientists have joined forces to obtain depth profiles of the Greenland ice cap and to core the ice for information on major climatic cycles in the Arctic. Development of a special coring rig is well advanced in the United States, and Danish scientists are preparing the radiosounding apparatus to be flown for the study.

## OCEAN SEDIMENT CORING PROGRAM

The Ocean Sediment Coring Program continued to conduct exploration of the floors of the deep-ocean basins by drilling and coring of underlying sedimentary layers and, to a limited extent, the igneous rock beneath. The operations are conducted from the drilling ship *Glomar Challenger*. In 1971 cores were taken at 65 sites on two crossings of the North Atlantic, in the Mediterranean and Caribbean Seas, and in the eastern North Pacific Ocean. The maximum penetration reached was 3,900 feet into the ocean floor, with a 100-foot penetration into basaltic rock beneath the sediment layer. In the Caribbean, for the first time a hole being drilled was successfully reentered, allowing a worn bit to be changed, and drilling resumed in 13,000 feet of water.

Earlier results of the program produced evidence substantiating the ideas of continental drift, seafloor spreading, and the general youthfulness of the oceanic basins. During the past year, crustal motions that were formerly expressed only as the movement of one sector of the earth's crust relative to another sector have been related to the rotational axis of the earth. In addition, these studies are leading to a better understanding of the large-scale motions of the crust of the earth with respect to the history and significance of deep-sea trenches, of the interaction between continents and ocean basins, of the origin of earthquake zones, and of the structure and composition of the oceanic

crust. Remarkable vertical motions of the oceanic floor have been detected.

The results of the program also include advances in the chemical history of the oceans, the history of ocean current systems and gross oceanic circulation, paleoclimatology, the origin of sediments and their changes after deposition, organic evolution and productivity, and changes in the continental portion of the earth.

Of immediate and practical significance is the continued broad evaluation of seafloor resource potentials and the acquisition of experience and technology for the effective exploration of the deep-ocean beds. In addition, understanding of the globe has been enhanced by the opportunity to interpret miles of geophysical surveys through direct correlation with physical samples.

The drilling and coring operations were conducted by Global Marine, Inc., under a subcontract with Scripps Institution of Oceanography. National and international scientific guidance to Scripps is coordinated through the Joint Oceanographic Institutions for Deep Earth Sampling (JOIDES). This consortium of five academic groups advises on drilling itineraries, site selection, initial core descriptions, and other aspects of the operations. Almost 200 scientists, including representatives from more than a dozen foreign nations, have served aboard the *Glomar Challenger* to conduct on-site analyses of samples fresh from the borehole.

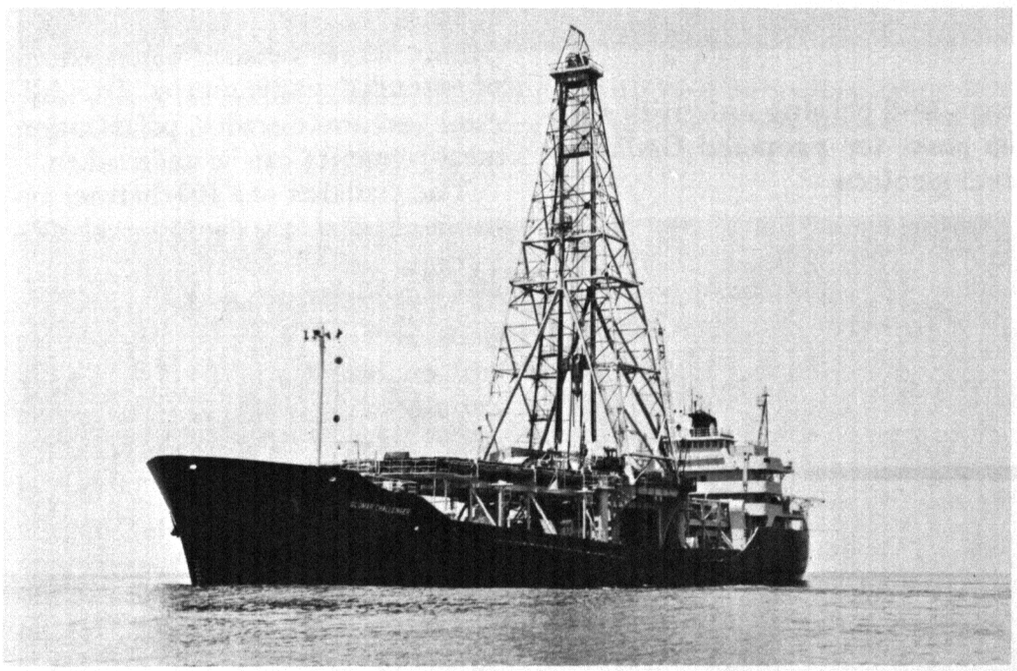
During the 1971 fiscal year, NSF published volumes IV, V, and VI of *Initial Reports of the Deep Sea Drilling Project*. Volume VII, a 1,750-page, two-part document, was prepared for printing, with distribution scheduled for August 1971.

## GLOBAL ATMOSPHERIC RESEARCH PROGRAM

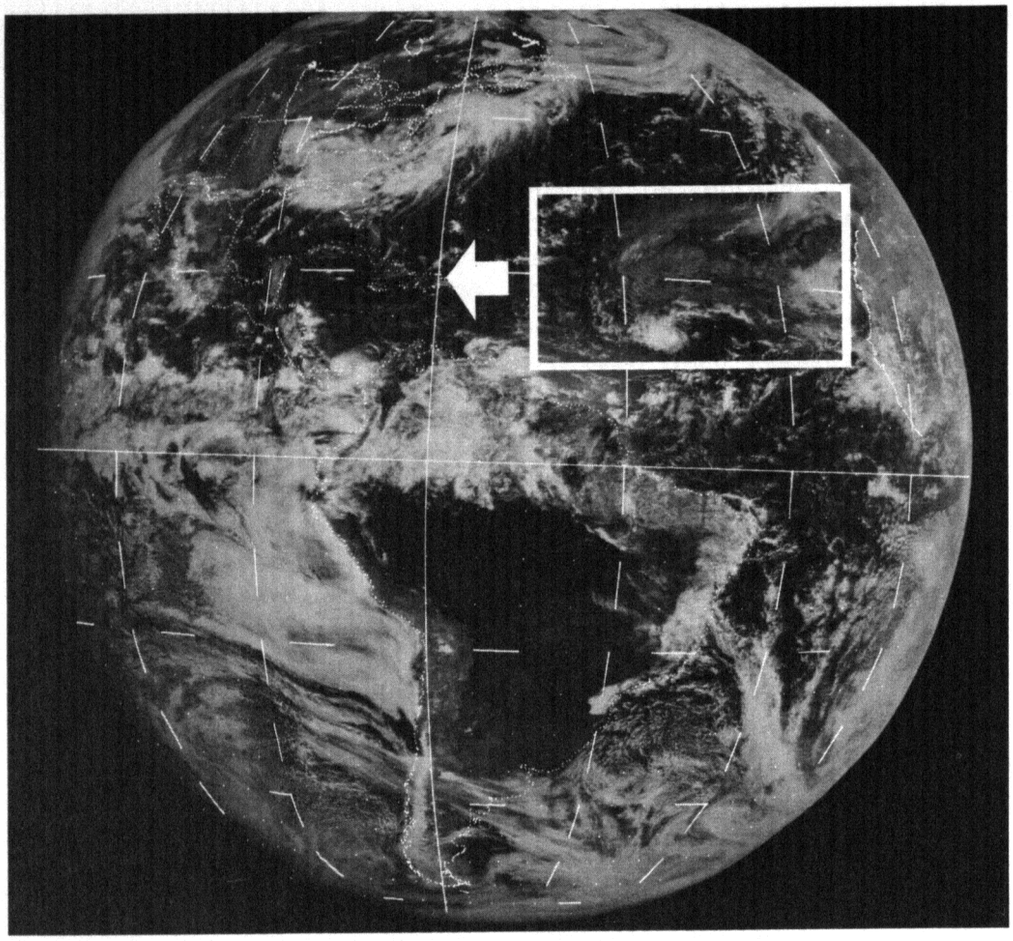
NSF's participation in the Global Atmospheric Research Program (GARP), under the Research Directorate, supports university research aimed at a better understanding of global atmospheric dynamics and numerical simulation studies related to global meteorological observations. Emphasis within GARP, nationally and internationally, in 1971 was concentrated on the planning and design of the GARP Atlantic Tropical Experiment (GATE) to be conducted in the summer of 1974. Using an array of ships, aircraft, and other observational platforms, including satellites, scientists expect to determine how the energy within the tropics plays an important role in global circulations. An international management structure has been established, and at least eight nations are expected to participate in GATE. Plans for U.S. participation have been issued by the U.S. GARP Committee of the National Academy of Sciences.

Experiments such as GATE and the Barbados Oceanographic and Meteorological Experiment (BOMEX) of 1969 provide opportunities for research leading to better understanding of the physical processes of the atmosphere and, eventually, for improving the numerical prediction models. BOMEX research on air-sea interaction showed that the tropical ocean reflects 3 percent of the radiation received from the atmosphere and has resulted in better values for the rates of transport of heat and moisture in the tropical ocean area. The research also revealed that there are great variations in day/night ocean surface temperatures, that wave-like formations exist at all ocean depths, and that great quantities of dust originating in the Sahara Desert are present over the South Atlantic BOMEX area. Additionally, the data from BOMEX have been used in numerical model studies of air-sea interaction and of the general circulation of the atmosphere, in a quantified description of solar energy distibution, and in the prediction of atmospheric currents.

The National Center for Atmospheric Research has been given responsibility for the coordination of all Observing Systems Simulation Experiments. Using global circula-



Port side view of the DSDP vessel *Glomar Challenger*. The vessel weighs 10,400 tons, is 400 feet long, and the million-pound hook-load capacity drilling derrick stands 194 feet above the waterline. The automatic pipe racker, just forward of the derrick, holds 24,000 feet of 5-inch drill pipe. (Photo Scripps Institution of Oceanography)



One of the findings of the Barbados Oceanographic and Meteorological Experiment was that dust over parts of the southwestern Atlantic had originated in the Sahara Desert. This photo, taken on August 11, 1970, shows a great mass of westward-moving dust as a gray area off the coast of Africa (upper right). (Photo NASA ATS-3, produced and gridded by NOAA)

tion models, NCAR along with the National Oceanic and Atmospheric Administration and the National Aeronautics and Space Administration is testing various configurations of observing systems to determine which combinations of conventional and satellite sensors will be most efficient for global observing networks.

The University Corporation for Atmospheric Research (UCAR), which operates NCAR, has formed a UCAR GARP Council to facilitate communications with universities for GARP plans and problems. NCAR's work on GARP is being coordinated by an NCAR GARP Task Group, which is identifying important problems and supplying staff support for the UCAR working groups and helping university scientists plan for proposed GARP research projects.

## NATIONAL RESEARCH CENTERS

### NATIONAL ASTRONOMY AND IONOSPHERE CENTER

The National Astronomy and Ionosphere Center (NAIC) is operated by Cornell University, Ithaca, N.Y., under contract to the National Science Foundation. Observing facilities are in Puerto Rico, at a site 12 miles south of the city of Arecibo. The principal instrument is a spherical antenna of 1,000-foot diameter—the world's largest radio telescope.

This spherical reflector is a major research instrument that functions both actively as a radar telescope and passively as a radio telescope. The capabilities of the instrument derive from its unique design, which includes a large fixed reflector, movable line feeds that correct for spherical aberrations, and high-performance transmitters, receivers, and computers.

A major project to upgrade the surface of the reflector was authorized in fiscal year 1971. This upgrading will provide the primary modification necessary to permit use of the reflector to wavelengths as low as 10 cm. Construction is scheduled to commence in fiscal year 1972 and will take 2 to 3 years to complete. A detailed engineering study is also under way to modify the feed support structure and install an S-band radar system.

A design study for a new high-power 430-MHz (million cycles per second) line feed was completed, with fabrication and installation of the feed planned for fiscal year 1972. The high gain of the main beam and the reduced side lobe level will permit more detailed observations of extended radio sources. In addition, accurate radio polarization measurements can be undertaken.

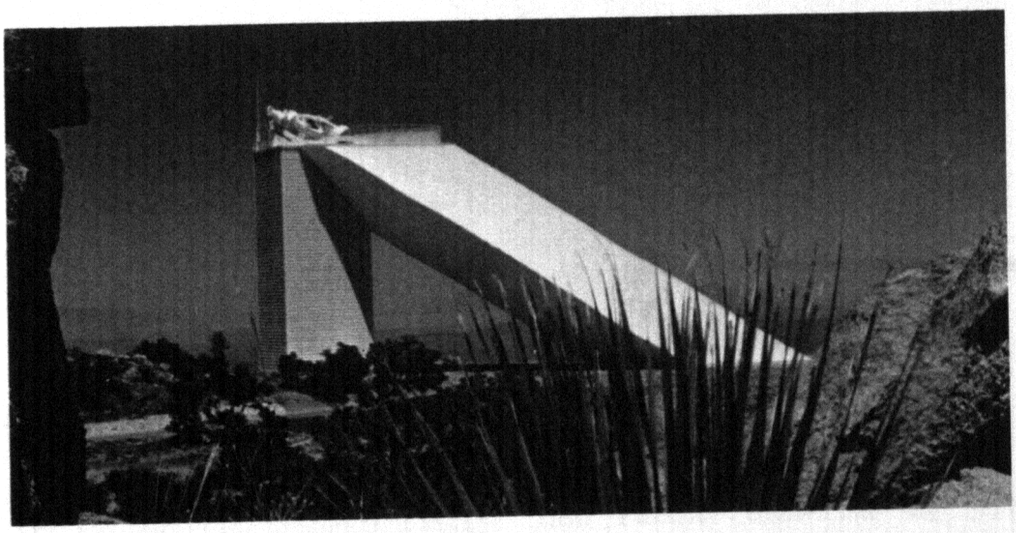
The transfer of a 100-channel autocorrelator from the Haystack Observatory in Massachusetts to Arecibo was accomplished and modifications are in progress. This device will enable the observatory to undertake more extensive spectral-line observations. The large reflector will then be used to study clouds of neutral hydrogen and the distribution of molecules in space.

As part of the ionospheric research program at NAIC, radio waves are transmitted into the ionosphere and the reflected signals analyzed to determine the electron densities and temperatures in the reflecting region. Particularly suc-

**Table 5**
**National Research Centers**
**Fiscal Years 1969, 1970, and 1971**

| | Fiscal year 1969 | | | Fiscal year 1970 | | | Fiscal year 1971 | | |
|---|---|---|---|---|---|---|---|---|---|
| | Capital obligations | Research operations and support services | Total | Capital obligations | Research operations and support services | Total | Capital obligations | Research operations and support services | Total |
| Cerro Tololo Inter-American Observatory | $3,449,000 | $1,101,000 | $4,550,000 | $365,000 | $1,535,000 | $1,900,000 | $ 313,000 | $ 1,967,000 | $ 2,280,000 |
| Kitt Peak National Observatory | 1,137,700 | 4,561,810 | 5,699,510 | 46,000 | 6,419,000 | 6,465,000 | 127,000 | 7,092,600 | 7,219,600 |
| National Radio Astronomy Observatory | 483,212 | 6,795,002 | 7,278,214 | 675,000 | 5,180,000 | 5,855,000 | - 0 - | 6,897,400 | 6,897,400 |
| National Astronomy and Ionosphere Center | ..... | ..... | ..... | 150,000 | 1,400,000 | 1,550,000 | 3,755,000 | 2,343,600 | 6,098,600 |
| National Center for Atmospheric Research | 425,000 | 10,611,737 | 11,036,737 | 212,840 | 11,228,960 | 11,441,800 | 484,280 | 14,194,626 | 14,678,906 |
| Total | $5,494,912 | $23,069,549 | $28,564,461 | $1,448,840 | $25,762,960 | $27,211,800 | $4,679,280 | $32,495,226 | $37,174,506 |

This view of the Arecibo installation shows two of the three towers supporting the feed support structure 435 feet above the spherical mesh reflector. (Photo Cornell University)



The Robert R. McMath Solar Telescope at Kitt Peak National Observatory, Arizona. (Photo KPNO)

cessful have been the heating experiments where a 100 kilowatt transmitter operating at 40 MHz is used to locally heat the ionosphere. These experiments have yielded valuable information on physical processes and motions in the upper atmosphere.

## KITT PEAK NATIONAL OBSERVATORY

Kitt Peak National Observatory (KPNO) is operated under contract to the Foundation by the Association of Universities for Research in Astronomy, Inc., a nonprofit consortium of nine U.S. universities. The observatory provides support facilities for a staff of 320 at its headquarters in Tucson, Ariz. Of these, 23 are scientists who carry out basic research in stellar and solar astronomy and in the planetary sciences.

Observing facilities, located atop Kitt Peak, 45 miles west of Tucson, include six stellar telescopes with apertures of 84, 50, 36 (two), and 16 (two) inches. The telescopes were used in fiscal year 1971 by 100 visiting astronomers and 51 graduate students from U.S. and foreign institutions. The two largest telescopes were assigned to visitors 65 percent of the available viewing time.

The Robert R. McMath Solar Telescope—the world's largest—is

also located on Kitt Peak. It was used by 33 visiting scientists from U.S. and foreign institutions in fiscal year 1971, accounting for 60 percent of the scheduled observing time. In addition, one scientist and 16 astronauts used the telescope as part of a NASA training program.

The building and rotating dome for the new 150-inch stellar telescope on Kitt Peak were completed, and installation of the telescope mounting was started. The primary mirror is nearly finished after 2½ years of grinding, polishing, and testing. The 158-inch-diameter mirror surface is accurate within a few millionths of an inch.

Public visitors to Kitt Peak during the year numbered over 52,300, with representation from all 50 States and five foreign countries.

*Journey into Light,* an informational film portraying the Kitt Peak facilities, functions, and programs, was produced by KPNO, and has been loaned to more than 100 organizations during the year.

## CERRO TOLOLO INTER-AMERICAN OBSERVATORY

Cerro Tololo Inter-American Observatory (CTIO), operated under contract to the Foundation by the Association of Universities for Research in Astronomy, Inc., is located in Chile, with headquarters in the city of La Serena. Observing facilities are at Cerro Tololo, a superb site in the Chilean Andes 40 miles to the southeast of La Serena. The facilities include five stellar telescopes with apertures of 60, 36, 24, 16 (two) inches and a Schmidt-type instrument with a 24-inch aperture. These telescopes provide unique opportunities for American astronomers to study celestial objects visible only from the Southern Hemisphere. Excellent observing conditions prevail at both infrared and visible wavelengths.

During fiscal year 1971, 66 astronomers from 35 institutions made observations at CTIO. Visitors from the United States, including graduate students, were assigned 62 percent of the available observing time. Another 13 percent of the telescope time was divided nearly equally among astronomers from Argentina, Canada, Chile, and West Germany. The remaining time was used by the CTIO staff.

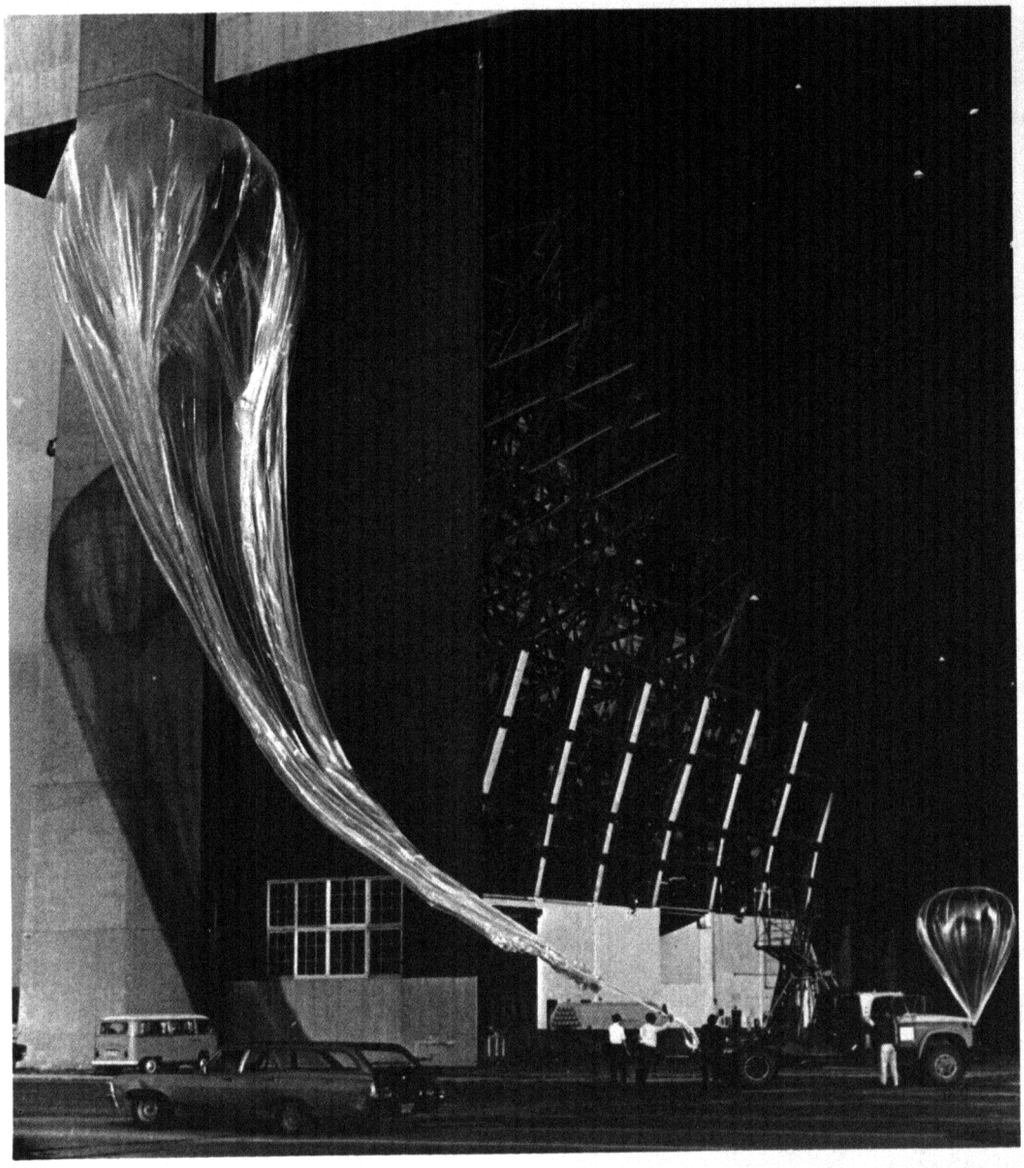
During the year, the coudé spectrograph of the 60-inch-diameter telescope became operational. This large spectrograph provides the means for accurate determination of many stellar parameters, including chemical composition, element abundances, and radial velocities. The telescope and pre-spectrograph optics are now being used in conjunction with a very high dispersion spectrometer for detailed topographic mapping of Mars during the current opposition. Improvements in image-tube techniques and computer-controlled data acquisition systems have increased telescope efficiency markedly.

Major construction work was concluded on a building to house the new 150-inch-diameter telescope. Two wings of a projected four-wing dormitory to house technicians were finished and occupied. In La Serena, an office addition to the headquarters building was completed. Also, an IBM 1130 computer was installed, enabling CTIO staff and visitors to reduce portions of their observational data while in Chile.

## NATIONAL CENTER FOR ATMOSPHERIC RESEARCH

The National Center for Atmospheric Research (NCAR) is operated under a Foundation contract by the University Corporation for Atmospheric Research, a nonprofit consortium of 30 United States and one Canadian universities. NCAR facilities consist of the Mesa Laboratory and the High Altitude Observatory at Boulder, Colo.; the National Scientific Balloon Facility at Palestine, Tex.; and the Research Aviation Facility at the Jefferson County Airport near Boulder. A principal mission of NCAR is to support the work of university scientists by operating facilities for joint use and by providing leadership for large atmospheric research experiments. In calendar year 1970, NCAR served 150 visiting scientists.

Airborne photo of observatory site at Cerro Tololo illustrates majestic isolation of the Andean environment. (Photo KPNO)



A 22-meter GHOST balloon is inflated in preparation for launching. The small tow balloon will provide supplementary lift for the first few thousand feet. (Photo NCAR)

During fiscal year 1971, the NCAR staff of 570 included about 100 scientists at the doctoral level representing meteorology, physics, chemistry, mathematics, and other physical sciences. NCAR's programs place special emphasis on problems requiring interdisciplinary research.

In recent years, NCAR has played a significant role in organizing and managing cooperative efforts by scientists from universities, Federal laboratories, and other organizations conducting field studies that are beyond the scientific, technical, and logistical capabilities of a single institution. For example, the National Hail Research Experiment, which began preliminary operations under NCAR management in northeastern Colorado in the summer of 1971, unites atmospheric and social scientists and technicians from five universities, three Federal departments, and one State agency.

A major step toward increasing NCAR's capability in solving large, complex problems in fields such as atmospheric dynamics was the acquisition, in June 1971, of a Control Data Corporation 7600 computer system.

In February, the Research Aviation Facility dedicated its new hangar and operations base at the Jefferson County Airport. This 24,000-square-foot facility includes laboratories and shops as well as hangar space for NCAR's four research aircraft. A significant advance in facilities for atmospheric research was the sophisticated instrumentation developed and installed in the deHavilland Buffalo for dynamic studies of the atmosphere.

## NATIONAL RADIO ASTRONOMY OBSERVATORY

The National Radio Astronomy Observatory (NRAO) is operated under contract to the Foundation by Associated Universities, Inc., a nonprofit consortium of nine U.S. universities. Observatory headquarters, located at Charlottesville, Va., provides support facilities, including a research library and computer, for a staff of 248. Thirty-seven scientists conduct basic research in radio astronomy using data gathered by radio telescopes located at Green Bank, W. Va., and Tucson, Ariz.

The major telescopes located at Green Bank include a 300-foot-diameter meridian transit instrument, a 140-foot-diameter fully steerable telescope, and an interferometer incorporating three 85-foot-diameter dishes and a portable 42-foot-diameter antenna for remote operations. The Tucson facility, located on Kitt Peak, includes a 36-foot millimeter-wave antenna. During the year, 140 visitors were allocated 67 percent of the available observing time on the telescopes.

Observing capacity at NRAO was enhanced by the development and installation on the Green Bank three-antenna interferometer system of a 1,420-MHz receiver system, designed to operate in conjunction with a new 384-channel autocorrelation receiver. Also, a new tunable receiver with a frequency range of 5 to 10 GHz (billion cycles per second) was constructed for the Green

NCAR technicians set up coherent cloud physics radar near Grover, Colo., for use in the National Hail Research Experiment. Radar is used to probe the growth, structure, and motions of thunderstorms. (Photo NCAR)

Bank 140-foot-diameter telescope for spectral-line studies. An additional receiver, operating in the 22 to 24 GHz range, was constructed for use on both the 140-foot telescope and the 36-foot telescope at Tucson.

At Tucson, the 36-foot telescope was placed in 24-hour operation for the first time. A new spectral-line receiver in the 67 to 101-GHz range and a computer processor also became operational. A capability for circular polarization observations at 31.4 GHz and 85 GHz was added during the year.

A new aluminum surface was installed on the 300-foot telescope, more than tripling the frequency coverage of the antenna. After the resurfacing, a four-channel, 2,700-MHz receiver was designed and installed for radio-source survey work. The variable-speed declination drive was computerized and modifications made near the focus to permit limited tracking of radio sources during meridional transit.

NRAO is collaborating with the following scientific research groups in the design, development and construction of terminal equipment for the very long baseline (VLB) interferometry of radio sources:

—Federal agencies

- Department of Defense (Naval Research Laboratory)
- Department of Commerce (National Oceanic and Atmospheric Administration)
- National Aeronautics and Space Administration (Jet Propulsion Laboratory)

—U.S. universities

- Cornell
- Harvard
- Massachusetts Institute of Technology

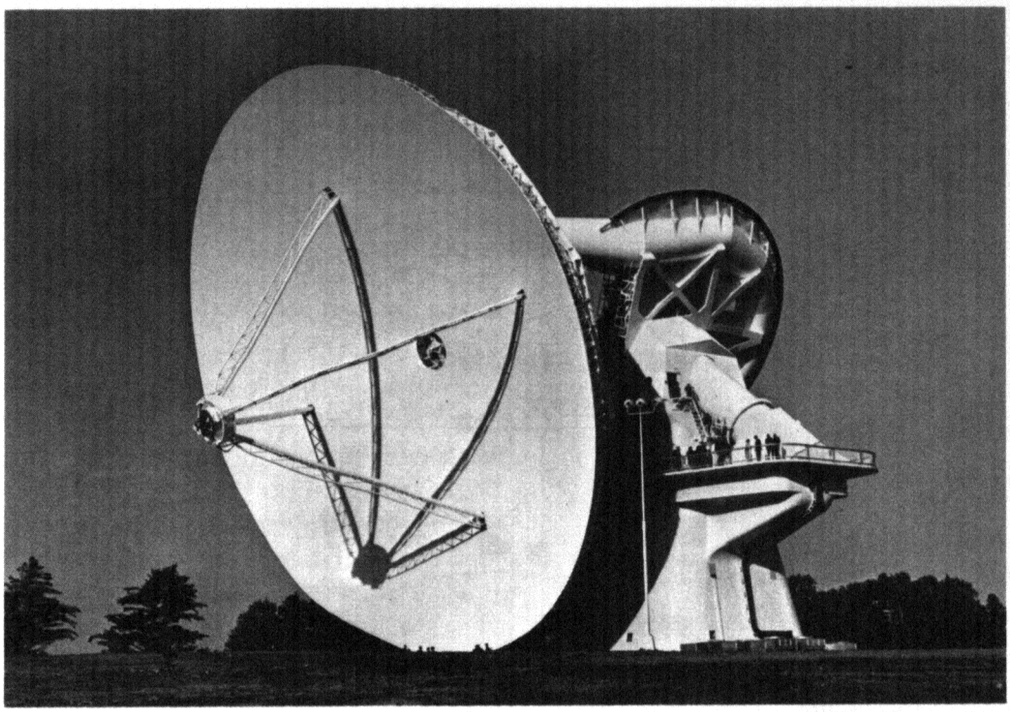
—Foreign research institutions

- Chalmers Institute of Technology (Sweden)
- Max Planck Institute (West Germany)

This collaboration has brought together the best in technical expertise from the radio astronomy community. These terminals, four of which are complete, incorporate special VLB signal processors to facilitate the first stage of data reductions.

## COMPUTING ACTIVITIES IN EDUCATION AND RESEARCH

The objective of the Foundation's program of Computing Activities in Education and Research is to provide the nation with a base of computer science knowledge which will make possible innovative approaches for the use of computers in education and research. In addition, Government, industry, academic insti-



The 140-foot telescope at NRAO is the largest equatorially mounted radio telescope in the world. Seven years were required for design and construction of this high-precision instrument intended for use at shorter wavelengths. (Photo NRAO)

tutions, and other users will be able to evaluate better the capabilities and limitations of computers and to use their potential more effectively.

In fiscal year 1971, the Office of Computing Activities was reorganized into three new sections to reflect the changing nature of national requirements. The Computer Science and Engineering Section sponsors research in fundamental computer science, the Computer Innovation in Education Section helps bring the power of the computer to bear on the problems of education, while the Computer Applications in Research Section fosters the development of advanced computer techniques to increase science research capability.

## COMPUTER SCIENCE AND ENGINEERING

The Foundation is supporting basic research in computer science and engineering to increase the fundamental knowledge available for continued progress in dealing with complex computational problems. During fiscal year 1971, attention was focused on three programs: Theoretical Computer Science, Software and Programming Systems, and Computer Systems Design.

Operating systems are computer programs which schedule and control a computer's activities, and their design is an area of special concern. Owing to their growing complexity through the decade of the 1960's, it has become increasingly difficult to design and implement such systems and virtually impossible to predict their performance using present knowledge and techniques. Research is being supported in computer science and engineering directed toward the discovery of principles that will enable the development of more manageable operating systems.

The principles for the design of more complex computer systems, the understanding of the effective means of implementing such systems, and the analysis of the limitations of complex systems need further development. During fiscal year 1971, these principles were investigated by researchers at many institutions, including the University of California (Los Angeles), the University of Texas, New York University, the University of Colorado, the State University of New York at Stony Brook, and the University of Washington. For example, at Stony Brook, Arthur J. Bernstein is studying the optimal scheduling of tasks for the different components comprising a computing system to minimize competition among computing jobs during simultaneous use of a single unit.

Another area of concern is that of system reliability. As the number of elements in computers and computer networks increases, the chance of individual failure resulting in breakdown increases. One principle of good design is to maximize the ability to detect and recover from error; another is to confine or localize the effects of each error. Edward J. McCluskey at Stanford University is studying one aspect of this problem—the effects of errors on networks of logical elements.

Automatic validation of input data assumes increased importance when data are received from automatic sensors or other sources without human scrutiny. This problem is being studied at Purdue University, Case Western Reserve University, and the University of California at Santa Cruz.

## COMPUTER INNOVATION IN EDUCATION

In order to make effective use of the computer in education, there must be flexible hardware and software systems, a meaningful curriculum base, and related computer application programs which can be distributed through shared facilities. In fiscal year 1971, approximately $6 million was awarded to academic and nonprofit organizations towards the attainment of these goals.

Among the more dramatic prod-

ucts in the area of computer technology and systems is the home terminal developed by the MITRE Corporation. It consists of a slightly modified but otherwise standard home television receiver and video tape recorder together with some supplementary electronics. This combination is capable of furnishing 600 television sets simultaneously with individual and personalized picture sequences over a single coaxial cable and may help make economically feasible the home delivery of individualized instruction.

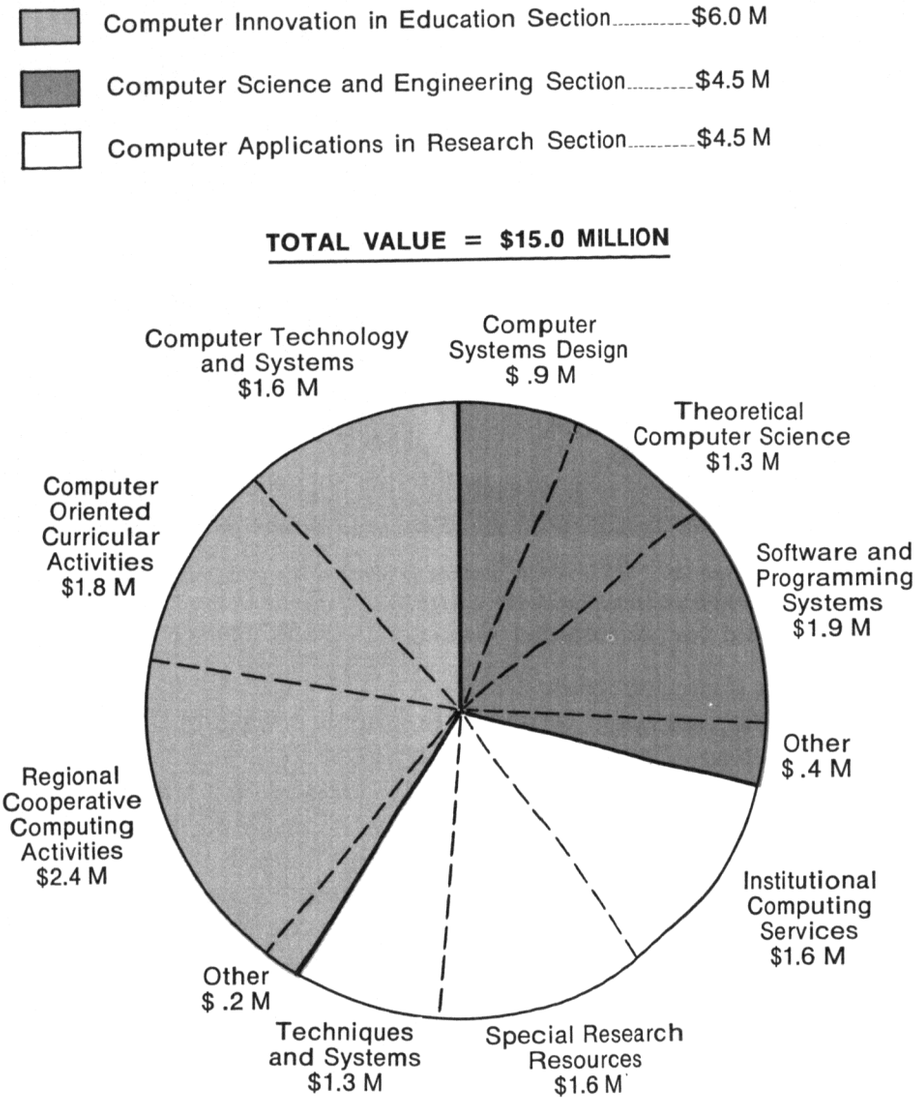
During fiscal year 1971, 23 grants were awarded for computer-oriented curriculum development at college and secondary school levels. The areas included engineering, mathematics, biology, chemistry, statistics, social sciences, and ecology.

The unit cost of computing continues to decrease as new equipment configurations, such as networks and minicomputers, offer a greater range of instructional alternatives. Research was carried out to determine how these developments might be used to increase instructional effectiveness.

The advent of lower cost pictorial displays spurred renewed interest in these devices for instructional purposes. The University of Oregon undertook a study of the use of graphics as an instructional aid in teaching physical sciences. Other experiments with instructional graphics are under way at the University of Michigan.

One of the most urgent needs in the instructional use of computers is the development of high quality instructional materials that can be adapted to several different systems. In this area, the Iowa Regional Computer Center is working with seven member institutions of a regional network to develop curricula in mathematics and biology. Dartmouth College will provide computer and staff support for six to 12 invited faculty members to develop course materials for use in teaching the environmental sciences.

**COMPUTING ACTIVITIES IN EDUCATION AND RESEARCH AWARDS BY PROGRAM CATEGORIES FISCAL YEAR 1971**

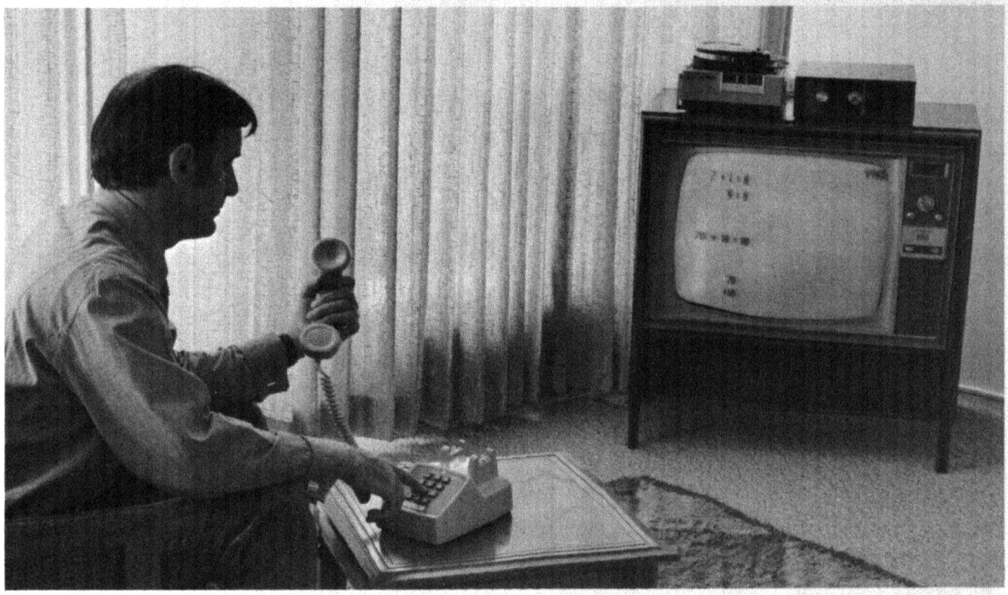



A second conference on "Computers in Undergraduate Curricula" was held at Dartmouth College in June of 1971 with NSF support. Partial support was also provided to the Illinois Institute of Technology and the Commission on College Physics to host a conference on "Computers in Undergraduate Science Education: Physics and Mathematics" in August of 1970. The growing attendance at these conferences and the marked increase in the quality of papers submitted are just two of the many indicators of a rapidly growing awareness of computer-based instruction.

The Foundation has been providing support for the establishment of educational computing networks through its Regional Cooperative Computing Activities Program since 1968. Typically, each network is organized around a major university which provides computer resources and assistance to a number of nearby institutions. The information and guidance offered enable participat-

ing faculties to discover discipline-oriented innovative techniques in computer usage and to develop computer applications which enhance the quality, depth, and breadth of their students' education. The regional activities also serve as a test bed for the computerized curricular products as well as for transfer and dissemination of new techniques.

In fiscal year 1971, 61 grants for regional activities, totaling approximately $2.4 million, included support for four major universities and 59 participating colleges in five States. Four new regional activities in New Jersey, Colorado, Washington, and California were added to the 18 established between 1968 and 1970. The wide variety of cooperative approaches is currently being analyzed, and the data will be presented in a forthcoming report.



A home computer terminal, utilizing conventional television technology and rapidly growing cable television systems, might allow computer-assisted instruction (CAI) and other graphic computational, data retrieval, and commercial computer services to be made available to mass populations at relatively low cost. (Photo MITRE Corp.)

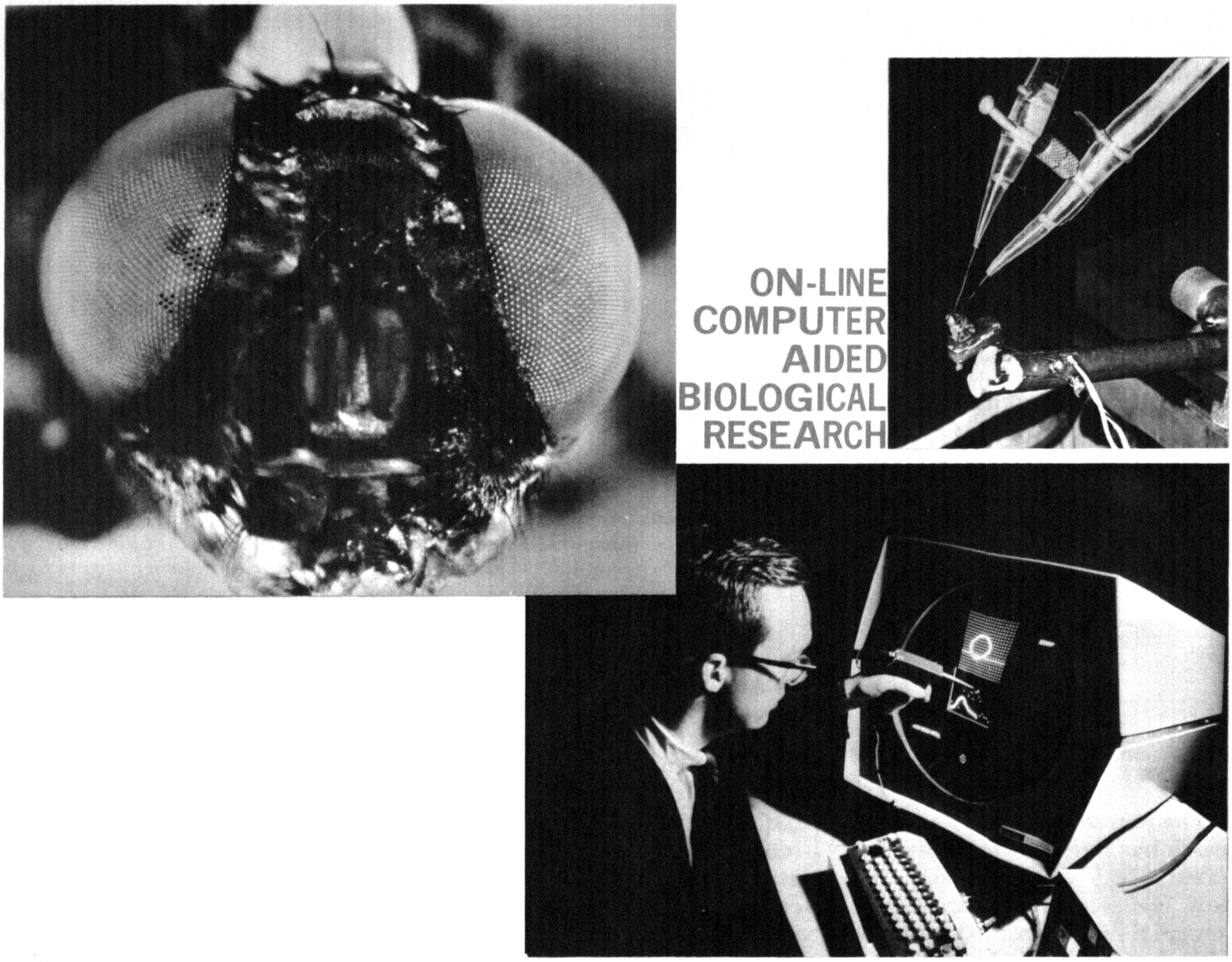
## COMPUTER APPLICATIONS IN RESEARCH

The potential of computers in research has increased markedly with recent advances in technology. It is now possible for researchers to achieve a high degree of interaction with the computer via a variety of remotely located terminals. In many instances a computer is an integral part of a complex laboratory setting. The Foundation started specific programs in fiscal year 1971 to advance science research capability through the development of sophisticated computer-based techniques and systems. Three projects are described which illustrate this new activity:

- Researchers in the life sciences and computer science at the California Institute of Technology are developing a computing system for direct interaction between the researcher and the experiment. The computer permits the researcher to evaluate and redirect his experiment while the experiment is in process. The researcher can apply strategies that range between the methodology of formal modeling and the current procedures for data acquisition and analysis. This system concept has already been applied in intensive study of the complete nervous system of insects, most notably the housefly, *Musca domestica*. The system has enabled the detection and study of 108 distinct classes of interneurons representing a population of 300,000 interneurons, or about one-third of the interneurons of the fly. Before the system was developed, only a very few interneurons could be studied. Foundation support will permit further development of this advanced computational system applicable to a wide range of interdisciplinary research activities.

- A major research center in computational technology for economics and management science has been established by the National Bureau of Economic Research in collaboration with leading scientists at academic institutions. Attention is being given to the development of more comprehensive analytical approaches to cope with modeling of interdependencies, nonlinearities, and other complications which arise when different economic groups and institutions adjust to changes in their external circumstances and policy environments. Particular emphasis is placed on distribution of the new techniques to the research community. The center is designed to attract leading researchers in these fields and in computer science from universities and colleges, Government, nonprofit institutions, industry, and commerce.

- The Architecture Machine group at the Massachusetts Institute of Technology has developed a computer system capable of recognizing rough handwritten drawings, e.g., architectural sketches, to a considerable psychological depth. The computer monitors a sketch drawn on an electronic tablet with a light pen, and infers information about not only the shapes and locations of lines and corners, parallelism, perpendicularity, coplanarism, etc., but also the degree of certainty or interest felt by the artist in each section as might be suggested, for instance, by the rate at which the section was




Scientist at California Institute of Technology in action at the console of a highly interactive computer-based system created to further research in insect vision. (Photo California Institute of Technology)

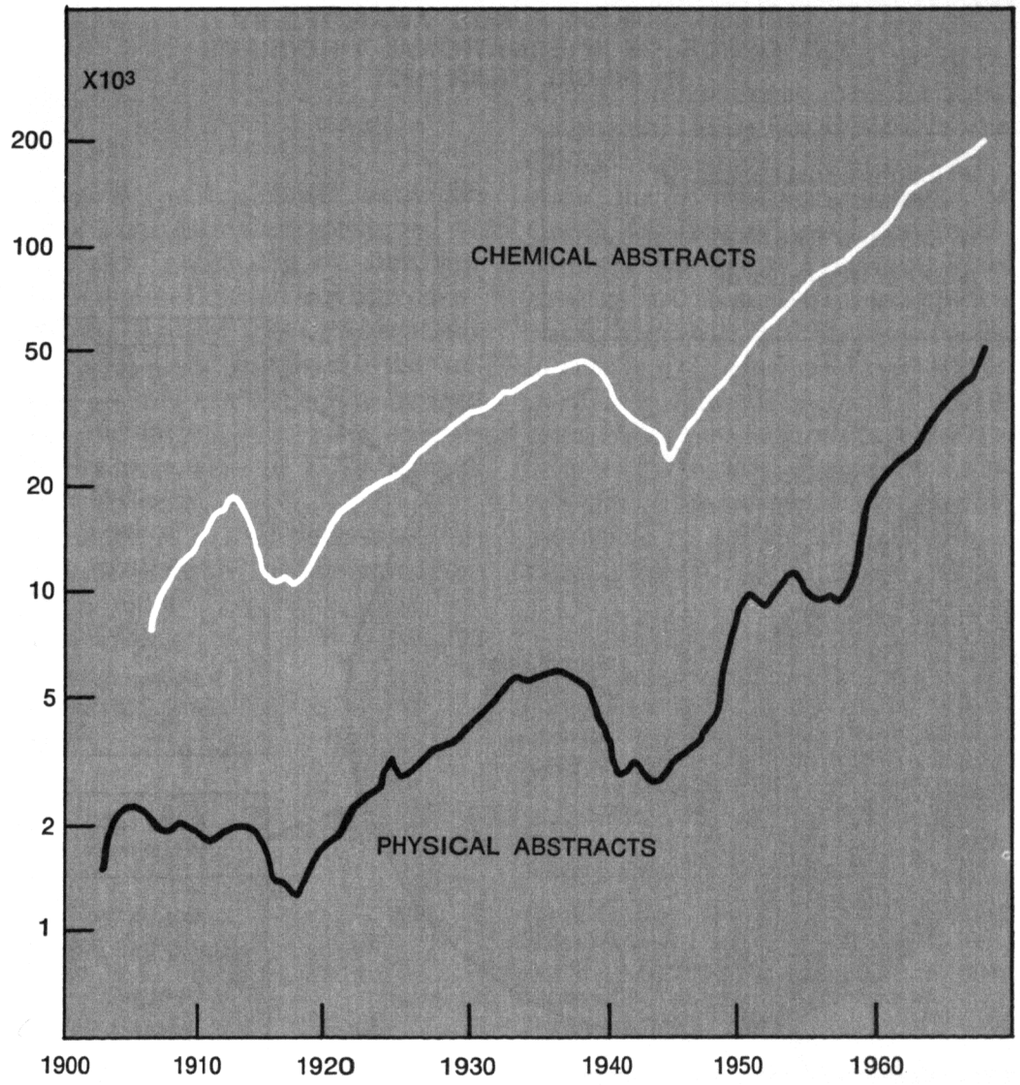
drawn. Projects such as this one provide the basis for more direct person/computer communication in the future, not only for architectural applications but for many other areas as well.

## SCIENCE INFORMATION ACTIVITIES

Scientific research relies upon the information generated by prior investigations and yields results which, when disseminated within the scientific community, form the basis for continuing research and applications. In pursuing its legislative mandate to provide for information services "leading to a more effective dissemination of scientific information," the Office of Science Information Service in fiscal year 1971 made 78 awards totaling approximately $11 million and negotiated nine contracts for an additional $1 million in equivalent excess foreign currencies.

## SYSTEM DEVELOPMENT AND IMPROVEMENT

Like research itself, investment in the improvement of the science communication system is cumulative in its effect. NSF assists professional societies in their development of information systems for their particular scientific disciplines, and it also assists universities in the development of information systems for the university community. The major focus in system development has been on the application of computer




Abstracts published in *Chemical Abstracts* and *Physics Abstracts,* doubling every 8.1 years except in wartime. (Photo ACS)

technology to information processing in order to reduce processing costs and to provide a variety of computer-produced services tailored to individual needs. The conversion to computerized systems hastens the time when the major information systems can be connected electronically through the use of standard telecommunication equipment.

## *Discipline-Oriented Science Information Activities*

The discipline-oriented information systems funded by NSF are in various stages of development, with the American Chemical Society's Chemical Information System the most advanced. The Foundation expects that the demand for information from these systems will be sufficient to ensure that they can be operated without Federal support once they become fully operational.

The Chemical Abstracts Service (CAS) completed the conversion of its indexes to computer-based production this year and continued development of its computer-controlled composition and publishing operations. There are now 10 organizations in the United States as well as groups in Canada, the Netherlands, Sweden, the United Kingdom, and West Germany that are licensed to provide public services from the CAS machine-readable files. In response to requests from potential customer groups, CAS initiated a series of user seminars for orientation in the use of its new computerized data bases.

The American Institute of Physics (AIP) continued development of its computerized information system. Achievements during the year include: (1) a monthly series of magnetic tapes, each containing bibliographic records of articles published in AIP journals; (2) an announcement journal and (3) specialized bibliographies in selected subfields of physics.

The American Psychological Association developed and is testing a computer-readable magnetic tape edition of *Psychological Abstracts* which can be searched on a wide variety of computer equipment.

## *University-Centered Information Systems*

Research libraries on university campuses have traditionally served the major information requirements of the academic community. In support of these libraries, computerized science information systems are being developed at six universities to exploit the machine-readable data bases produced by the professional societies. This past year marked the beginning of cooperative projects on a number of campuses to pool computer capabilities and share information system resources. A remote terminal at the University of Pittsburgh will provide access to data bases that can be searched more effectively and economically at the University of Georgia. Lehigh University has initiated plans to extend its system to serve a consortium of universities in the Delaware Valley region.

The University of Pittsburgh is expanding its chemical information system into a multidisciplinary campus-based information service. The Ohio State University began development of a computerized general science information system closely coordinated with its existing library facilities. A final grant was awarded

for development of the Treaty Information System at the University of Washington. The University of Arizona received a grant to study the feasibility of an Arid Lands Information Network involving the major arid lands research institutes in the United States.

## INFORMATION SERVICES AND PUBLICATIONS

The Foundation's program for support of information services and publications is designed to help various scientific and engineering discipline organizations maintain information systems and services at an operational level sufficient to meet the essential needs of scientists and engineers.

Thirty projects received support for the operation or production of a variety of science information systems, services, and publications. Forty percent of the total obligation of about $3.5 million was for the support of the Science Information Exchange, which will be supported in the future by the Smithsonian Institution.

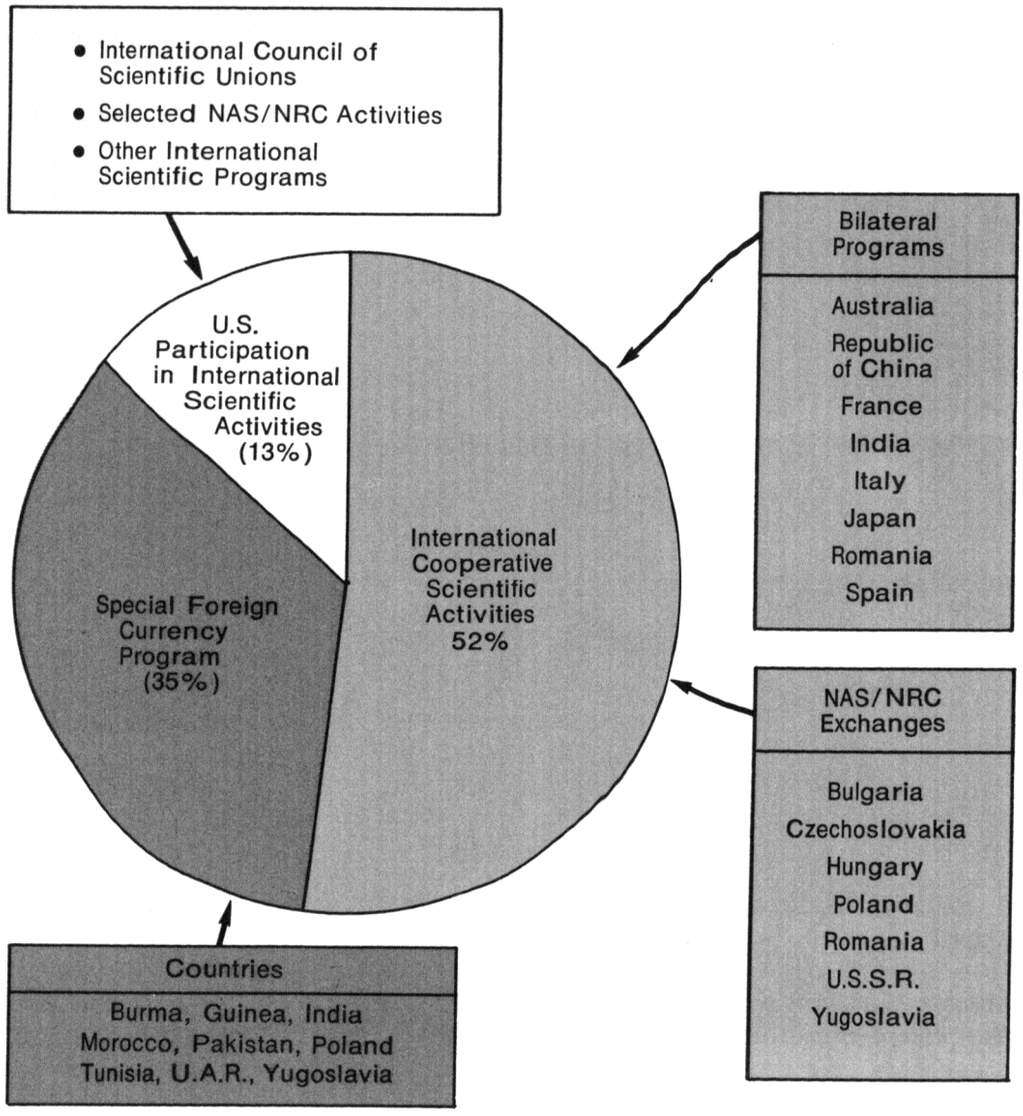
Major emphasis was directed to the existing communication system for science and engineering, which will continue to be central in the emerging national network of science information systems. Support was provided to activities in the fields of biology, psychology, physics, geology, engineering, and atmospheric sciences.

Support for primary publications was limited to one journal and two monographs, one of which recorded the geological history of the Alaska earthquake of 1964. A significant project of data compilation in the field of nuclear physics was undertaken with NSF support.

## SCIENCE INFORMATION RESEARCH

Support for science information research during fiscal year 1971 was reoriented to cover a broad spectrum of research efforts ranging from basic through applied studies and pilot demonstrations in such problem areas as information formatting, data manipulation, library innovation, networking studies, system evaluation measures, user studies, and user education techniques.

**DISTRIBUTION OF FUNDS AWARDED BY THE OFFICE OF INTERNATIONAL PROGRAMS IN FISCAL YEAR 1971**




## SPECIAL FOREIGN CURRENCY PROGRAM FOR SCIENTIFIC AND TECHONOLOGICAL INFORMATION

Science information activities supported under the Agricultural Trade Development and Assistance Act of 1954 (Public Law 480) involve the use of foreign currency credits in countries where such credits are in excess of normal U.S. governmental requirements. Contracts with nine foreign organizations resulted in the translation and republication in English of approximately 70,000 pages of primary journals, patents, and monographs from Russian, East European, Japanese, and other languages, as well as preparation of abstracts, compilation of annotated bibliographies, and preparation of guides to foreign scientific institutions and information services.

# INTERNATIONAL SCIENCE ACTIVITIES

International scientific activities of the Foundation are designed to foster the interchange of information between U.S. and foreign scientists, to produce new scientific knowledge, and to enrich the national scientific effort with foreign ideas and approaches, with concurrent advancement of U.S. foreign policy interests.

As much as 10 to 15 percent of the funds obligated by the National Science Foundation in fiscal year 1971 may be identified with projects having international implications. Among the more apparent are the Global Atmospheric Research Program, the International Decade of Ocean Exploration, and the International Biological Program. Less obvious are Foundation-supported research grants that include funds to enable the principal investigator to visit a laboratory in a foreign country, awards to foreign scientists to attend Foundation-funded summer institutes, and grants to American scientists for travel to international scientific meetings.

| *Name of Program* | *Year Initiated* | *Activity Summary, FY 1971* |
|---|---|---|
| United States-Japan Cooperative Science Program | 1961 | Fifteen awards were made for joint research in mathematics, biochemistry, biology, meteorology, physics, and geophysics; 18 joint seminars were held. Support was provided for the continuation of the United States-Japan Science Film Project. An Eminent Visiting Scientists Program was initiated. Funds obligated: $212,890 |
| India-United States Exchange of Scientists Program | 1967 | Eight Indian scientists visited the United States for familiarization with research centers and activities; seven U.S. scientists traveled to India to lecture and consult. Funds obligated: $22,565 |
| United States-Italy Cooperative Program in Science | 1967 | One award was made for a seminar in mathematics held in Udine, Italy. Funds obligated: $8,500 |
| United States-Australia Agreement for Scientific and Technical Cooperation | 1968 | One joint seminar on "Recent Advances in Photosynthesis" was held in Canberra. Funds obligated: $4,000 |
| United States-Republic of China Cooperative Science Program | 1969 | Five U.S. scientists traveled to Taiwan to teach and conduct research in engineering, mathematics, biochemistry, and palynology. Funds obligated: $79,200 |
| Agreement of Friendship and Cooperation between the United States and Spain | 1970 | Activities were limited to program development. No funds obligated. |
| United States-France Exchange of Scientists Program | 1970 | Grants were made to 11 French scientists for study in the United States. Awards were received by 12 U.S. scientists for study in France. Funds obligated: $113,647 |
| Program of Exchange between the United States and Romania | 1970 | One joint research project on atomic and plasma physics was supported; 17 Romanian scientists visited the United States for familiarization with U.S. technology and research activities; and five American scientists went to Romania for research and study. Funds obligated: $90,000 |

The above activities are discussed elsewhere in appropriate sections of this report. Programs described on the following pages are those administered directly by the Office of International Programs.

# INTERNATIONAL COOPERATIVE SCIENTIFIC ACTIVITIES

During fiscal year 1971, the Foundation served as executive agency for bilateral research and exchange programs with Australia, the Republic of China, France, India, Italy, Japan, Romania, and Spain. The cooperative programs with France, India, and Romania involve exchanges of scientists between the United States and those countries; the other bilateral programs include support for the U.S. portion of joint research projects, seminars, and scientist visits. The Foundation assumed responsibility for the United States-France Exchange of Scientists Program on July 20, 1970, and accepted executive agency responsibility for the science and technology aspects of the United States-Spain Agreement of Friendship and Cooperation on December 14. The table lists the eight current bilateral programs, the year initiated, and a summary of activities in fiscal year 1971.

The Foundation supports the National Academy of Sciences Exchange Program with the Academies of Science of the U.S.S.R. and East European countries. During fiscal year 1971, 27 U.S. scientists visited the U.S.S.R. and 25 Soviet scientists visited the United States under this program.

Fifty U.S. scientists also visited research institutes of the East European Academies of Science during fiscal year 1971: Czechoslovakia, 12; Poland, 17; Romania, 15; and Yugoslavia, 6. Twenty-seven East European scientists visited the United States for an average stay of 4 months each.

## U.S. SCIENTIFIC PARTICIPATION IN INTERNATIONAL PROGRAMS

The Foundation provided funds to the National Academy of Sciences (NAS) for staff and other assistance to U.S. representation in 30 international organizations. These funds support meetings of the U.S. national committees for various international scientific unions, program reviews and meetings held by the Advisory Committee on International Organizations and Programs, and U.S. dues to the International Council of Scientific Unions (ICSU) and its 16 affiliated unions.

Other Foundation support to the National Academy of Sciences enabled U.S. scientists to participate in discussions of a proposed center for the study of problems of advanced societies. Several meetings among British, French, Italian, Soviet, United States, and West German officials have resulted in the drafting of a charter, the formation of a site-location committee, and an official name for the center: the International Institute for Applied Systems Analysis.

Partial support was provided for the NAS Committee for International Environmental Programs (IEPC). The IEPC has prepared position papers for U.S. participation in the 1971 Economic Commission for Europe Conference in Prague, the UNESCO Man and Biosphere Program, and the United Nations Conference on the Human Environment to be held in Stockholm in 1972. The IEPC also serves as the adhering committee to the ICSU Scientific Committee on Problems of the Environment, establishes communication with nongovernmental national organizations in other countries, and acts as a national information center on international environmental activities.

An American scientist conducts a short course in gas chromatography at the University of Punjab, India. (Photo American Chemical Society)

## SPECIAL FOREIGN CURRENCY PROGRAM FOR SCIENTIFIC RESEARCH AND RELATED ACTIVITIES

The first project to be approved (in April 1971) was support for a Regional Conference on Planning and Design of Tall Buildings in Bled, Yugoslavia. In May, another 18 research projects were approved: 14 in Yugoslavia, two in Egypt, one in Poland, and one multicountry project involving research in Tunisia, Morocco, and Egypt. Twenty-one international travel grants were awarded for program development and consultation in special foreign currency countries. These activities are supported under the Agricultural Trade Development and Assistance Act of 1954 (Public Law 480).

## SCIENCE EDUCATION IMPROVEMENT PROGRAM IN INDIA

This program, started in 1966, is supported entirely by funds transferred to NSF by the Agency for International Development. The objective of the program is to improve scientific and technical education in biology, chemistry, mathematics, and physics at the high school and college levels, technology at the junior college level, and engineering at the college level. During fiscal year 1971, 63 consultants for curriculum development and institutional development activities were supported under this program. Other activities included a binational conference on education and research and the presentation of six American Chemical Society short courses.

*Research Applications*

# RESEARCH APPLIED TO NATIONAL NEEDS

In fiscal year 1971, the NSF organized the bulk of its problem-focused research into a single set of program activities administered by a new Research Applications Directorate. Existing programs in Earthquake Engineering, Weather Modification, and Interdisciplinary Research Relevant to Problems of Our Society (IRRPOS) form the nucleus of the program of Research Applied to National Needs (RANN). Also administered by the Research Applications Directorate is the Office of Intergovernmental Science Programs, now entering its third year.

The Foundation has supported problem-oriented research for more than a decade. Programs such as Earthquake Engineering, Weather Modification and others have yielded considerable experience in the successful management of these efforts. The Foundation is now applying and building on this experience with a significant part of its resources to encourage research targeted on objectives and foreseeable benefits. Through these programs the Foundation seeks to mobilize a portion of the nation's scientific talent and technological capability for resolving important problems of national concern.

RANN is organized into four major program areas. The Division of Environmental Systems and Resources administers programs in the areas of regional environmental systems, environmental aspects of trace contaminants, and weather modification. The Division of Social Systems and Human Resources administers programs in the areas of municipal operations and services, social data and community structure, and methodologies for evaluating social programs. The Division of

**Table 6**
**Research Applications Obligations**
**Fiscal Year 1971**
**(Millions of dollars)**

| | Number of awards | Funds obligated |
|---|---|---|
| Research Applied to National Needs | 213 | $34.0 |
| Division of Social Systems and Human Resources | | |
| Municipal Systems Operations and Services | 7 | 1.6 |
| Social Data and Community Structure | 7 | 5.4 |
| Evaluation Methodologies for Social Programs | 1 | .1 |
| Subtotal | 15 | 7.1 |
| Division of Environmental Systems and Resources | | |
| Weather Modification | 22 | 3.4 |
| Trace Contaminants | 7 | 1.5 |
| Regional Environmental Systems | 19 | 4.3 |
| Subtotal | 48 | 9.2 |
| Division of Advanced Technology Applications | | |
| Disaster and Hazard Research | 36 | 3.6 |
| Technology Needs and Opportunities | 52 | 5.3 |
| Urban Technology | 8 | .7 |
| Energy Resources, Research and Analysis | 26 | 5.1 |
| Subtotal | 122 | 14.7 |
| Office of Exploratory Research and Problem Assessment | | |
| Problem Definition and Assessment | 16 | 1.4 |
| Exploratory Research | 12 | 1.6 |
| Subtotal | 28 | 3.0 |
| Intergovernmental Science Programs | 28 | .8 |
| Total | 241 | 34.8 |

Tributary of the Gallatin River, which may be affected by a recreational development to be known as Big Sky. Scientists at Montana State University are performing baseline measurements to measure the degree of impact on the environment. (Photo Montana State University/Max Hunke)

Advanced Technology Applications administers programs in the areas of energy resources research and analysis, urban technology, earthquake engineering, fire research, excavation technology, enzyme technology, industrial processing, and instrumentation technology. The Office of Exploratory Research and Problem Assessment provides support for efforts to define and analyze emerging problem areas and promising research strategies, to assemble and synthesize relevant existing knowledge underlying such problem areas, and to initiate research efforts in new areas which might be the subject of concentrated research efforts. Problem assessment and technology assessment functions are centered in this office. The Office of Intergovernmental Science Programs focuses on the development of improved programs and institutions for making science and technology available for use by States and local governments in solving problems, including the utilization of results from both RANN and other NSF programs that have important applications to those problems.

## ENVIRONMENTAL SYSTEMS AND RESOURCES

The major goals of RANN programs on the environment include an improved understanding of environmental systems for more effective efforts to prevent environmental degradation, wise development of national resources, and accommodation of man's activities to environmental constraints.

The studies currently supported generally fall into three categories: comprehensive investigations of regional environmental systems, analyses of environmental aspects of trace contaminants, and weather modification research.

### *Regional Environmental Change in Southwestern Montana*

An interdisciplinary team of investigators has been organized at Montana State University to examine the nature and magnitude of the environmental, social, and economic consequences of a large-scale, diverse recreational development in southwestern Montana, known as Big Sky. They have gathered baseline data on many variables likely to be influenced and are now beginning to monitor changes. Their results will include such things as changes in water quality due to the introduction of sewage systems and the changes in community service requirements due to rapidly expanding population. These results are intended to provide a basis for conducting environmental impact studies for similar developments in other parts of the country and for land planning efforts on the periphery of Big Sky. Preliminary data from an exploratory study have already proven useful to a number of agencies and organizations such as the U.S. Forest Service and local planning groups.

### *Methyl Mercury, A Trace Contaminant*

Thomas W. Clarkson at the University of Rochester is concentrating on the biomedical dangers of methyl mercury and related compounds, an environmental problem that received widespread public attention during 1971. Known as a poison since ancient times, mercury has been released, with minimal caution, chiefly into aquatic environments. Despite the growth in numbers of industrial sources and the quantity of mercury processed, the widespread belief that such wastes were very dense and very insoluble had led to what now turns out to be a false sense of security. It is now recognized that some aquatic microorganisms can convert previously in-

soluble deposits of mercury to highly soluble, diffusible and toxic mercury compounds.

As a result, (1) mercury contamination is much more widespread than expected; (2) its concentrations are higher than expected; (3) it is being concentrated still further in the food chains; (4) the toxicity of methyl mercury is many times greater than inorganic mercury itself; and (5) the problem may be irreversible, since few data exist to develop a useful technology to neutralize the mercury already released.

The work at Rochester, a series of coordinated interdisciplinary studies, is concerned with the dynamics of mercury flow through man, including its chemical transformations and the effects it produces. Specific experiments will evaluate conversions of inorganic mercury to the more toxic methyl mercury in microorganisms, the selective action of mercury on the microecology of the intestine, the essential parameters that determine absorption, distribution, and excretion of methyl mercury from the body and its effects on the central nervous system, on the fetus and on the genetic apparatus. Means of reducing absorption and of increasing excretion of mercury will be examined as potential therapeutic and preventive measures. The Food and Drug Administration is cooperating with the National Science Foundation in support of this effort both scientifically and financially.

### *The National Hail Research Experiment*

A major portion of the weather modification program in fiscal year 1971 was directed toward strengthening the effort on the National Hail Research Experiment which is being conducted in northeastern Colorado under the management of the National Center for Atmospheric Research.

A field headquarters has now been established in Grover, Colo., and airborne and ground elements of the field observing network were calibrated and tested in the field in preparation for the first full field operation in the summer of 1972. The objective of the experiment is to develop an understanding of the mechanisms of severe storms which generate damaging-sized hailstones, and then to devise modification techniques which will suppress their formation. A "protected area" of 600 square miles has been extensively instrumented to observe the effects of silver iodide seeding upon hail formation. During the trial phase in 1971, no aircraft-launched rocket seeding devices were deployed due to the need to complete further FAA qualification tests. However, pyrotechnic seeding devices were carried by small aircraft into critical updraft areas of the storms and ignited. A dual wavelength hail detection radar has been constructed jointly by the University of Chicago and the University of Illinois and is now being tested in the vicinity of Urbana, Ill., before being installed in northeastern Colorado. The radar is expected to be capable of differentiating between the echo received from a liquid water droplet or an ice particle in a cloud. The National Hail Research Experiment will involve the cooperation of seven universities in addition to the participation of five Federal agencies and the Colorado Air National Guard.

Hail causes hundreds of millions of dollars worth of damage to crops and property every year in the United States. This field of corn near Julesburg, Colo., destroyed by a hailstorm in June 1970, illustrates the sort of destruction that hail can inflict on farmers of the Great Plains. (Photo NCAR)

## SOCIAL SYSTEMS AND HUMAN RESOURCES

The effort to develop an improved understanding of social systems and social data is intended to increase our ability to deal with problems which affect the quality of our society. The research programs on municipal systems, evaluation methodology, and social data and community structure pursue the objective of providing information and analysis of concrete and realistic policy alternatives available to State, local, and Federal officials.

### *Studies of the Municipal System of New York*

One of the problems of the individual in a municipal system who must make policy decisions is the availability of up-to-date information. The Urban Science and Engineering Program of the State University of New York at Stony Brook has a program in which members of its faculty have been working closely with agencies of the New York City government. For instance, they have assisted a city agency in developing cost-effective means of scheduling sanitation crew work loads efficiently and to provide crews for peak collection periods while also giving workers the maximum number of 3-day weekends and equitable work assignments.

### *Carbon Monoxide in St. Louis*

A quite different form of information to serve decision-makers is being provided in the St. Louis area. Drawing on the diverse disciplines of sociology, mathematics, hematology, geography, systems engineering, and urban and regional planning, investigators from Southern Illinois University and the medical schools of St. Louis and Washington Universities are collaborating in an effort to develop a carbon monoxide diffusion model to be used in transportation planning. The project also involves the cooperation of the St. Louis chapter of the Red Cross, the St. Louis County Health Department, the Illinois Environmental Protection Agency, and the Department of Public Safety in the collection and provision of data. In addition, members of a black community group, Black Survival, will participate in providing information to inner-city residents about the purposes and results of the project. Major aims are to determine the relationships between carboxyhemoglobin in individuals and various personal, environmental, and vehicular traffic factors, and to develop a predictive model of expected carboxyhemoglobin levels under changing environmental conditions for use in national and local transportation planning.

### *The Social Science Research Council and Evaluation Methodology*

The need for new methods to come to grips with the rapid pace of social change has led to another set of research activities. One of the more pervasive problems of social programs is the development of satisfactory methods for evaluating their effectiveness. The Social Science Research Council, with the encouragement of the President's Science Advisor and the President's Science Advisory Committee, is continuing its work on the methodology of social experimentation. The council will concentrate on the scientific, managerial, and institutional aspects of carrying out and evaluating experimental studies of social innovations. A core group of senior social scientists with special competence in methodology was assembled by the council for an initial workshop during the summer of 1971 and, during the summer of 1972, will submit a report for publication.

### *Acquisition of New Data on Social Behavior*

New methods are also being developed to help study the impact on man of the environment he builds around him. An interdisciplinary group of architects, planners, and social scientists at Princeton University is studying the effects of buildings and communities on personal behavior, effectiveness, and satisfaction. This project's goal is to define new criteria, concepts, and methods for assessing environmental effects on behavior. Research sites will include both a working and a living habitat and communities consisting of buildings designed by individual architects as well as by community planners and real estate developers. The researchers expect to develop methods of analyzing and measuring the user's perception of spatial environment, his reactions to it, and the satisfactions he draws from it.

Consideration of both the need for more rigorous methods and the need for more complete information on the quality of life in the nation has led to a broad 3-year grant to the University of Michigan. There the Institute for Social Research (ISR) is measuring and assessing changes in the socioeconomic status, living conditions, and attitudes of the population of the United States. The institute is collecting new data as well as preparing historical data to identify long-term changes. Moreover, with strengthened technical and statistical resources, ISR is improving the quality of the social data they are making available.

Social phenomena are complex, but research can contribute to analyzing and eventually understanding the interaction of the many factors. A team of engineers, physicists, and social scientists at Brown University received an exploratory award for research on which to base an empirical test of an urban dynamics model developed by Jay Forrester. They intend to apply the model to the Providence area, to supply more detailed data than used in Dr. Forrester's initial model, and to demonstrate to policy-makers and decision-makers how the model may be used for dealing with real problems.

## ADVANCED TECHNOLOGY APPLICATIONS

This category of RANN projects involves the application of advanced scientific and engineering knowledge to major social, economic, and environmental problems. The objectives of the program are to foster the development, augmentation, and

application of technologies that will aid in the solution of such problems.

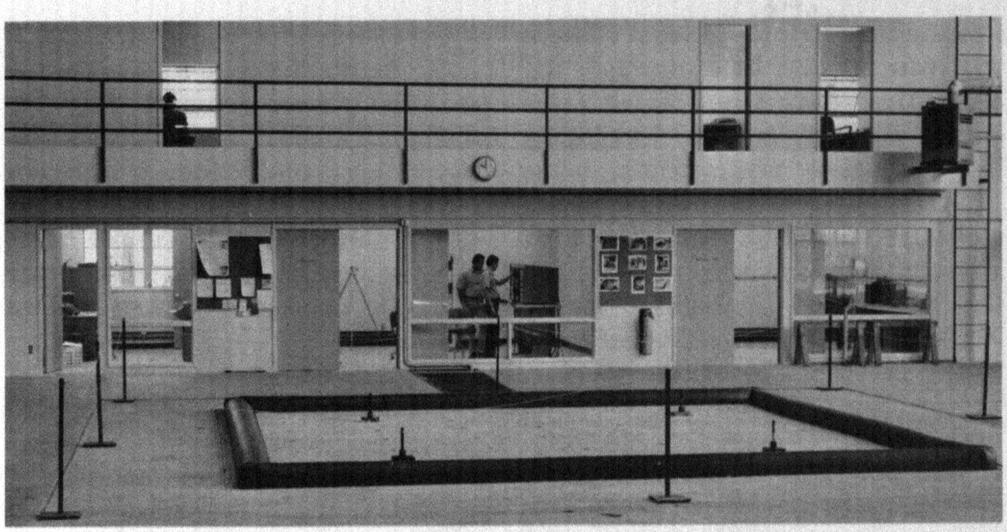
Work currently supported includes elements of programs previously under way elsewhere in the Foundation on research related to fire, energy studies, and earthquake engineering.

## *Fire Research*

An important factor in determining the relative safety of various materials is to test the damage they will do to human skin under fire conditions. So many variables are involved that what is needed is a system that will allow actual experimentation using an analog of human skin. A group at MIT, under the direction of Glenn Williams, has developed just such a simulant of skin for use in measuring the flammability characteristics and burn potential of fabrics. The simulant also serves as a tool to check the reliability of theoretical analyses which are being developed. The MIT project and another grant, for ignition studies, at Georgia Institute of Technology are part of a cooperative effort with the National Bureau of Standards which is directed at the problems associated with establishing standards for fabric flammability. Three trade associations have provided funds for complementary research in two nonacademic institutions—Factory Mutual Research Corporation and Gillette Research Institute.

## *Earthquake Engineering*

The San Fernando earthquake of February 9, 1971, caused damage of nearly a billion dollars to buildings and facilities in the San Fernando Valley and in the Los Angeles metropolitan area. Because of the number of modern structures damaged and because of the unusually complete acceleration measurements obtained, this earthquake is of very great engineering significance and presents unparalleled opportunities for research in all aspects of earthquake engineering.



This structure at the University of California, Berkeley, is being used to subject full- or half-scale structures or structural components to the types of motions that actually occur during earthquakes. (Photo University of California, Berkeley)

In the past several years, new mathematical tools utilizing large-scale computing equipment have been developed to analyze the effects of earthquakes on engineered structures. To verify these analytic tools, laboratory tests of model and full-scale structures, shaking tests of actual buildings, and studies of strong-motion responses of structures subjected to actual earthquakes have been undertaken. In addition, the magnitudes, frequencies, orientations, and durations of the forces resulting from earthquakes must be better known: There is much information that cannot be reconstructed by simply examining the damage. The San Fernando earthquake yielded 272 strong-motion records; the instruments were mounted on dams, rocks, soils of several different characteristics, building basements, and upper stories. These records are a vital link in the efforts of engineers to develop improved methods of design and analysis.

As a first step in recovering as much information as possible from this event, Caltech is processing and disseminating copies of the strong-motion records to researchers and engineers in the field. The second step is a series of detailed studies of engineering consequences by six universities (Purdue, Caltech, UCLA, Berkeley, MIT, and Illinois). This collaborative program includes the following basic topics: (1) damage documentation studies—a systematic seismic risk analysis of the performance of modern buildings; (2) structural response to earthquake loading—an analytical and experimental investigation of critical damage observed in certain buildings as a result of this earthquake; and (3) soil-foundation response to earthquake motion—the correlation of known soil motions and structural response.

Prior to the San Fernando earthquake, the National Information Service for Earthquake Engineering (NISEE) was established by concurrent grants to the California Institute of Technology and the University of California, Berkeley. This is a program to collect, organize, and disseminate information. Basic collections are being strengthened and made more accessible to structural engineers, research workers, and building department officials. Catalogs of such material will be issued, and facilities are being established for the rapid reproduction of reference materials so that they can be

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supplied at nominal charge. Caltech will concentrate on collecting and evaluating data about earthquake strong motions and on developing instruments to measure them, while Berkeley will be headquarters for computer methods for structural analysis, dynamic tests of soils and structures, and an abstract service for foreign and domestic literature.

### *Energy Problems*

The activities of the energy resources program fall into two general classifications: (1) surveys and analyses of energy resources and research; and (2) support of specific research and development projects that will have direct impact on the energy problems of the nation.

The first classification includes analysis of energy systems and technology to determine their impact on the environment, inventories of energy research, and identification of significant elements of energy economics and policy. One such project undertaken by the National Academy of Engineering seeks to develop a mechanism for supporting the formulation of national energy policies.

The second classification includes research projects on land use, power plant siting and power transmission, solar energy, and thermal energy storage. For instance, one of the great problems for electric power generating systems is the variability of demand for its product and the inability to stockpile it. One of the most obvious aspects of the problem is the summertime "brownout" produced by too-heavy demands on the system by late-afternoon use of air conditioners. Manfred Altman's group at the University of Pennsylvania has presented a technique, using salt hydrates that can "store coolness," that may help alleviate the brownout problem. The salt hydrates, or thermal energy storage material, can be cooled at night, when demand for power is low, and its coolness given up during the heat of late afternoon when demand is high, thereby helping to iron out the peaks in power demand. The Altman group has come up with a prototype air conditioner which not only evens out power demand, but —even though it must run 24 hours a day—uses 15 percent *less* power overall to produce the same amount of cooling.

At the California Institute of Technology, the Environmental Quality Laboratory, under the direction of Lester Lees, is mounting a concerted and sustained attack on critical environmental problems affecting modern society. Among their studies are investigations of power utilization and power-plant siting in relation to power needs, economics, and environmental deterioration. EQL's power-plant siting study will investigate the possibilities of dispersing waste heat by remote siting of power plants, or by offshore, under-ocean, or underground siting. Their engineering and economic study will be interpreted in the light of alternate projections of the increase and distribution of human populations in the affected area. Correlated studies by scientists will estimate how different populations would be affected under varying assumptions of energy distribution.

## EXPLORATORY RESEARCH AND PROBLEM ASSESSMENT

A critical concern for the overall RANN program is the identification of emerging national problems on which research is most needed and to which research can be effectively applied.

The purpose of exploratory research and problem assessment is to examine the total context of societal problems and to identify the research opportunities which are critical for dealing with them. Research on improved assessment and evaluation methodologies is encouraged, as is the development of effective organizations and procedures for problem-oriented interdisciplinary research. Innovative institutional groupings and joint arrangements between universities and both nonprofit and commercial firms are of particular interest in this latter regard.

### *Exploratory Research*

The Center for Policy Research in New York is examining both the technical features and social "rules" for use of cable television as a mass participatory technology system which would allow citizens to interact with public officials and with each other. An integrated social science-engineering team is undertaking a number of tasks, such as testing the effect of alternative uses of the system in reducing public apathy, alienation, and polarization, and on expanding opportunities for expressing new ideas and minority views. The Center is also investigating the development and testing of random switching, instant polling, and use of telephone exchanges compared to CATV networks and other technological innovations, and comparing of audio-only with audio-visual systems.

Development Sciences, Inc., of East Sandwich, Mass., is exploring alternative pollution abatement techniques by locating recycling plants to convert pollutants into resources in an existing consumer-producer network. It is also looking for opportunities to substitute one process for another to reduce pollution or to enhance reuse potential. It will attempt to identify partners for a shared waste disposal system and a dumping strategy that would either return wastes to a natural ecosystem or isolate them harmlessly. Alternatives for Government policy or industrial applications are being identified through computer scanning of a matrix of industries and chemical processes.

The International Research and

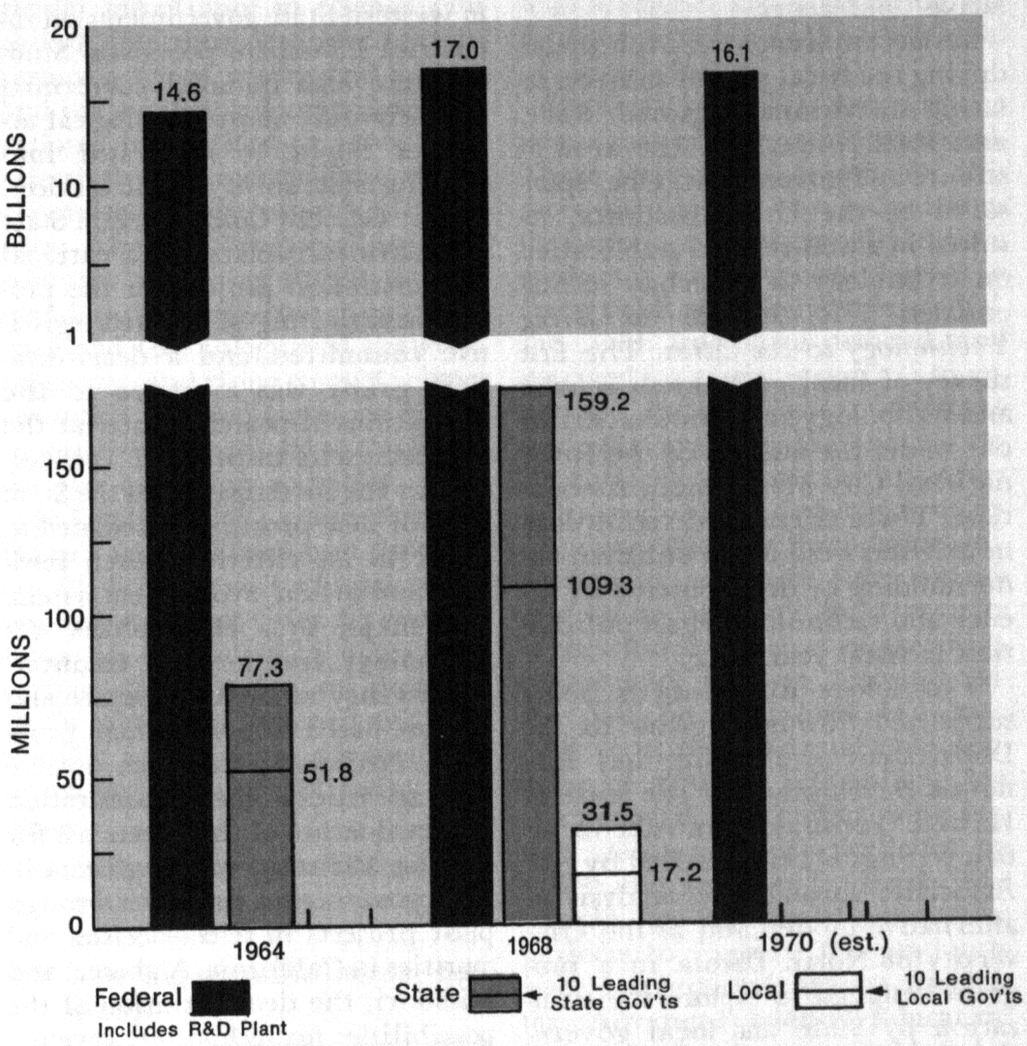
Development Corporation of Washington, D.C., has developed a theoretical model to describe the flows of physical materials and energy throughout the U.S. economy and to and from the environment, taking into account the actual physical and chemical transformations which occur. It is expected that this analytical approach can aid various Government agencies in fulfilling the requirements of the National Environmental Policy Act of 1969, and to assist the Bureau of the Census in structuring the 1972 Census of Manufacturers.

### *Problem Assessment*

An interdisciplinary team at the University of Oklahoma is performing a technology assessment of offshore oil operations. Projections of the technologies inherent in these operations will be made for 10 to 15 years into the future, and assessments will concern a wide range of consequences–from legal-political to physical-biological. The results will point out and analyze alternatives available to implement policies for offshore oil facility management. The results will also be couched in the context of future national energy needs. Barring unforeseen developments, oil availability will play a large part in satisfying those needs over the next few decades. Past spillages and leakages illustrate the risks and costs inherent in the transportation of oil and in operation of offshore oil facilities. The analysis being undertaken should contribute to needed national and international perspectives on this problem.

Hittman Associates, Inc., of Columbia, Md., is conducting an "Evaluation of the Ecological, Resources and Socioeconomic Impacts of Advanced Automotive Propulsion Systems." The objective is to define and evaluate the major ramifications of the transition from present internal combustion engine technology and practices to any of the potential alternatives. Transitional effects on materials resources, environmental ecology, energy resource balance, and the socioeconomy will be stressed. A systems analysis approach will enable evaluation of component and total effects of the transitions and comparison with present system baselines. Optimization trends will be identified and assessed as will the policy implications for pertinent areas of the public sector.

**RESEARCH AND DEVELOPMENT EXPENDITURES BY FEDERAL, STATE AND LOCAL GOVERNMENTS FISCAL YEARS 1964-1970**




## INTERGOVERNMENTAL SCIENCE PROGRAMS

The Intergovernmental Science Programs assist State and local governments in strengthening their capabilities to foster and support the development and use of scientific methods and technologies, and to discover and exploit ways of enhancing the application of scientific methods and technologies by these levels of government as they deal with their critical needs.

The Office of Intergovernmental Science Programs administers its functions in close coordination with the intergovernmental activities of the Federal Council for Science and Technology (FCST), and provides both the chairmanship and the executive secretariat to the FCST's Committee on Intergovernmental Science Relations. Close coordination is also maintained with the National Governors' Council on Science and Technology and with the

Science and Technology Committees of the National Governors' Conference and the National Legislative Conference.

Seven conferences were conducted during the fiscal year on subjects relating to national, regional, State, and local concerns in the area of science and government. One, sponsored by the Urban Institute, resulted in a well-received publication on technology in the urban setting entitled *The Struggle to Bring Technology to the Cities*. The first survey of local government science and technology activities was carried out under the auspices of the International City Management Association. Three science and technology newsletters designed to enhance understanding of developments in science and technology began publication in fiscal year 1971.

Technology forecasting is being supported through a grant to the Department of Planning and Economic Development of the State of Hawaii. Technology transfer in urban settings is being studied by Abt Associates through the analysis of alternative models, and at the University of North Dakota in a program designed to explore the utilization by State and local governments of graduate-level and other research. Technology assessment techniques at the State level are being explored by the National Academy of Public Administration and the Western Interstate Nuclear Board, which will recommend optimum decision-making procedures in western State governments on industrial Plowshare proposals. Studies were also initiated concerning how scientific and technological activities might be integrated into existing systems of public services.

The Citizens Conference on State Legislatures is planning a national demonstration project for the professional staffing of selected legislative committees and a demonstration grant was awarded to the Operations Research Center at the Massachusetts Institute of Technology for the investigation at the State level of new procedures designed to result in an effective citizen feedback and citizen involvement system.

A major area of emphasis was technology transfer and reconversion as they relate to aerospace and defense-based activities and problems. Projects in this area involve such activities as the demonstration and evaluation of the potentials for placing scientists and engineers in local government positions through pilot projects in selected cities and counties in California, Alabama, and Missouri; the demonstration of the possibilities for technology development available through a State government-based technology exchange; and a study of the role that colleges of engineering should play in their regional environments.

## *Science Education Support*

The last several years have seen increasing stress in two areas of particular importance in science education: the strong tensions in the interface between science and society, and the mounting demands on educational institutions to serve more effectively an increasingly varied clientele with diverse goals and abilities. The resulting problems of scientific manpower supply and demand, public understanding of science and technology and their implications, and rising costs of science education with no apparent rise in productivity are crucial to the Foundation's education activities.

In fiscal year 1971, these problems led to a range of responses throughout the Foundation's education and resource study activities. In general, focus has shifted from almost exclusive concentration on students likely to major in science and continue to a traditional advanced research degree to the following concerns:

- making professional science education more responsive to current needs;
- fostering scientific literacy generally;
- making science education more effective.

In graduate education, the first steps have been taken in what is likely to be a major reorientation of the Foundation's direct support of education in the sciences at that level. For the past several years, the principal mechanisms for such support have been: fellowships (awards to individuals selected by NSF in national competitions); traineeships (awards to graduate students selected by universities successfully competing for NSF grants); and grants for the support of field training or training in advanced, highly specialized areas—training not generally available in graduate curricula. On a comparative basis, only relatively modest emphasis has been given to the support of projects aimed at improving the educational system itself, e.g., the development of new graduate programs designed to give science and engineering students alternatives to the traditional advanced degrees.

In fiscal year 1971, however, no new traineeships were granted. There were several reasons for this decision. First, it was judged that the supply of conventionally trained graduates with advanced degrees in many fields was in approximate balance with immediate demand, and the need for special incentives to encourage individuals to undertake graduate training looking to research careers in those fields appears to have diminished. Second, other programs and new Foundation initiatives in education were considered to be of higher fiscal priority at this time. A review of the manpower and program priority balance will be maintained. However, NSF continued its traditional program of graduate fellowships, but at a reduced scale, emphasizing further the concept of excellence on which the program is based. The vehicle for support of innovative projects to improve the graduate-level instructional process itself is the Advanced Science Education Program. Funds are provided for the development of experimental courses, new curricula (e.g., alternative advanced degree programs to broaden career options), and training aimed at specific areas of need, such as the environmental field.

The problems of interactions among science, technology, and society are receiving much attention in undergraduate instruction. Student response has stimulated the development of interdisciplinary course sequences to clarify and define some of these problems and work toward successful solutions. A second area of emphasis is the strengthening of additional choices in higher education other than the departmental 4-year science major, e.g., instruction for prospective technicians and technologists, special programs for future teachers of sci-

ence, and upgrading of science instruction in the first 2 years of post-secondary education. Along with improvement in content, changes are also being introduced in the mode of instruction. Audio-tutorial techniques for transmitting information allow the student to work at his own pace, with the instructor available for individual help and tutoring. Even greater choice and responsibility are given to students in the new program of support for Student-Originated Studies, in which the students themselves determine for a portion of their education what they will study and how they will go about studying it.

Pre-college programs continue to stress curriculum reform and actual implementation of improved courses and teaching approaches in the schools. Curriculum development goals at this level include general education in science for the nonscientist with emphasis on individual multi- or interdisciplinary problem-oriented courses, and possible approaches to problems of both horizontal and vertical integration of science education, that is, across fields of science and mathematics and across grade levels. Some completely new approaches are also being explored through a few projects developing science components for new kinds of schools and school organizations, and patterns for outside-the-classroom instruction. The teacher training programs comprise a range of activities varying from courses for individual teachers through the training of leadership personnel to support of comprehensive region-wide plans for the upgrading of a particular aspect of science education. Summer and in-service institutes instruct individual teachers in new curriculum materials; academic year institutes and resource personnel workshops develop master teachers and supervisors able to institute reform programs; and cooperative college-school science projects and comprehensive grants make possible systematic approaches to the problems of improving science education in the schools. Thus, the programs at this level form an interrelated network serving to improve the quality of instructional tools and the capability of the instructors expected to use these tools.

**Table 7**
**Education in Science**
**Fiscal Year 1971**
**(Dollars in thousands)**

| | Number of proposals received | Dollar amount requested | Number of awards | Funds obligated |
|---|---|---|---|---|
| **Graduate Education in Science:** | | | | |
| Fellowships | 12,322 | $ 80,392 | 2,497 | $15,322 |
| Traineeships | 315 | 106,412 | 315 | 19,777 |
| Advanced science education program | 179 | 10,455 | 79 | 3,124 |
| **Undergraduate Education in Science:** | | | | |
| College teacher program | 458 | 10,459 | 339 | 4,905 |
| Science curriculum improvement | 168 | 28,743 | 118 | 9,583 |
| College science improvement program | 147 | 21,862 | 66 | 5,500 |
| Undergraduate student program | 1,559 | 20,245 | 502 | 5,502 |
| **Pre-College Education in Science:** | | | | |
| Institutes | 1,196 | 52,081 | 561 | 25,873 |
| Comprehensive and systems approach | 6 | 2,465 | 6 | 1,466 |
| Cooperative college school science program | 439 | 18,508 | 158 | 4,899 |
| Course content improvement | 120 | 15,102 | 74 | 6,061 |
| Summer science training | 370 | 6,054 | 126 | 1,839 |
| **Planning and Policy Studies** | 47 | 4,472 | 38 | 3,219 |

The Foundation's program of science resources and policy studies is designed to help provide the framework for the formulation of science policy and effective management of the scientific enterprise. Science resources studies provide a more thorough understanding of the present and long-range issues affected by the status of the nation's basic resources for science and technology—scientific and technical manpower, science education, scientific institutions, the funding of research and development, and the economic impact of research and development. Science policy studies address the identification and analysis of key science policy issues such as the status of science in general and of its numerous disciplines, methodologies and criteria for the allocation of resources, and the dynamics of the research process and its management.

Special projects worked on during this past year related to a number of current issues: unemployment of scientists and engineers; the impact of changes in the rate of Federal funding on academic institutions; a state-of-the-art review of the relationship of research and development to economic growth and productivity; additional work designed to pinpoint the relationship between key scientific events and subsequent technological innovation; and detailed projections of future science and engineering doctorate supply and utilization. Studies of various funding, manpower, and policy issues continue to provide the basis for evaluating the current state of the scientific enterprise.

Table 7 reflects NSF support for educational activities and resource studies in fiscal year 1971.

## GRADUATE EDUCATION IN SCIENCE

While the encouragement of innovative patterns in graduate science education became an explicit major NSF goal during the past year, the largest proportion of funds continues to be invested in the development of scientific talent through support of individuals,

**Table 8**

**NSF Fellowship and Traineeship Programs**
**Fiscal Year 1971**

| Program | Awards requested by institutions | Individuals involved in applications | Awards offered | Net amount |
|---|---|---|---|---|
| Graduate traineeships | 18,564 (227)[1] | ..... | 3,458 (224)[1] | $18,044,578 |
| Summer traineeships for graduate teaching assistants | 9,110 (215)[1] | ..... | 926 (208)[1] | 1,041,180 |
| Graduate fellowships | ..... | 9,315 | 1,972 | 9,418,229 |
| Postdoctoral fellowships | ..... | 1,546 | 185 | 1,300,000 |
| Senior postdoctoral fellowships | ..... | 395 | 54 | 689,000 |
| Science faculty fellowships | ..... | 982 | 214 | 3,000,000 |
| Senior foreign scientist fellowships | ..... | 84 | 72 | 914,395 |
| Total | 27,674 | 12,322 | 6,881 | $34,407,382 |

[1] Number of institutions involved.

principally through the fellowship and traineeship programs. Fellowships for U.S. citizens have been available not only to graduate students seeking advanced degrees but also to both young and senior postdoctorals, and experienced faculty members whose teaching responsibilities are primarily at the undergraduate level. In addition, fellowships have enabled a number of distinguished senior foreign scientists to spend up to a year in residence at U.S. universities, where they contribute to the strengthening of the graduate programs of these institutions. A summary of the 6,881 fellowship and traineeship awards made in 1971 is given in table 8.

Another 2,200 individuals—graduate students, postdoctorals, university faculty, and research scientists—attended NSF-supported Advanced Training Projects designed to increase the participants' qualifications in research and teaching. Convened for periods of from 1 week to an academic year, the projects consist of conferences, formal courses and field training programs, and cover a wide range of science disciplines. Examples of projects supported this year illustrate typical kinds of activities:

- Social scientists at the University of Colorado explored population growth, inheritance of behavior patterns, and related problems in a summer training project in the interdisciplinary area of population biology and the social sciences.
- Glaciologists studied the Juneau ice field in Alaska in a summer project dealing with arctic sciences and mountain environments.
- Biologists at the Oak Ridge National Laboratory, Tenn., analyzed the effects of radiation on mammals.

### Traineeships

Initiated in 1964 in engineering only and expanded 2 years later to cover all fields of science, the graduate traineeship program peaked in 1968 with a total of 5,656 awards, including 2,211 for beginning graduate students. Its purpose was twofold: to avert a possible shortage of scientific manpower and to attain a wider institutional distribution of student support. The problems that the traineeship program was designed to address appear at present sufficiently well in hand so that a general program to encourage traditional graduate study in the sciences is no longer deemed of prime importance. Hence, except for summer-only awards, no new traineeships were granted this year, and none are planned for fiscal year 1972. The 3,458 graduate traineeships awarded this year covered only commitments from prior years; such commitments will number 1,808 in 1972, and 982 in 1973. The Foundation plans to follow carefully current and projected trends in manpower supply and demand in general and for specific and new fields, as well as the effects of changing support patterns on institutions, so as to institute mediating measures when necessary.

### Graduate Fellowships

Although the program of general graduate traineeships is being phased out, NSF plans to continue its program of graduate fellowships, but on a reduced scale and on a restructured basis.

Through this year, 2-year fellowships were offered to new applicants, with the option to apply for renewal of the fellowships. Beginning in 1972, new awards will be offered for periods of 3 years (subject to the availability of funds) only to individuals who will be beginning graduate students or who have had only a minimum amount of graduate training. The second and third year of the fellowship will be approved by the Foundation on certification by the institution of the student's satisfactory progress toward an advanced science degree. Awardees will be required to begin their fellowship activity not later than the fall term following the receipt of the award, but will be permitted to use the remaining 2 years of support within the following 4 years. This will enable them to engage in other approved activities that contribute to their training. Increases in the basic fellowship stipend and in the cost-of-education allowance to the university are also planned.

The number of graduate fellowships awarded in fiscal year 1971 (1,820 awards) reflects about a 25 percent reduction in the level at which this program has been supported during each of the past 5 years. This was necessary as part of a transitional measure toward a reduced total program in fiscal year 1972. Beginning then, about 500

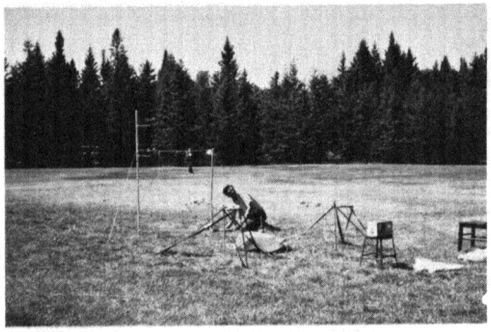
new awards will be made each year, with an estimated total of 1,500 graduate fellows being supported at any given time.

NSF has awarded graduate fellowships, without interruption, since 1952. The program is designed for the support of individuals with the greatest potential for assuring the nation's continued well-being in the sciences. It is the only Federal program available over the broad spectrum of the sciences in which the fellows are selected solely on the basis of ability in a national competition. The reduction in the number of awards and the planned changes in tenure arrangements and financial terms are designed to further emphasize quality over numbers.

### Advanced Science Education Program

In addition to its responsibilities for the Advanced Training Projects described above, the Foundation's Advanced Science Education Program (ASEP) supports a wide range of quality-based projects to improve the graduate-level instructional process itself, such as development of experimental courses, new curricula, training aids, and conferences on problems of graduate science education. The Foundation hopes to increase emphasis on this type of support, while reducing programs of primary benefit to individuals. In fiscal year 1971, ASEP awarded 36 grants at a funding level of $1.4 million.

*Alternative Degree Programs.* Support of the development of alternative kinds of degree programs, which was initiated in fiscal year 1970 with a grant to the SESAME (Search for Excellence in Science and Mathematics Education) program at the University of California at Berkeley, continued this year with three awards. One was made to the University of California at Los Angeles for planning a new program in environmental science and engineering. This new program is expected to lead to a doctorate in 5 years, one of which will be devoted to interdisciplinary problem-solving courses. At the completion of his course work, the student will spend 2 years in applied research at an outside institution—Government, industry, or nonprofit corporation — during which time he will work on practical problems under the supervision of an expert who has agreed with the university to join the student's doctoral committee. After satisfactory completion of 2 years of applied research and the submission of suitable reports, it is anticipated that the student will be awarded the degree of Doctor of Environmental Science and Engineering.



With NSF support, the Committee on Institutional Cooperation, representing 11 universities in the midwest, sponsors a Biometeorology Graduate Training Program to develop proficiency in the use of expensive and sophisticated research tools necessary for ecological studies. Top: Student compares the energy balances of meadow versus forest. Center: Group prepares for measurements of light, temperature, and oxygen profiles in Lake Itasca, Wisc. Below: The turtle is instrumented with thermocouples on a light cable to permit the student to follow thermal regime and calculate its heat balance. (Photos University of Wisconsin)

Another award went to the University of Montana for the development of a new mathematics Ph.D. option. This new option will complement the present program for training research specialists. It is designed to produce competently trained and properly oriented mathematics teacher-scholars to staff undergraduate colleges and work with other scientists on socially important interdisciplinary projects.

The third award in this category was made, in conjunction with a complementary award from the National Institute of Mental Health, to Northwestern University to initiate a pioneering program to produce scholars trained in both law and the social sciences. Upon successful completion of this 5-year program, students will receive both a Ph.D. and a J.D. The first summer for each student will be devoted to special team-research training emphasizing legal issues, while the second summer will emphasize social science content and methodology.

*Toward Training Environmental Problem-Solvers.* There are several Federal agencies which can provide for the assessment of national environmental problems and/or furnish research support directed toward their solution. There are, however, relatively few agency programs oriented toward the training of individuals who will be competent to serve as future university teachers and/or researchers, or as practitioners or technologists in the environmental field. This has been one of the thrusts of ASEP in the past several years. Some potential researchers and university teachers

can be trained via the research assistant method, as has been done in the past. However, there are almost no programs designed to produce prospective practitioners and technologists in the field, and this type of personnel currently is in short supply. The need to train both future teachers and practitioners for this area of national concern and increasing activity led to nine awards.

Six grants were made in fiscal year 1971 for training in methods of control of pest populations. Five of these involve an interuniversity doctoral training program in an innovative cooperative project whereby all of the students have access to the expertise of the staff and to the equipment and facilities of five centers distinguished for their work on pest population control. The centers are the University of California, Berkeley; the University of California, Riverside; Oregon State University; Cornell University; and North Carolina State University.

Three of the projects are concerned with the advanced education of practitioners, who will be prepared to act as liaison between State or Federal Government personnel, agricultural and industrial producers, and research scientists in universities. Their future jobs will likely involve serving as advisers on the best procedures for solving immediate environmental problems. The particular problems stressed in the projects are acid-mine drainage and disposal of sewage effluent (Pennsylvania State University), marine pollution (Rutgers), and integrated methods of insect pest control (North Carolina State University). These are novel types of graduate degrees in applied ecology; it is expected that the students enrolled will not go on to research doctorates but will terminate at the master's level and then enter on their career jobs in environmental science. For this master's level program, there also exists a cooperative arrangement among the schools for the exchange of students and staff.

*Student-Originated Projects.* One pilot grant was made during fiscal year 1970 in the category of Interdisciplinary Student-Originated Research Training (ISORT) projects. Even though this activity was not widely publicized, 12 proposals were received from graduate students for consideration during fiscal year 1971, three of which resulted in grants. Seven students sponsored by the University of Oregon are carrying out a seismological, geological, and ecological study of the Galapagos Archipelago. A grant to the Claremont University Center was for an investigation of the skill-transfer ability of aerospace professionals to other fields which will be made by two students whose combined backgrounds include training in industrial psychology, human relations, organization theory, economics, and statistics. The third project is concerned with a study of voluntary birth planning involving 2,000 female subjects between the ages of 18 and 25 in Ingham County, Mich. The birth planning study is being carried out under the direction of two graduate students (one in multidisciplinary social science and one in ecological psychology) and 10 student assistants drawn from the Schools of Human Ecology, Nursing, and Medical Science at Michigan State University.

In funding ISORT projects, the Foundation seeks to provide students with a novel type of training which, if successful, could have a significant impact on tradition-bound graduate curricula. Support for these projects is also a partial response to the growing desire of graduate students to exercise greater independence and stronger initiative in their training.

### Experimental Projects

Examples of one-of-a-kind activities include support for training graduate students in the preparation of science courses for nonscientists; an institute for academic law librarians on the social, behavioral, and natural sciences which is designed to help assimilate the literature from these sciences into the curricula of law schools; and an experimental project for re-education of mid-career unemployed scientists and engineers. This last project is designed to test novel approaches in retraining, conversion, and appropriate utilization of the major resource represented by the pool of unemployed scientists and engineers.

## UNDERGRADUATE EDUCATION IN SCIENCE

At the college and university level the interactions between science and society are giving rise to marked changes in what is taught, to whom it is taught, and how the teaching takes place. These reactions are in part responsible for the Foundation's decision to expand the target audience of its education efforts to reach that large group of students whose principal interests lie outside of science, and to bring to science students a new awareness of what nonscientists consider important. Coupled with this is an expansion into an area of postsecondary education designed to provide to technicians and technologists the kind of scientific understanding and skills needed to operate the complex technologies of modern society.

In addition, new devices are affecting the way in which the sciences as well as other subjects are taught, making possible increased use of a variety of new instructional modes such as self-paced instruction. Thus, in science education the Foundation is supporting experiments ranging from sophisticated machine-based instructional systems to those in which the student plays a major role in determining the method and the pace of the instruction.

### Changes and Improvement in Content

Three projects concerned with providing meaningful instruction on problems of science and society are receiving Foundation support: (1) the Project on Science, Technology, and Society, at Cornell University; (2) the development of an Interdisciplinary Curriculum in Environmental Studies, at Dartmouth College; and (3) the Project to Build Educational Bridges Between Science and the Humanities, at the Rensselaer Polytechnic Institute (supported jointly with the National Endowment for the Arts and Humanities). In these programs, courses at the introductory level are focused on the entire undergraduate population, not just the science and engineering majors. The content is broad and exploratory, emphasizing the strategies by which explicit and manageable problems within complex societal settings are identified, and the intellectual resources necessary to attack them are marshaled. Typical course topics are social implications of engineering, biology and society, earth as an ecosystem, human dimensions of environmental problems, resources and man.

Upper division courses rely on the skills and information acquired through studies in the classical disciplines, and take advantage of diverse backgrounds in a series of problem-oriented workshops. For instance, the Cornell seminar on Technology Assessment will bring together upperclass and graduate students of engineering, the physical sciences, sociology, and law. Rensselaer's project will include an emphasis on the long-range viability of man's society, and will engage students from the humanities and from engineering and science in an analysis of concepts of social and economic progress.

The same themes of science-technology-society and interdisciplinary studies run through many of the summer institutes for college teachers. At the Catholic University of America, R. J. Seeger's group is dealing with interdisciplinary approaches to the solution of contemporary problems, especially those arising in the life, environmental, and social sciences. At Colorado State University, J. Forbes McClellan presents an approach to botany, zoology, ecology, and geology which integrates these fields through study of their interrelationships occurring in the natural state.

Related to this trend is the melding of mathematics and computers with the social sciences, again reflected in the orientation of a number of summer institutes dealing with such topics as Quantitative Methods in Sociology (Loyola University, Chicago), Mathematical Psychology (University of Michigan), and Mathematical Applications in Political Science (Virginia Polytechnic Institute). Current trends in the social sciences are also influencing the subject matter of summer institutes, as illustrated by projects in Mass Political Communication (Ohio University), Urban Economics (Stanford University), and Linguistics, Logic, and Philosophy (University of Connecticut).

Summer activities informing college teachers of recent developments in such areas as Digital Computers in Chemical Instrumentation (Purdue University), Ocean Engineering (University of Rhode Island), Primate Behavior (University of California at Davis), and Models of Urban Spatial Structure and Ecology (Ohio State University) help assure that the content of courses and curricula will be kept up to date.

About 2 years ago, the Foundation began laying the groundwork for a program to develop an additional option in higher education, namely, the training of technicians and technologists. Projects to produce needed course materials are under way in electronics, chemistry, biology, and physics. The projects in biology and physics are the most recent. Both will produce an array of instructional modules from which the instructor can select those best adapted to his needs. The projects are national in scope, and involve widespread testing of the materials before a final version is prepared. The biology project plans some 100 modules; the physics project, 20 modules produced at four different cooperating institutions.

An experimental grant of $77,000 designed to test the feasibility of institutional support for technician education was made to Charles County Community College, La Plata, Md. This college has instituted a pioneering curriculum to train technicians in the complex physical, chemical, and biological factors of estuary environments. Twenty-five students will enter the program in the fall of 1971. At the end of 2 years of successful work, they become eligible to receive the Associate of Arts degree in estuarine resource technology.

The technician education program is further bolstered by summer institutes at Rochester Institute of Technology and at Wentworth Institute which provide special training for 55 persons who teach electrical or mechanical technology.

With the announcement of the Technician Education Development Program, the implementation of improvements in specific institutions has begun. Institutions with technician training programs have responded quickly, and the Foundation expects to make this program fully operational during the coming year.

### Changes and Improvements in Modes of Instruction

*Self-Paced Instruction.* Increasingly, the trend toward self-paced instruction is influencing science education in colleges and universities. Students vary tremendously in their maturity, degree of interest in academic work, preparation for college-level study, and motivation. Self-paced instruction appears perhaps

the most practical means for accommodating to differences among students. Rapid advancements in instructional technology have given added impetus. Instructors are likely to adopt, and students will quickly accept, tools which promise to remove from the classroom and put under the control of individual students the requisite amount of drill on factual material. Thus, self-paced instruction also helps reduce tedium for both the teacher and the student.

Self-paced instruction takes a variety of forms. Among the best known is the audio-tutorial scheme which is spreading widely from its center of development in the Division of Biology at Purdue University. Created initially by S. N. Postlethwait as an aid in teaching plant science, the approach has been adapted to courses in a variety of disciplines throughout the country and uses a wide array of techniques for transmitting information. The bulk of the instruction occurs in a semiprivate setting with a resource person always available, and involves self-testing and advancement to the next unit when the student has mastered each preceding one. The instructor is freed to a large extent from routine chores of teaching and is available for the kind of personal interaction with students associated with the tutorial mode of instruction.

With support from the Foundation, Dr. Postlethwait is now engaged in packaging for use by other institutions a broad program of instruction in biology. Each package or "minicourse" contains all the basic instructional materials needed by a teacher in presenting a given topic, and so arranged as to encourage individual modification to meet the requirements of a specific teaching situation.

Another variation is the so-called Keller method, utilized by Ben Green of the Education Research Center at MIT, which involves self-pacing on the semester scale rather than a weekly schedule as used by Dr. Postlethwait. The Keller method depends more heavily on written materials and does not make use of the regular group meetings which characterize the Postlethwait procedure.

*Student-Originated Studies.* Recognizing the role of the student in determining what he will study, the Foundation has initiated a program of support for student-originated studies to:

- encourage college students to express in productive ways their concern for the quality of the environment;
- provide support for groups of college and university students who can demonstrate their readiness to assume increased responsibility for their own educational development.

Students, both undergraduate and graduate, in groups generally of five to 15 persons, submit proposals describing the scientific or technological studies they wish to carry out and the costs involved. Key features of the projects are that they should be student-originated, student-planned, and student-directed interdisciplinary studies dealing with a problem or set of associated problems related to the environment—physical, biological, or social. The host institution, in each case, is a 4-year college or university, and a faculty member is designated project advisor, but the students and the student project director carry full responsibility for the work. The projects occupy the student participants full time for a period of 10 to 12 weeks.

In fiscal year 1971, 560 student groups submitted proposals, with all States except Arkansas and Montana represented. Undergraduate students were invited to serve as panel reviewers with full voting rights, a first in NSF procedures for proposal evaluation. Each panel also included four scientists or engineers, generally faculty members, one each representing the biological sciences, physical sciences, social sciences, and engineering. The $1.5 million allocated was enough to fund a total of 103 proposals from 97 institutions in 47 States and the District of Columbia, providing support for 1,102 participants. Even so, there were 185 meritorious proposals requesting $2.67 million for the support of 1,892 participants for which funds were not available. In an unprecedented move, the Director of the Foundation issued Letters of Honorable Mention to these 185 student groups, with copies to State governors and institutional heads. Several honorable mention recipients have successfully used this testimonial to piece together enough local support to go forward with at least parts of their planned projects.

*Bringing Institutes to Teachers.* For a number of years, the Foundation has supported summer institutes and short courses to give college teachers an opportunity to study recent trends in various disciplines with leading scientists. Typically, the faculty members were brought to a major campus where the institute or short course was being held. Last year the Foundation began experimenting with a different format in which leading scientists spend 2 days at each of a number of different centers within easy commuting distance of a substantial number of colleges. The scientist introduces his subject using whatever techniques of presentation he favors, and leaves with the teachers (his students) an array of reading assignments and homework pending his second visit several weeks later. At the second meeting, questions are discussed in the light of what has been learned, and loose ends are pulled together.

Experience with the trial projects suggests that this scheme is highly cost-effective. Travel and subsistence for participants are greatly reduced, the participants have an opportunity to study and reflect on the material at their leisure, and the plan ensures multiple exposure rather than the concentrated one-shot ses-

sions of conventional short courses. These new-style short courses are being expanded during academic year 1971–72. Through a grant of $586,000 to the American Association for the Advancement of Science, 12 field centers have been established, organized into three "circuits" of four centers each. Eleven courses have been arranged on such subjects as human genetics and societal problems, air pollution, and computer techniques for natural and social science faculties. More than 2,700 college teachers are expected to participate in these courses.

*Instructional Technology.* The computer continues to play a predominant role in technological support of instruction but, while powerful, it is not alone in this field. The instructional film still has its place. For example, cultural anthropologists are interested in a recently completed film on primitive tool-making in which the unique expertise of anthropologist Donald Crabtree in flintknapping was recorded by a team at Idaho State University.

The advent of relatively inexpensive and easy-to-use video equipment is bringing new competition to film for use in instruction. Video tape is especially useful to those who wish to prepare informal, on-the-spot illustrations of laboratory methods, procedures, or special phenomena. The ready playback and erasure capability enables both instructors and students to record, evaluate, and rework materials with minimum delay and expense. There are problems to be solved, such as incompatibility of various makes of video equipment, the high cost of color video, and development of a more general understanding of the potential and the limitations of the medium. Yet video is making a very strong bid for an important place in education.

An exceptionally advanced system in instructional technology is operated by the North Texas Association for Graduate Education and Re-

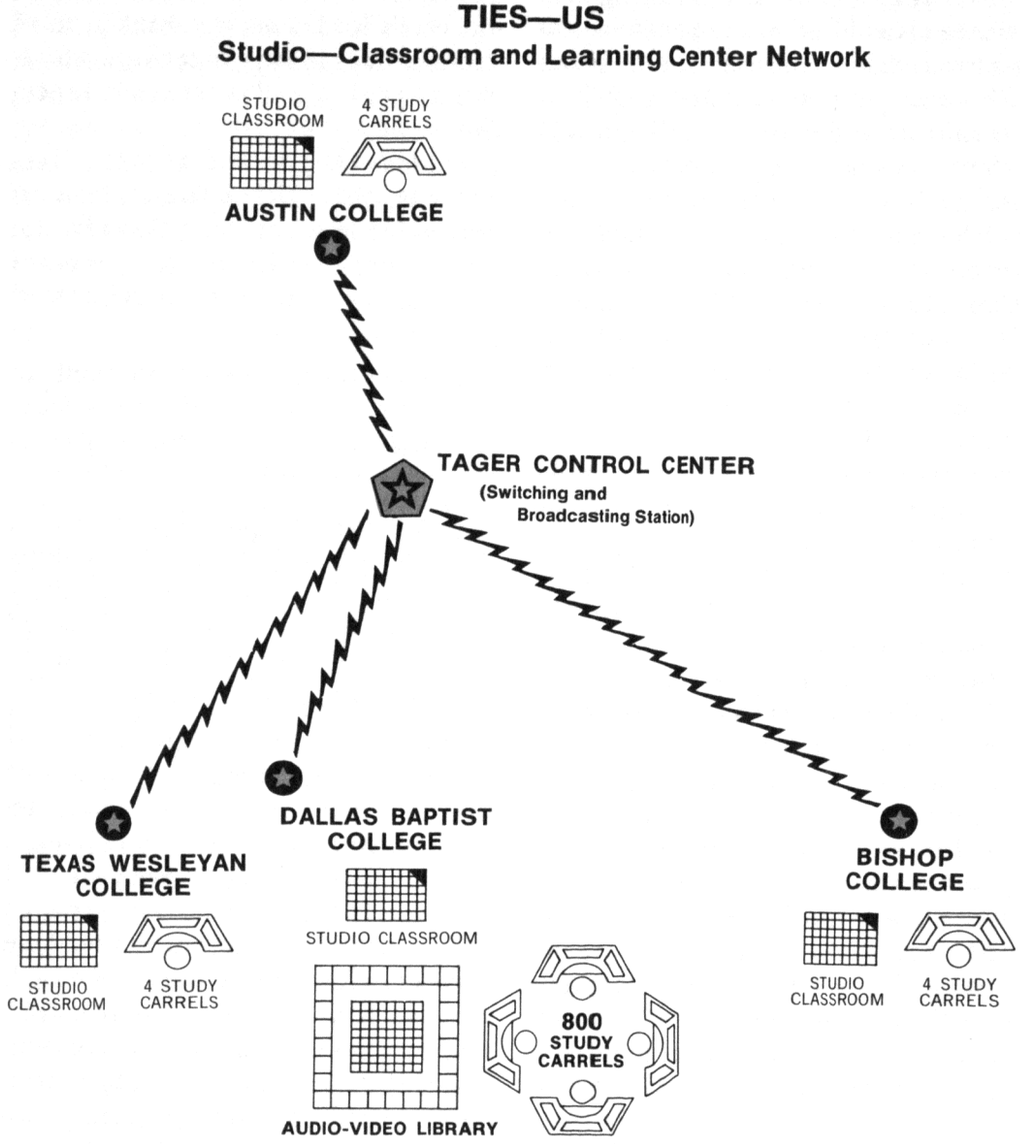
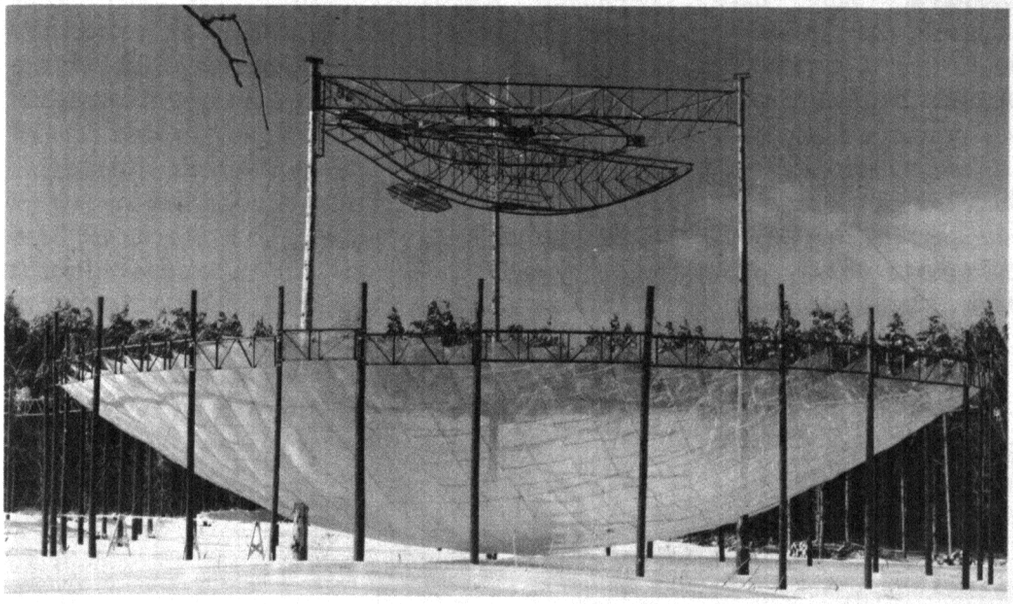



**Table 9**

**COSIP Section C Fiscal Year 1971**
**Cooperative Projects for 2-Year Colleges**

**AWARDS BY DISCIPLINE**

| Discipline | Number | Amount | Percent of Total $ | Number of Departments |
|---|---|---|---|---|
| Biology | 6 | $254,000 | 17 | 60 |
| Chemistry | 6 | 317,900 | 21 | 96 |
| Engineering | 3 | 192,600 | 13 | 22 |
| Environmental Sciences | 0 | 0 | 0 | 0 |
| Mathematics | 6 | 160,000 | 11 | 53 |
| Physics | 4 | 205,200 | 14 | 86 |
| Social Sciences | 4 | 224,100 | 15 | 103 |
| Interdisciplinary | 2 | 122,900 | 8 | 67 |
| Multidisciplinary | 1 | 17,600 | 1 | 7 |
| | 32 | $1,494,300 | | 494 |



First antenna of the Five Colleges Radio Astronomy Observatory. The wire mesh surface is supported by cables and 26 utility poles. The central feed structure is supported by three 70-foot poles and is steerable in both azimuth and elevation. (Photo NSF)

Students raise a 70-foot pole for the feed support structure of the fourth antenna for the Five Colleges Radio Astronomy Observatory. The first antenna, completed and in operation, can be seen at left. (Photo NSF)

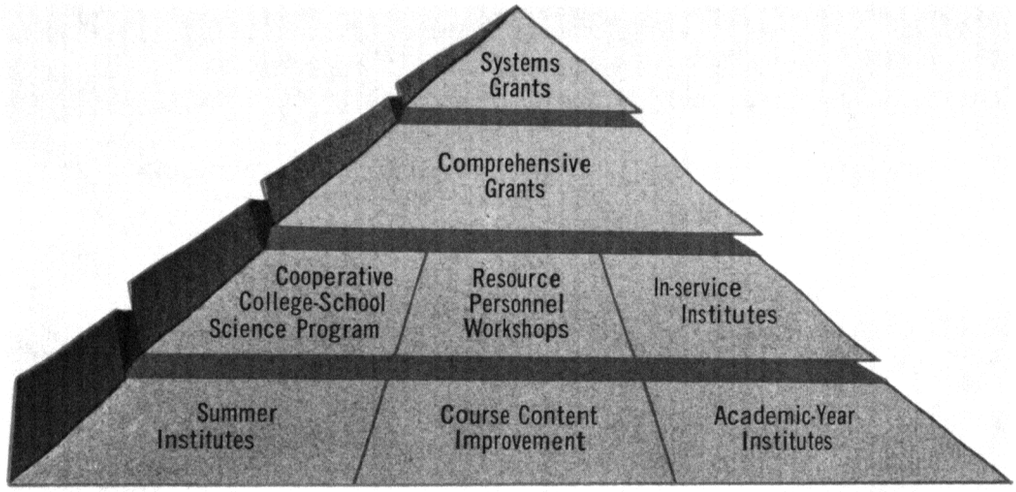
search (TAGER). The Dallas Baptist College has been added to the group of institutions making up the Tager Institute for Environmental Studies in Undergraduate Science (TIES-US), thereby bringing to the group a learning center with over 800 individualized audio and video carrels located in a unique library-conference faculty office building. The grant provides for a marriage between the traditional academic expertise at the previously supported institutions (Bishop College, Texas Wesleyan College, and Austin College) and the advanced methodology of Dallas Baptist. Not only is the electronic classroom extended to the new institution, but each of the other participating institutions is now connected to the 20 video and 100 audio channel "electronic library" at Dallas Baptist. The project offers the prospect of marked economy in professional staff time through the use of advanced mechanical and electronic tools coupled with carefully designed curricula.

*Cooperative Activities.* Through its program of Cooperative Projects for 2-year Colleges, the Foundation seeks to enliven and strengthen science instruction and to help smooth the transition into advanced education for the student who begins his higher education at a 2-year institution. This program has now had an effect, in one or more subject-matter areas, in slightly over half of all 2-year colleges in the nation. In fiscal year 1971, it reached into nearly 500 departments in nine disciplinary areas. Table 9 shows awards by discipline for fiscal year 1971.

One project, supported prior to fiscal year 1971, deserves comment because it is now nearing completion. With the cooperation of such funding groups as the Research Corporation, Sloan Foundation and others, a group of five New England colleges (Hampshire, Amherst, University of Massachusetts, Smith, and Mt. Holyoke) has developed a high-quality radio telescope facility for use by undergraduates participating in the "Five Colleges Astronomy Project." The accompanying photograph of the nearly completed telescope serves to emphasize that this is a facility which most predominantly undergraduate institutions could not realistically support, either financially or academically. By pooling resources, however, an economical and very high-quality program can be made available to undergraduate students.

# PRE-COLLEGE EDUCATION IN SCIENCE

With the exception of the Student Science Training Program aimed directly at high school students, Foundation programs at the pre-college level emphasize the development of improved instructional materials and patterns, together with a coordinated effort to assist instructors and school systems to put resulting reforms into practice. The interrelationship between programs is represented schematically in the accompanying figure. There is no sharp boundary between the layers, nor between activities in a given layer. The base layer provides new tools of instruction and in-depth studies of new curricula. The institutes also develop leadership capabilities for implementation activities. The second layer introduces implementation in schools through the Cooperative College-School Science (CCSS) projects, as well as in-service institutes, which may be focused on implementation or teacher education, or both. An implementation project may involve institutes, a Resource Personnel Workshop, a CCSS project, regional agencies or institutions, or various combinations of these. Both comprehensive and systems grants are new activities designed to extend the impact of local implementation. Table 10 summarizes the extent of Foundation efforts for in-service education of teachers.




One purpose of the Student Science Training Program is to bring outstanding students into contact with research scientists. In this picture, students and instructor participate in the study of aquatic biology at Rattlesnake Creek, Mont. (Photo University of Montana)

## Case Histories

An example of the variety of interactions just described is the Intermediate Science Curriculum Study, a 3-year sequence developed at Florida State University with joint support of the Office of Education and the National Science Foundation. The seventh-grade materials have been published in a commercial edition and used this past year by approximately 100,000 students in 47 States. The content is organized around the twin themes of energy, its forms and characteristics, and measurement and operational definition. Organizing themes for the eighth grade are matter and its composition, and model building. The ninth-grade course is designed to synthesize and extend the investigative experience and knowledge gained up to that point and to apply them to problems of practical and scientific significance.

The Foundation has supported the development of the eighth- and ninth-grade materials, and the dissemination of information, teacher training, and other implementation. Nine Resource Personnel Workshops have been supported in the past 4 years, extending leadership training to 308 individuals. Twenty-one projects supported in the past 3 years through the Cooperative College-School Science Program have provided a total of 468 training op-

**Table 10**

**Pre-College Education in Science Teacher Education Activities**

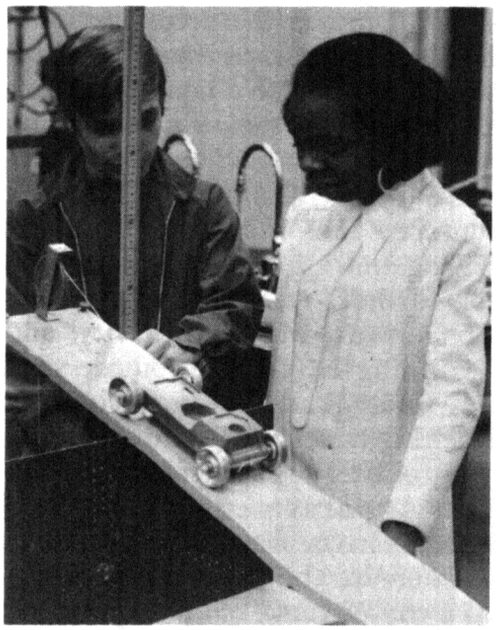
| Program | Fiscal Year 1970 | | | Fiscal Year 1971 | | |
|---|---|---|---|---|---|---|
| | No. of Grants | No. of Partic. | $ Amt. Granted | No. of Grants | No. of Partic. | $ Amt. Granted |
| Summer Institutes | 464 | 19,500 | $23,300,000 | 459 | 19,618 | $23,300,000 |
| In-Service Institutes | 348 | 24,021 | 5,214,917 | 222 | 11,780 | 970,612 |
| Academic Year Institutes | 64 | 1,530 | 8,421,014 | 28 | 444 | 1,296,188 |
| Comprehensive and Systems Approach | .... | ..... | ..... | 6 | 1,444 | 1,561,291 |
| Cooperative College-School Science | 136 | 6,309 | 1,760,000 | 158 | 2,684 | 4,729,900 |
| Resource Personnel Workshops | 53 | 2,078 | 4,654,421 | 43 | 1,726 | 1,690,000 |
| Totals | 1,065 | 53,438 | $43,350,352 | 916 | 37,696 | $33,547,991 |

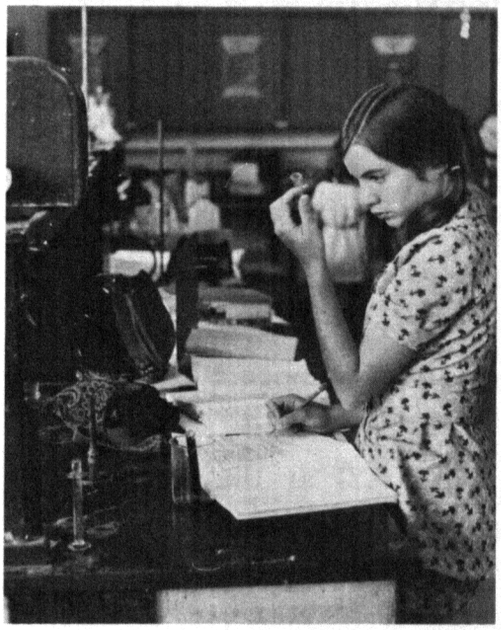
portunities. Nine Summer Institutes conducted in 1970 and 1971 have trained 355 teachers, and 11 In-Service Institutes in 1969, 1970, and 1971 have included 415 participants.

Another illustration is provided by the combination of projects initiated by a science supervisor in the school system of San Antonio, Tex., as a result of attendance at a summer conference on new science courses developed with NSF support. Through consultation with Foundation staff and the University of Texas, San Antonio school officials mapped out a general strategy for implementing the changes they desired, with NSF support to be used only where local funding was unavailable or insufficient. Among the existing resources pooled were NDEA funds (Office of Education) for science equipment, new course materials already available, and teachers who had attended NSF Summer and In-Service Institutes in biology, chemistry, and earth sciences. Very helpful relationships were established with local colleges —Trinity University, Incarnate Word College, and University of Texas. These resources were organized into several CCSS projects, beginning with the senior high schools. Results were:

- Biology—adaptation of BSCS* to all language groups in the schools, particularly Mexican-Americans.
- Chemistry — adoption of CHEMS** in the local area and State-wide adoption for Texas.
- Physics—spreading of PSSC***, increased professionalization of physics teachers.

The junior high school shows similar results, with CCSS projects organized around teachers who had already received good background through institutes and who were now accepted as leaders. Thus, grades 8 and 9 have NSF-supported science courses as the standard curriculum. Now a massive attempt for the elementary schools is being mounted for dissemination of *Science—A Process Approach* entirely with school system resources, together with an experimental joint effort with the University of Texas to develop integrated elementary mathematics-science based on the same curriculum but taught in each school by specially trained teacher specialists. In this last project, a Resource Personnel Workshop at the University of Texas and a Cooperative College-School Science project





The Intermediate Science Curriculum Study is a 3-year sequence developed for students in the 7th, 8th, and 9th grades. The content is organized around the themes of energy, its forms and characteristics; matter and composition, and model building. (Photos Florida State University)

*BSCS — Biological Sciences Curriculum Study

**CHEMS — Chemical Education Material Study

***PSSC — Physical Science Study Committee

These are major NSF-supported curriculum reform groups having developed multimedia courses in the three disciplines.

are closely linked, with participants in the former providing leadership and training for the inner-city elementary school teachers involved in the latter.

Similar patterns can be found on a somewhat lesser scale elsewhere, for example, in Memphis, San Diego, Northern Louisiana, Philadelphia, the Denver-Boulder area, and Portland, Oreg.

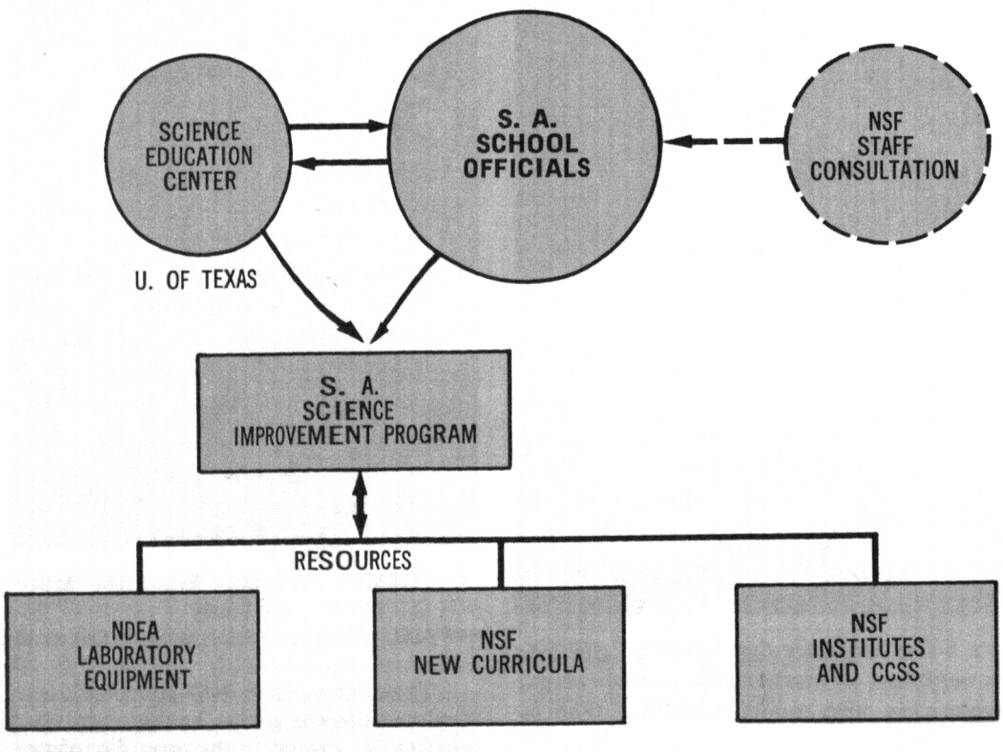
### Institute Programs

In the appropriation act for fiscal year 1971, a large proportion of funds for in-service education of teachers was earmarked for support of summer institutes for secondary school teachers. As a consequence of this, Academic Year Institutes (AYI) had to be limited to projects providing leadership and supervisory training. Such projects could have a "national orientation"—drawing participants for leadership training from the country as a whole—or a "regional orientation" focused on a service area around the host institution. Of those in the first category, the AYI at the University of Wisconsin is a good example. Ten science teachers and 10 mathematics teachers who have strong academic and teaching records, hold master's degrees in science or mathematics, and are interested in supervisory training are selected nationally for a full calendar year of advanced work at the University of Wisconsin. During this time, each participant spends a semester of supervisory internship in a selected school system, which may be in one of the larger city systems in Wisconsin or be in association with one of the Cooperative Educational Service Agency (CESA) districts in that State. The other semester and the related summer are spent in academic work relevant to supervision, but concentrating on the participant's specific discipline. The cooperating school systems contribute substantially to the project.

The AYI at the University of North Carolina is representative of the second or regionally oriented type. This project involves an interrelated mix of three categories of participants from North Carolina: experienced teachers, intern teachers, and undergraduates who are preparing to become teachers. Twelve intern teachers, after spending a summer and a semester in residence, will be formed into six teams, each of which will replace an experienced teacher who will then return to the campus for a full semester of study. During the preceding summer, the six experienced teachers will have been on campus for one of the summer sessions, interacting with the intern teachers who will replace them. During the following summer, the experienced teachers will again be in residence on campus for further work in the program. Concurrent with this activity, and beginning in their sophomore year, six undergraduates preparing for teaching careers will be involved in progressively more responsible positions as paraprofessionals, working with the interns and the experienced teachers in the cooperating schools. As a consequence of this experience, their awareness of the practicalities of teaching as a career and their dedication to the profession should be enhanced.

A wide variety of opportunities for part-time or short-term, full-time study for secondary school teachers without stipend support is included in the In-Service Institutes Program. These activities are characterized by a specific local orientation and a low relative cost. By encouraging the use of off-campus sites which often makes it more convenient for the teachers to attend, In-Service Institutes have the potential of reaching a larger fraction of the teachers than other teacher education activities. Every effort is made to encourage innovative activities and broaden the scope of the program, particularly in such areas as the social sciences and technical education. For example, the institute at Queens College, New York, will introduce 40 teachers in

**SAN ANTONIO SCIENCE CURRICULUM IMPROVEMENT**



greater New York to sociology and Sociological Resources for the Social Studies materials and teach them to conduct in-service training among their associates in area schools. This use of the "multiplier effect" will be an important component of any effort to reach a substantial fraction of the total teacher population.

Projects in the Summer Institute program range through all the scientific disciplines, with emphases on leadership training through sequential institutes and on use of new curriculum materials. Approximately one-fourth of the institutes for the summer of 1971 were based on new curriculum materials developed through Foundation grants, and another fourth had components involving these materials to a lesser degree. An innovation introduced in the Summer Institute program is exemplified by five projects in which groups of participants from a particular school attend the institute to develop and adapt course material for use in their own classes when they return to school. One such project enrolled 20 participants in teams of two to five teachers from a single school. Admission to the institute was based on the merits of proposals from the teacher groups for the summer's work, with the period of participation varying from 6 to 10 weeks. The staff of the Education Research Center at MIT provided support, guidance, and facilities for the participants in the institute.

### New Patterns in Teacher Education

The two top layers of the figure on p. 74 represent new ways to organize teacher education, both initiated in fiscal year 1971. Activities include both pre-service and in-service teacher education components and place strong emphasis on interaction with schools in the region of the host institution to help meet their needs. Five Comprehensive Grants were awarded in fiscal year 1971 to the University of Mississippi, University of Notre Dame, San Jose State College, the University of South Dakota, and the University of Wyoming.

The Comprehensive Project at the University of Wyoming is a good example of this new program. The University of Wyoming has been continuously engaged in teacher education activities since 1954. These activities have increased the university's interest in the education of secondary school teachers of science and developed a close working relationship between the university and the high schools of the State. Through the Comprehensive Project, a system of "portal schools" will be developed throughout the State to serve as centers where teachers will be trained in the use of newly developed curricula and materials. Conducting these in-service programs will be teachers who will have been trained in summer and academic year programs at the university. The "portal schools" will also provide prospective science teachers with the opportunity to work under the guidance of a master teacher. An associated intern program for post-baccalaureate certificated teachers will permit both the interns and the experienced teachers whom they will in part replace to acquire appropriate advanced training. Also part of the program are a distinguished professional chair in science education, extension of activities to neighboring States, and a science teaching center to serve as library, research center, and coordinator of project activities.

The systems approach, represented at the top of the tetrahedron on page 74, attempts to focus the now more or less independent educational efforts of Federal, State, and local government, and of private agencies on regional science education needs. In this context, a system is defined as an integrated group of interacting agencies, designed to carry out a predetermined function. The agencies in question may include institutions involved in the education of science teachers; a State department of education, other State and Federal agencies; cooperating school districts; private foundations, and industrial and business organizations. The function to be performed is to be expressed in terms of objectives and related to the overall plans for science education in the region.

The first experimental grant for this approach was awarded in fiscal year 1971 for the Del Mod System, a State-wide coordinated project in Delaware planned cooperatively by the University of Delaware, Delaware State College, Delaware Technical and Community College, the Delaware State Department of Public Instruction, the school systems of Delaware, the DuPont Company and the National Science Foundation. It is organized around two concepts: Science Resource Centers and Science Education Field Agents. The four Science Resource Centers will serve as focus for various aspects of in-service and pre-service teacher education, as sources of materials, and as bases of operation for Science Education Field Agents. The Science Education Field Agents will provide liaison between the institutions of higher education and the school systems in roles somewhat similar to County Agricultural Agents, having major responsibility for in-service education and for implementation in the schools. Around these key concepts will be built a comprehensive mix of activities for in-service and pre-service teacher education, including the development of curricular materials in marine science and population studies, with related curricular changes and new teaching strategies in the classrooms of the schools in the State. The implementation phase has been planned in close consultation with the 26 school systems in Delaware whose cooperative involvement will increase as the project develops. Attention will also be devoted to technical education, initially through the development of a science education technician program at Dela-

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ware Technical and Community College. In the first phase of the project, the major thrust will be science in the middle schools, with expansion to include the role of mathematics in science (a pilot mathematics project is included in the first year), and eventually science and mathematics, kindergarten through 12th grade. A continuing and substantive program of testing and evaluation, starting with the collection of base-line data and designed to measure changes in both achievement and attitude, will be an integral part of the project.

An example of experiments developing new approaches to science education is a project at Hahnemann Medical College in Philadelphia. Fifty high-ability high school seniors devoted full time during the 1970–71 academic year to an organized curriculum of research participation and independent study in the biomedical sciences under the guidance of research scientists of Hahnemann. To fulfill 12th-grade requirements, they also attended seminars and lectures in English and history; time was allotted as well for an elective subject and a physical education course. By arrangement with the State Department of Public Instruction and local school systems involved, the students graduated with their respective high schools in June 1971. A number of colleges and universities have agreed to admit these students to their sophomore class upon completion of the Hahnemann program and thus eliminate the freshman year of college study. Further experimentation of this kind is planned to develop increasing flexibility in pre-college science education.

# SCIENCE RESOURCES AND POLICY STUDIES

Sciences resources and policy studies are conducted by the Foundation through periodic surveys and special analytical studies undertaken to meet the needs of the Foundation and other Federal groups. These study activities are also of service to State and local government bodies, the nonprofit sector, industry, and the general science community.

Staff studies and analyses are supplemented with a program of grants and contracts conducted mainly with universities, other nonprofit organizations, and other Government agencies. In fiscal year 1971, the Foundation published 31 resources and policy reports, while another 19 were the product of NSF-financed grants and contracts. Following are highlights of some of the more significant science resources and policy study activities of the past year.

## Science Resources Studies

### *Manpower*

*Employment-Unemployment of Scientists and Engineers.* In the spring of 1971, more than 3 percent of the engineer work force and as many as 45,000–65,000 scientists and engineers were estimated as unemployed. Scientists and engineers represent a relatively small portion of the total labor force of more than 85 million, yet the loss of their professional contributions to the nation's welfare is a serious matter. Since they do represent a small group, special surveys and studies are necessary to secure accurate data on the extent of unemployment and the characteristics of the unemployed.

The Foundation provided support to the National Research Council for the second year to conduct a survey of academic departmental chairmen on the employment status of 1969 and 1970 Ph.D. graduates in science and engineering. Over this period, the proportion unemployed and seeking employment increased from 0.5 percent of the 1969 graduates to 1.1 percent of the 1970 group, and the proportion considered underemployed rose from 0.7 to 1.2 percent. Also in fiscal year 1971, with financial support shared with the Departments of Defense and Labor, NSF undertook special surveys of the employment status of scientists and engineers. Information on scientists was obtained through a survey of more than 300,000 scientists who had previously responded to the 1970 National Register of Scientific and Technical Personnel. Of all scientists responding to the survey as of spring 1971, 2.6 percent were unemployed compared to 1.5 percent in spring 1970; the rate for doctorates was 1.4 percent in 1971 compared to 0.9 percent a year earlier, while the rates for nondoctorates were 3.5 and 2.9 percent respectively. A similar survey of engineers was in process at the end of the year.

*Science and Engineering Doctorate Utilization.* During the past year, in the report *Supply and Utilization of Science and Engineering Doctorates, 1969 and 1980,* the Foundation updated its previous analysis of the future supply and utilization of science and engineering doctorates.

The new projections show that as many as 315,000–336,000 doctorate scientists and engineers may be available by 1980, compared to 270,000–297,000 available positions. This represents a greater likelihood of a future oversupply than the previous NSF projections developed 2 years earlier. Furthermore, wide differences in the various broad areas of science were indicated, with some serious potential imbalances signalled for engineering and the social sciences.

The study also points to some probable changes in the pattern of utilization over the next decade. Although about two-thirds of all science and engineering doctorates in 1969 were engaged in teaching and research in graduate schools or employed in nonacademic R&D positions, only one-half of the new doctorates entering employment in the 1970's are expected to be in such positions. The other half are projected

to be teachers of undergraduates or in non-R&D positions outside the academic world.[1]

*National Register of Scientific and Technical Personnel.* The 1970 canvass of scientists will be the final one of a series dating back to 1954 because the maintenance of a list of scientists for purposes of locating individuals with specific characteristics is no longer essential, and the use of samples instead of full coverage promises relatively small savings. Resources will be available in fiscal year 1972 to explore and develop alternative methods for securing required information on scientists and engineers.

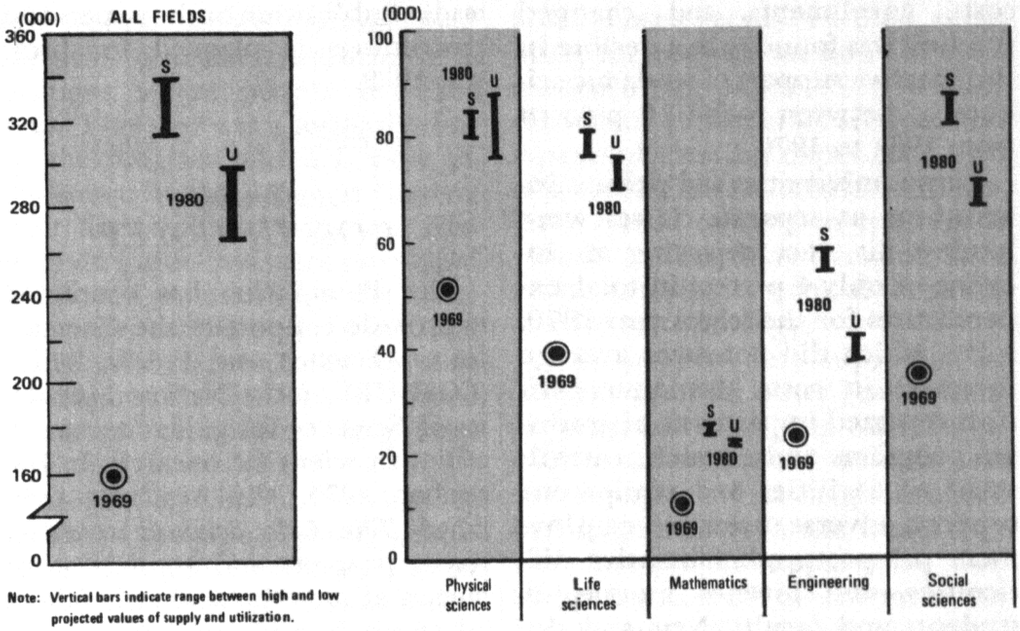
## *Research, Development, and Academic Science Expenditures*

*Federal R&D Funding by Budget Function.* A new Foundation report, *An Analysis of Federal R&D Funding by Budget Function, 1960–72,* compares Federal R&D expenditures in the period 1960–72 for 12 budget functions (i.e., health, defense, etc.) with total Federal outlays for each function, analyzes trends and developments, and describes current R&D programs.

Federal expenditures for research and development have experienced a reduction in priority since the mid-1960's when compared with total Federal expenditures. From 1960 to 1965, the share of total Federal outlays representing R&D expenditures rose from 8.5 to 12.4 percent. As the total Federal budget has increased, the proportion allocated to research and development decreased each year to an estimated 7.4 percent share in 1972, the lowest in the entire 1960–72 period.

National defense, space research and technology, and health have represented the chief areas of Federal R&D funding throughout the 1960–72 period. In 1972, these functions are expected to make up 86 percent of the estimated total R&D expenditures of $15.7 billion.

**SUPPLY AND UTILIZATION OF SCIENCE AND ENGINEERING DOCTORATES, BY BROAD AREA OF SCIENCE, 1969 and 1980**




Note: Vertical bars indicate range between high and low projected values of supply and utilization.

Source: National Science Foundation

*Federal Support of Higher Education.* The Foundation is the implementing agency for the Committee on Academic Science and Engineering of the Federal Council for Science and Technology and is responsible for collection and analysis of data on Federal funding of academic activities. Federal agencies reported to the Foundation that their obligations to universities and colleges for both science and nonscience activities totalled $3.2 billion in 1970. This was nearly 7 percent below the 1969 funding level, the lowest level of Federal support since 1966, and the first decrease, in actual dollars, in direct Federal funding since 1963, the first year for which these data are available. In *Federal Support to Universities and Colleges and Selected Nonprofit Institutions, Fiscal Year 1970,* the National Science Foundation reported that the greatest impact of this reduction occurred in academic science support which decreased some 8 percent from the previous year's amount compared to a 3 percent reduction in the funding of nonscience activities. Federal funds obligated for academic research and development, including R&D plant funds, declined nearly 4 percent.

The results of two other surveys showed that expenditures of funds for academic science—both research and education—from all sources increased by 7 percent and 8.5 percent in the school years 1969 and 1970, respectively, but failed to keep pace with increases in college enrollments and costs. The academic institutions in these two surveys provided financial information in terms of expenditures while Federal agencies, in the study of *Federal Support to Universities and Colleges and Selected Non-profit Institutions, Fiscal Year 1970,* reported in terms of obliga-

[1] It should be emphasized that analyses such as this one are projections and not predictions. These projections are derived from statistical models based on past trends and on an awareness of current happenings. Actual events may well turn out to be different from some of the projections.

tions. In terms of constant dollars, the effective increase in expenditures over the 2 years from 1968 to 1970 was substantially less–about 5 percent. During the same period, college enrollments rose by 13 percent. The net result of increased costs, enrollments, and changed funding was found to be a decline in the effective support of academic science of between 5 and 10 percent from 1968 to 1970.

Large universities and private institutions as separate classes were hardest hit, each reporting an increase of only 4 percent in total expenditures for the school year 1970, a rise which did not cover average increases in costs. Academic officials reported impairment of graduate programs and research, curtailment of facilities and equipment support, adverse career and employment prospects, administrative difficulties, and lowered morale of students and faculty. New and developing institutions frequently reported problems in meeting planned goals as a result of changes in Federal funding.

*Economic Impact of Research and Development.* The interest in the relationship of research and development to economic growth and productivity was a major influence in the Foundation's commissioning of four distinguished economists to prepare papers on the topic. A resulting "Colloquium on the Relationship between Research and Development and Economic Growth/Productivity" was held to review these papers and to discuss the subject in general, with some 70 representatives of Government, universities, and other institutions participating. The major conclusions reached were: (1) available evidence indicates that research and development is an important contributor to economic growth and productivity; (2) differences concerning present research findings seem to affect the degree of confidence in the estimates rather than the direction and rough magnitude of the economic return; and (3) the United States is probably underinvesting in civilian sector research and development from a purely economic growth/productivity point of view, though little can be said as to where particular R&D investments should be made. Publication of the papers and proceedings is planned for fiscal year 1972.

### Science Policy Studies

## *Activities of COSPUP-COPEP*

The Foundation has continued to provide support to the Committee on Science and Public Policy (COSPUP) of the National Academy of Sciences for guidance on priorities in scientific research. In December 1970, the Academy published *The Life Sciences* covering recent progress and application to human affairs, the world of biological research, and requirements for the future. Additional surveys of technical priorities in the disciplines of physics and in astronomy are well along. The most recent COSPUP survey, undertaken by the Academy with support from the Foundation and the Advanced Research Projects Agency (ARPA), concerns Materials Science and Engineering.

A parallel Committee on Public Engineering Policy (COPEP) of the National Academy of Engineering has continued to receive support. During fiscal year 1971, two COPEP reports were published, *Federal Support of Applied Research* and *Priorities in Applied Research,* which were integral to the planning and initiation of the Foundation's new program of Research Applied to National Needs (RANN).

## *Retrospective Analysis of Key Scientific Events*

Also during fiscal year 1971, a follow-up to the 1969 report *Technology in Retrospect and Critical Events in Science* (TRACES) was initiated. The first TRACES study traced the key R&D events which led to five technological innovations with major economic and sociological impacts. The new study will build on the cases and materials developed in the original study and will expand the number of case histories with five new ones concentrating on innovations with major societal benefits. The study will concentrate on the principal interface between basic knowledge and application and will try to identify major factors which accelerated the application phase.

### University Science Planning and Policy

The University Science Planning and Policy Program is designed to develop capabilities for research and teaching in the area of science planning and policy, and to support research on national science policy issues.

Institutions currently receiving grants under this program include: Harvard University, Massachusetts Institute of Technology, State University of New York at Albany, Cornell University, Rockefeller University, Stanford University, Indiana University, and the Universities of California (Berkeley), Illinois, Virginia, and Washington.

These grants help to support teaching, research, and special seminars on such science policy problems as the support and use of science and technology; the use of science in international affairs; scientific and technical manpower; environmental management; nuclear energy; the law and international affairs; the effects of new educational technology; legal and moral implications of modern biology and medicine; the effects of technology on economic growth and telecommunications policy.

Under current grants, Harvard University is developing a series of case studies to demonstrate the application of analytical techniques to public policy problems; Stanford

University is analyzing the technical and policy alternatives involved in cable television; the University of Washington is studying the problem of the Social Management of Technology; Rockefeller University is sponsoring a series of seminars on science policy problems; and Cornell University is studying and teaching such subjects as Biology and Society, Social Implications of Technology, and Technology Assessment.

## PUBLIC UNDERSTANDING OF SCIENCE

The Public Understanding of Science Program, in conjunction with other science education and information programs of NSF, through support of projects by nongovernmental organizations, seeks to enhance citizen knowledge and understanding of both the potentials and the limitations in the use of science and technology. This involves not only communicating the "facts" of science but an understanding of the relationships of science to the universe we live in and the use of science and technology in meeting current and emerging societal problems. In fiscal year 1971, the Foundation made 11 awards amounting to $436,279 for public understanding of science projects. These included general support of public understanding of science activities; the design and production of films illustrating the nature and application of science, science exhibits in museums and public buildings; specialized seminars for science writers; and mobile science "laboratories" designed to demonstrate science in locations where people live and work. This year was a formative one for the program which is now administered by the Office of Government and Public Programs. New program guidelines were developed and issued to encourage the scientific community to become involved in and take responsibility for communicating the results and impact of scientific research to the general public.

In order to stimulate interest in science on the part of young people and to disseminate information on science to a broad audience, a general-support grant was made to Science Service, Inc. Other projects supported during fiscal year 1971 included an award to the Maryland Academy of Science for a public lecture series by scientists on the subject of science and its contribution to the quality of life. The Academy schedules engagements with civic and professional groups, chambers of commerce, PTA's, educational groups, and other public audiences throughout Maryland.

A public exhibits program on science was supported through the New York State Science and Technology Foundation. Unlike more traditional "fixed-base" science exhibits in museums, these large but portable exhibits are designed for use at a number of sites throughout the New York City metropolitan area, chosen because of their suitability for reaching an unusual cross section of the public. The subjects chosen for each exhibit are common aspects of everyday experience with two specific characteristics—the subjects are of concern to most individuals in their daily lives and have an underlying structural basis in science or technology.

Two projects were supported in conjunction with other Foundation program offices to bring exhibits on science to both rural schools and communities and to neighborhoods and large schools in the inner city. The first project supports the Oak Ridge Associated Universities in the development of a prototype traveling lecture-demonstration program. One-day visits to 40 selected high schools in Tennessee and Alabama are planned in the first phase of the program. The other project under the direction of the Federal City College in Washington, D.C., involves the use of a mobile science laboratory, manned by FCC faculty and students, to help instruct District of Columbia high school students and residents on the relevance of science to problems of an urban community.

*Institutional Programs*

In fiscal year 1971, the Foundation's institutional programs provided substantially larger support for social science departments, made supplementary grants to nine universities to permit them to complete the final stages of their comprehensive plans for quality improvement, and awarded the 10th annual series of Institutional Grants for Science to 659 colleges and universities. The Science Development Program also received and evaluated a variety of proposals for the development of interdisciplinary and problem-oriented research capabilities. The suspension of the program in February resulted in the transfer of several of these proposals to the program of Research Applied to National Needs where, after some modification, they received support through that new Foundation activity.

During the 7 years since the establishment of the Science Development Program, the Foundation has awarded $222 million to 102 universities to assist them in improving the quality of their research and educational activities in science. Most of these grants still have from 1 to 3 years to run.

One other major institutional program, Graduate Science Facilities, was suspended at the beginning of fiscal year 1971. During the 11 years of its activity, the Graduate Science Facilities Program provided $186 million to 179 institutions of higher education for the renovation and construction of academic facilities for scientific research and research training.

The Foundation's obligations under the institutional programs discussed below are shown in table 11.

## INSTITUTIONAL GRANTS FOR SCIENCE

Institutional Grants for Science provide general support for science in a large number of colleges and universities. Unlike other NSF awards, which are based on individual or institutional proposals to perform specific kinds of research or educational activities, institutional grants permit college and university officials to allocate Federal science funds at their own discretion. Local determination of the use of the grants, so long as the funds are spent only for direct costs of science, makes the program a highly valued one among university and college administrators.

Since the program began in fiscal year 1961, over 900 colleges and universities have received institutional grants, and many of these institutions have received grants every year. For all 10 years, the grants total $108.4 million. In fiscal year 1971, 659 institutions—the largest number to participate in any single year—received grants amounting to $14.5 million. Each of the 50 States, the District of Columbia, Puerto Rico, and the Virgin Islands had one or more institutions receiving grants in fiscal year 1971. Although the grants ranged from $1,000 to $142,756, the average grant was only about $22,000, about $14,000 less than the average 5 years before. The program budget has remained at approximately the same level since fiscal year 1966 despite a substantial increase in the number of institutions eligible to receive the grants.

Eligibility for an institutional grant depends on the receipt of Federal awards for scientific research. For several years, only NSF grants served to establish eligibility, but in fiscal 1970 the Foundation put into effect a suggestion made by the Federal Council for Science and Technology that the grants be based on the research awards of other Federal science agencies as well as those of NSF. Although many institutions benefited by participation in the program for the first time because of the shift to a broader Federal base, many regular participants received smaller grants than before.

In fiscal 1971, as in the year before, each institution's award was

**Table 11**
**Obligations For Fiscal Years 1968, 1969, 1970, and 1971**
**(Millions of dollars)**

| Program | Fiscal year 1968 | | Fiscal year 1969 | | Fiscal year 1970 | | Fiscal year 1971 | |
|---|---|---|---|---|---|---|---|---|
| | Number of Awards | Amount | Number of Awards | Amount | Number of Awards | Amount | Number of Awards | Amount |
| Science Development: | | | | | | | | |
| University Science Development | 9 | $29.6 | 9 | $23.1 | 9 | $15.9 | 9 | $11.2 |
| Departmental Science Development | 22 | 12.0 | 15 | 8.6 | 18 | 10.6 | 14 | 8.7 |
| Institutional Grants for Science | 497 | 14.2 | (1) | (1) | 634 | 14.5 | 659 | 14.5 |
| Graduate Science Facilities | 50 | 17.8 | 14 | 6.0 | 15 | 3.7 | (2) | (2) |
| Total | 578 | 73.6 | 38 | 37.7 | 676 | 44.7 | 682 | 34.4 |

[1] A change in the timing of awards from June 1969 to fall 1969 resulted in no obligations in fiscal year 1969.
[2] The Graduate Science Facilities Program was suspended in fiscal year 1971.

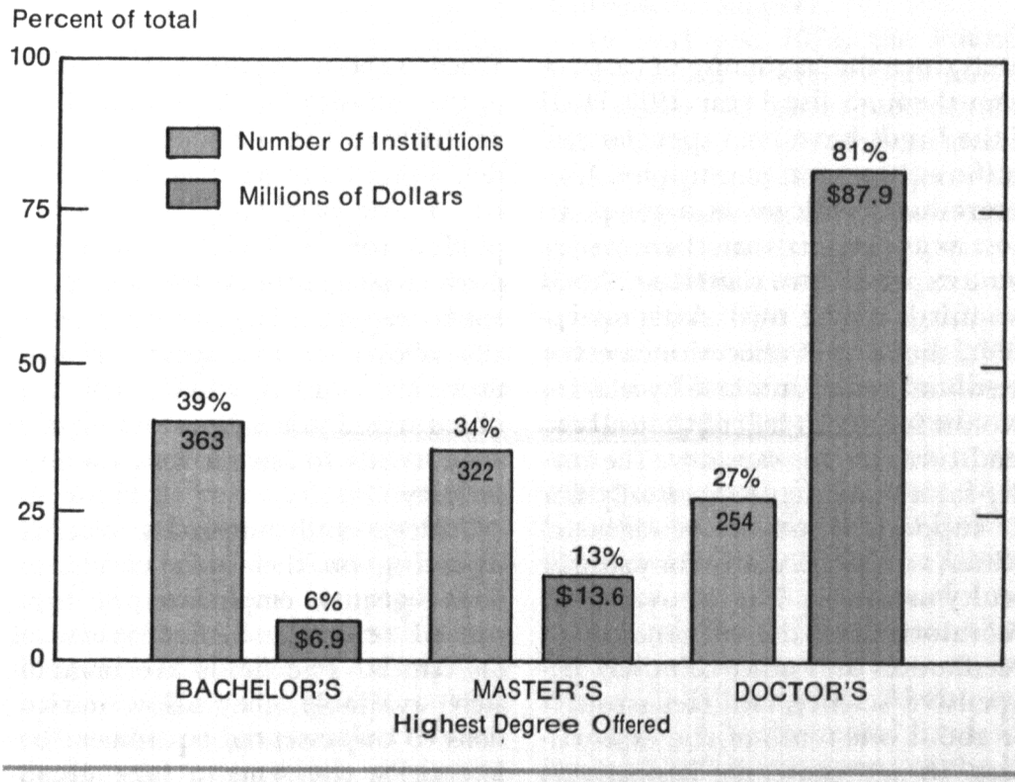
determined by applying a graduated arithmetical formula to the institution's "base" amount—that is, the total amount of Federal support for scientific research (not including support from the U.S. Public Health Service) in fiscal year 1969. (Public Health Service research awards are excluded from the base to prevent any overlap with a similar program of formula grants conducted by the National Institutes of Health.) The departments and agencies whose research awards entered into the computation of institutional grants were: Departments of Agriculture; Commerce; Health, Education, and Welfare (excluding PHS) ; Housing and Urban Development; Interior; and Labor; Agency for International Development; Atomic Energy Commission; National Aeronautics and Space Administration; National Science Foundation; and Office of Economic Opportunity.

Although the formula used in calculating the grants provided 100 percent of the first $10,000 of an institution's base, in the next step the percentage was reduced to 2.25, and the universities receiving the largest amounts of Federal research funds derived only 0.05 percent of the base amounts above $20 million. The sharply tapered formula results in institutional and geographic distribution of institutional grant funds which differs somewhat from the distribution of the research funds on which the grants are based. Although undergraduate institutions receive only a small percentage of institutional grant funds, their share would be much less without the 100 percent feature of the formula.

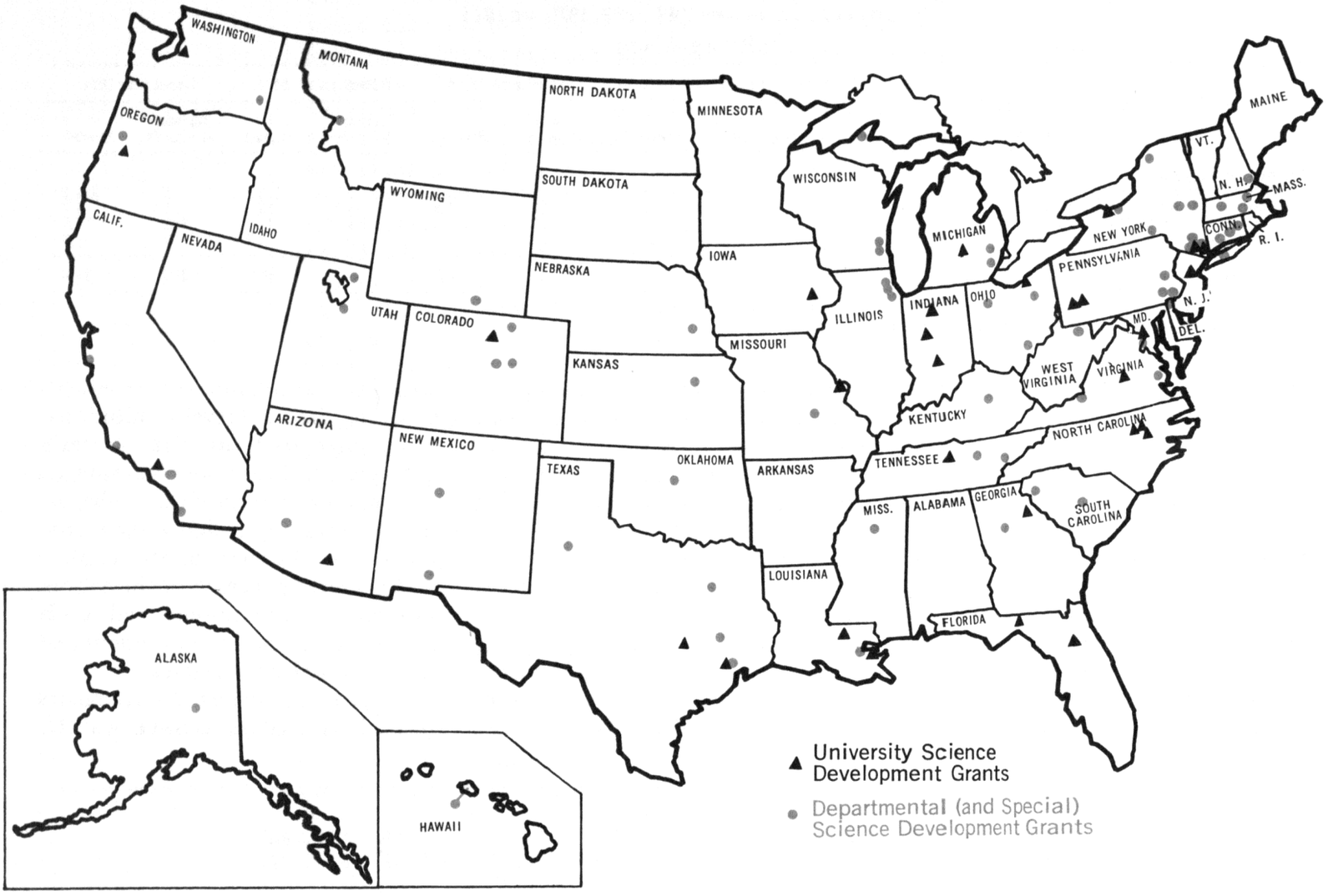
Of the 659 institutions receiving grants during the year, well over two-thirds offered graduate degrees —37 percent offering the doctorate degree in one or more fields and an additional 35 percent offering the master's; the remaining 28 percent awarded no degrees higher than the bachelor's. Three-fourths of the institutional grant funds were awarded to the doctoral-level institutions, about one-sixth to the master's grantors, and less than one-tenth to the entirely undergraduate colleges. The accompanying figure shows, for all years of the program, the number and percentage of each of these three groups of institutions and each group's share of the total amount of institutional grant dollars.

Table 12 shows how the recipients of institutional grants have used the

**INSTITUTIONAL GRANT AWARDS FOR FISCAL YEARS 1961-1971**



**SCIENCE DEVELOPMENT GRANTS**
**FISCAL YEARS 1965-1971**




funds since the beginning of the program through fiscal year 1970. Half of the funds have been spent for scientific equipment and supplies. Undergraduate colleges, as a group, in most years report that their equipment expenditures constitute about two-thirds of the total. After equipment, the largest allocations are for personnel costs, and faculty salaries account for about half of the total expenditures in this category. The faculty salary payments are usually for the support of summer research activities, and particularly for younger faculty members. The renovation of laboratories and the construction of greenhouses and other relatively inexpensive science facilities account for about one-tenth of the expenditures. In aggregate, the institutions allocate about one-third of the funds to the physical sciences and about one-fifth to the life sciences. In recent years there has been a gradual rise in the percentage of funds expended for the social sciences and psychology; universities are more apt to report a large share of their allocations to the social sciences than are undergraduate colleges, whose need for laboratory equipment tends to have a much higher priority.

College and university officials, reporting on their uses of institutional grants, emphasize the high rate of return and effectiveness of the funds. The funds are immediately available; they allow institutions to buy essential equipment before price rises and to take advantage of other opportunities for savings. Frequently the grants permit institutions to provide continuing support of research projects during temporary lapses in outside funding, and they enable institutional officials to make commitments during delays in State and Federal appropriations proceedings. Besides sustaining important ongoing activities, the funds give administrators leverage to put new ideas into effect and to encourage interdepartmental programs and cooperative undertakings with other institutions.

## SCIENCE DEVELOPMENT

Foundation programs for the improvement of science in doctoral-

**Table 12**
**Uses of Institutional Grant Funds**
**Fiscal Years 1962-70**
**(Millions of dollars)**

| A. Type of use: | Amount spent[1] | Percent of total expenditures |
|---|---|---|
| Equipment and supplies | $41.1 | 50.1 |
| General | 37.8 | 46.1 |
| Libraries | 3.3 | 4.0 |
| Facilities | 13.3 | 16.2 |
| General | 9.1 | 11.1 |
| Computers | 4.2 | 5.1 |
| Personnel | 23.6 | 28.9 |
| Faculty salaries | 11.1 | 13.5 |
| Graduate assistants | 4.7 | 5.7 |
| Other student stipends | 2.3 | 2.8 |
| Visiting lecturers | 1.2 | 1.5 |
| Technicians' salaries | 2.2 | 2.7 |
| Other | 2.1 | 2.7 |
| Travel | 2.0 | 2.4 |
| All other | 2.0 | 2.4 |
| Total | 82.0 | 100.0 |

| B. Field of science: | Amount spent[1] | Percent of total expenditures |
|---|---|---|
| Physical sciences | $28.5 | 34.8 |
| Astronomy | 1.2 | 1.5 |
| Chemistry | 14.6 | 17.8 |
| Physics | 11.5 | 14.0 |
| Other | 1.2 | 1.5 |
| Mathematical sciences | 4.2 | 5.1 |
| Environmental sciences | 6.7 | 8.2 |
| Atmospheric science | .8 | 1.0 |
| Earth sciences | 4.6 | 5.6 |
| Oceanography | 1.3 | 1.6 |
| Engineering | 10.4 | 12.7 |
| Life sciences | 17.6 | 21.5 |
| Psychology | 3.3 | 4.0 |
| Social sciences | 5.2 | 6.3 |
| All other (inter- & multidisciplinary) | 6.1 | 7.4 |
| Total | 82.0 | 100.0 |

[1] From awards made fiscal years 1961-69. Total amount of awards, $93.9 million; total expenditures fiscal years 1962-70, $82.0 million.

level universities were reoriented in fiscal year 1971. The revised Science Development Program represented a restructuring of the earlier University Science Development and Departmental Science Development programs into a form that would not only further the original objectives, but would also help build research and educational competence which could contribute to the solution of national problems.

Four categories of science development proposals were invited under the restructured program:

1. To strengthen departments or groups of departments in the natural sciences, mathematics, and engineering. (Essentially this category provided for the continuation of single-department awards like those made under the Departmental Science Development Program or multidepartment supplementary awards to institutions which had earlier received 3-year grants under the University Science Development Program.)
2. To strengthen the social sciences, computing sciences, and other areas that have been inadequately funded or whose rapid improvement is a national need.
3. To help academic institutions develop research and training activities that combine traditional scientific and engineering disciplines in ways to create new interdisciplinary approaches to the attack on scientific problems and the solution of social problems.
4. To develop centers and institutes that are directly aimed at problem-solving activities in the national interest.

Nearly all of the grants actually awarded through the Science Development Program were of the first two types. Early in 1971, a decision was made to suspend the Science Development Program, and about half of the fiscal year's allocation of development funds was reprogrammed to other areas of the Foundation. No new proposals were accepted thereafter by the Science Development Program. A number of the category 3 and category 4 proposals, submitted to the program earlier by academic and other kinds of institutions, had already been evaluated, and some of these had been recommended for funding. The problem-orientation of several of these proposals made them suitable for consideration by the newly organized program of Research Applied to National Needs and, after appropriate modifications to fit the research emphasis of RANN, they received Foundation support.

In fiscal year 1971, the Foundation awarded a total of $20 million for support of 23 science development projects. Nine of these awards, amounting to $11.2 million, were university science development supplemental awards to support the final 2 years of broad 5-year improvement plans; the initial grants to these nine universities totaled $39.5 million. The institutions qualifying for the supplemental awards, by reason of significant progress toward their long-term goals, were North Carolina State University at Raleigh, Rutgers University, Tulane University, and the Universities of Iowa, Maryland, North Carolina at Chapel Hill, Notre Dame, Texas at Austin, and Washington. About one-third of the supplemental funds will be used for improvement of the life

sciences, one-fourth for physical sciences, and nearly one-sixth for the social sciences. Mathematics and computing sciences, environmental sciences, and engineering account for the remainder of the allocations. Over 60 percent of the funds will be used for personnel costs and 36 percent for equipment and supplies.

The other 14 science development grants, largely of the departmental type, totaled $8.8 million. By far the largest part of these 3-year grants will be used for improvement of social science departments. Six grants, totaling $4.7 million, were awarded for departmental development in anthropology (Southern Methodist University); economics (Texas A&M University and University of California, San Diego); psychology (Claremont Graduate School and University of Massachusetts); and sociology (Washington State University). In addition, a grant of $1.5 million was made for the development of the Institute of Social Science at Yale University. An award of $848,000 for the Institute of Fundamental Studies at the University of Rochester will be used for the development of interdisciplinary capabilities for the study of several kinds of urban, economic, and environmental problems and for research on the quantitative aspects of social indicators which measure changes in society. The remaining six departmental grants will support improvements in biology (State University of New York at Albany); chemistry (Emory University and University of Utah); electrical engineering (Texas Tech University and University of California, Santa Barbara); and geology (University of Montana). Three-fourths of the funds in all 14 grants will be used for personnel costs, and nearly all of the remainder for equipment and supplies.

Since the first science development grants were announced in fiscal 1965, the Foundation has awarded through these programs a total of $222 million to 102 institutions. About 260 departments or areas of science—approximately 8 percent of the more than 3,000 university science departments engaged in Ph.D. training—have received support through the science development programs; the universities have also contributed large amounts of non-Federal funds to the improvement of the departments. As the accompanying map shows, the programs have furthered one of the Foundation's original aims when it started the experiment of investing Federal funds in the improvement of universities—to stimulate the building of university science education and research of the highest quality in all parts of the nation. Through assisting universities to carry out their plans for quality improvement, the Foundation believes that it has helped to further the goal of equal educational opportunity for all citizens and to foster the kinds of economic, social, and cultural benefits that accrue to communities and regions from excellent universities.

Some of the development grants have now terminated, but at the end of fiscal year 1971, more than 100 were still in progress. Attention is now being directed to the important task of studying the impact of the science development grants. There are several indications that the grants have been instrumental in bringing about substantial improvement in the grantee institutions—for example, in ability to recruit outstanding faculty members, to attract better graduate students, and to participate in Federal research support programs. Thus far, however, most of this evidence comes from institutions receiving university science development grants rather than from those receiving awards through the departmental program, which was started later.

The Science Development Program, undertaken by the Foundation in 1964 after several years of study and planning, has been one of the most exciting experiments in Government-university relations during the past decade. From the outset, the Foundation's paramount objective was to improve the quality of research and instruction in science departments already conducting doctoral programs of recognized merit. The intention was to ensure that qualified students who chose scientific careers would have opportunities to pursue that choice and receive first-rate training, and not solely in one of the score of geographically clustered institutions that had already achieved recognition as "centers of excellence." The science development grants were awarded in every instance for improvement of departments that were already engaged in Ph.D. training and that were considered to have suitable strength upon which to build further. No new graduate departments were created. Only about one in 12 of the 3,000-plus departments offering doctoral training in science benefited directly from university or departmental science development grants, though the Foundation believes that the improvements in quality in the supported departments have stimulated improvements in related areas as well. Grants have been awarded to 102 universities, but in most institutions only a single science department out of all of those in the natural sciences, the social sciences, and engineering has received NSF development funds.

The choice of institutions and departments for science development grants has been rigorously selective. Because of this selectivity it is all the more important that this experimental Federal program, designed to select good quality and to help universities improve it significantly, be subjected to close study. A careful evaluation of the experiment—both as it affected the 102 universities directly involved, and the rest of higher education as well—should furnish invaluable information for future planning of Federal programs in science and higher education.

# Appendix A

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Durham, N.C.

David E. Fairbrothers
Department of Botany
Rutgers, The State University
New Brunswick, N.J.

Morris Goodman
Department of Anatomy
Wayne State University
Detroit, Mich.

Paul D. Hurd, Jr.
Smithsonian Institution
Washington, D.C.

Anthony J. Provenzano, Jr.
Miami, Fla.

S. David Webb
Department of Natural Sciences
University of Florida
Gainesville, Fla.

# *Appendix B*

## *Organizational Changes and Appointments*

### Office of the Director

Dr. Raymond L. Bisplinghoff was appointed by the President as Deputy Director of the National Science Foundation. Dr. Bisplinghoff, formerly the Dean of the School of Engineering, Massachusetts Institute of Technology, took the oath of office on October 14, 1970.

Several changes occurred affecting the Director's Staff Assistants. Mr. Richard A. Edwards, Special Assistant, resigned to accept the position of Executive Assistant to the President, Bowling Green State University. Dr. Donald E. Cunningham, Special Assistant for Assessment Activities, transferred to the new Research Applications Directorate.

Dr. William V. Consolazio, who had been serving as Division Director, Division of Institutional Development, was appointed Special Assistant, and Mr. Theodore D. Drury, formerly a Special Assistant to Senator Symington, was also assigned to the Director's Office as Special Assistant.

### Management Council

The Director established the new Management Council on September 4, 1970. The council consists of the Deputy Director as Chairman, the Deputy Assistant Directors, the General Counsel, and the Director of the Office of Government and Public Programs. The council serves to improve staff communication and to resolve policy or procedural problems which involve more than one directorate.

### Assistant Director for Education

In August 1970, the Office of Economic, Manpower, and Special Studies was transferred to the Assistant Director for Education to become the fourth organization in the directorate, the Division of Science Resources Studies.

### Assistant Director for National and International Programs

A new Office for the International Decade of Ocean Exploration was established in this directorate in September 1970.

A new function, the National Oceanographic Laboratory System, was added to the directorate in October 1970. In March 1971, this function was developed into the Office for Oceanographic Facilities and Support.

The Office of Sea Grant Programs was transferred to the newly established National Oceanic and Atmospheric Administration of the Department of Commerce in October 1970.

### Assistant Director for Research Applications

In March 1971, the new Research Applications Directorate was established to implement a new program of problem-oriented research, Research Applied to National Needs. Dr. Alfred J. Eggers, Jr., formerly the Assistant Administrator for Policy at NASA, was appointed Assistant Director for Research Applications on March 14, 1971. The directorate absorbed certain activities of other directorates including the Office of Interdisciplinary Research (Research Directorate) and the Office of Intergovernmental Science Programs (National and International Programs Directorate). The Research Applications Directorate is organized into three divisions and two offices: the Divisions of Environmental Systems and Resources, Social Systems and Human Resources, and Advanced Technology Applications; and the Offices of Intergovernmental Science Programs, and Exploratory Research and Problem Assessment.

### Assistant Director for Institutional Programs

The Institutional Programs Directorate was reorganized in April 1971, combining the Division of Institutional Development into the Division of Institutional Resources.

### Assistant Director for Administration

The Office of Budget, Programming, and Analysis was redesignated Budget, Programming, and Planning Analysis to reflect the addition of certain planning and policy functions transferred from the Education Directorate.

### Staff Changes

In addition to the appointments mentioned above, the following key staff appointments were announced during the year.

Joel A. Snow, Deputy Assistant Director for Science and Technology, Research Applications Directorate.

Leon A. Schwartz, Deputy Assistant Director for Program Management, Research Applications Directorate.

Philip L. Johnson, Deputy Director, Division of Environmental Systems and Resources, Research Applications Directorate.

Leonard L. Lederman, Deputy Director, Office of Exploratory Research and Problem Assessment, Research Applications Directorate.

Charles E. Falk, Director, Division of Science Resources Studies.

Senta Raizen, Special Assistant to Assistant Director for Education.

Feenan Jennings, Head, Office for International Decade of Ocean Exploration.

Worth D. Nowlin, Jr., Deputy Head, Office for International Decade of Ocean Exploration.

Melvin S. Day, Head, Office of Science Information Services.

Harry S. Francis, Jr., Executive Assistant to the Deputy Assistant Director for National and International Programs. Subsequently detailed as Acting Head, Office of International Programs.

Mary K. Johrde, Head, Office for Oceanographic Facilities and Support.

Harold A. Spuhler, Deputy Head, Office for Oceanographic Facilities and Support.

Bodo Bartocha, Executive Assistant to Assistant Director for National and International Programs.

Albert P. Crary, Director, Division of Environmental Sciences.

John F. Lance, Executive Assistant to Director, Division of Environmental Sciences.

Sidney Passman, Head, Science Policy Research Section, Division of Social Sciences.

John B. Talmadge, Head, Congressional Liaison Office.

Jack Renirie, Public Information Officer, Office of Public Affairs.

Robert T. Preston, Personnel Officer.

George Pilarinos, Management Information System Project Officer.

Harry J. Piccariello, Head, Evaluation Staff; Office of Budget, Programming, and Planning Analysis.

John E. Kirsch, Director of Equal Employment Opportunity.

### Resignations

Glenn R. Ingram, Deputy Head, Office of Computing Activities, left the Foundation to accept a position as Director of the Computing Center, Washington State University.

Arthur Roe, Head, Office of International Programs, retired from Federal service after more than 11 years with the Foundation.

Howard S. Schilling, Director of Equal Employment Opportunity, retired after 29 years of Government service.

Roland D. Paine, Public Information Officer, left the Foundation to accept a position with the National Oceanic and Atmospheric Administration, Department of Commerce.

Thomas D. Fontaine, Deputy Assistant Director for Education, retired after more than 30 years of Government service to accept a position at the University of Florida at Gainesville, Fla.

Burton W. Adkinson, Head, Office of Science Information Service, retired from Federal service to accept a position as Director of the National Geographical Society.

Howard E. Page, Special Assistant to the Director, retired after 29 years of Federal service.

### Changes in the National Science Board

During fiscal year 1971, no changes took place in the membership of the National Science Board. However, the following changes occurred in the institutional affiliations and academic positions of certain members: Dr. Roger W. Heyns (Vice Chairman, National Science Board), from Chancellor, University of California at Berkeley, to Professor of Psychology and Education, Department of Psychology, University of Michigan; Dr. Norman Hackerman, from President, The University of Texas at Austin, to President, William Marsh Rice University; Dr. Charles F. Jones, from President to Vice Chairman of the Board, Humble Oil & Refining Co., Houston, Tex.; Dr. James G. March, from Professor of Psychology and Sociology, School of Social Sciences, University of California at Irvine, to David Jacks Professor of Higher Education, Political Science, and Sociology, School of Education, Stanford University; Dr. Robert S. Morison, from Professor of Biology and Director, Division of Biological Sciences, to Professor of Science and Society, Program on Science, Technology and Society, Cornell University; Dr. William A. Fowler, from Professor, to Institute Professor of Physics, California Institute of Technology; and Dr. David M. Gates from Director, Missouri Botanical Garden, to Professor of Botany and Director, Biological Station, Department of Botany, University of Michigan. Dr. Athelstan F. Spilhaus became Fellow, Woodrow Wilson International Center for Scholars, Smithsonian Institution.

# *Appendix C*

## *Financial Report For Fiscal Year 1971*

## *Salaries and Expenses Appropriation*

| | | |
|---|---|---|
| **Fund Availability** | | |
| FY 1971 Appropriation | $511,000,000 | |
| Unobligated balance carried forward from FY 1970 | 624,815 | |
| Reimbursement from non-Federal source | 263,302 | |
| Transfer to Department of Commerce (NOAA) | 7,038,810 | |
| Transfer to GSA for rent | 85,275 | |
| Fiscal Year 1971 total availability | | $504,764,032 |
| **Net obligations** | | |
| Scientific research project support: | | |
| Atmospheric sciences | 9,155,195 | |
| Earth sciences | 8,002,267 | |
| Oceanography | 9,917,592 | |
| Biological sciences | 43,367,668 | |
| Physics | 25,042,042 | |
| Chemistry | 17,937,460 | |
| Astronomy | 6,422,573 | |
| Mathematics | 12,931,933 | |
| Social sciences | 17,387,376 | |
| Engineering | 13,528,588 | |
| Materials research | 10,876,736 | |
| Subtotal, scientific research project support | | 174,569,430 |
| Specialized research facilities and equipment: | | |
| Atmospheric research equipment and facilities | 290,533 | |
| Earth sciences research equipment | 121,300 | |
| Oceanographic research equipment | 66,856 | |
| Biological research equipment and facilities | 903,606 | |
| Physics research equipment and facilities | 1,499,731 | |
| Chemistry research equipment | 1,699,783 | |
| University astronomy research instruments | 249,800 | |
| Social sciences research equipment and facilities | 272,100 | |
| Engineering research equipment | 695,973 | |
| Materials research equipment | - 0 - | |
| Subtotal, specialized research facilities and equipment | | 5,799,682 |
| National and special research programs: | | |
| International biological programs | 7,502,134 | |
| Global atmospheric research program | 1,899,500 | |
| International decade of ocean exploration | 15,000,000 | |
| Ocean sediment coring program | 7,126,889 | |
| Arctic research program | 2,000,378 | |
| U.S. Antarctic research program | 7,762,321 | |
| Oceanographic facilities and support | 8,565,329 | |
| Subtotal, national and special research programs | | 49,856,551 |
| National research centers: | | |
| National Astronomy and Ionosphere Center | 6,098,600 | |
| Kitt Peak National Observatory | 7,219,600 | |
| Cerro Tololo Inter-American Observatory | 2,280,000 | |
| National Radio Astronomy Observatory | 6,837,300 | |
| National Center for Atmospheric Research | 14,678,906 | |
| Subtotal, national research centers | | 37,174,506 |
| National Sea Grant Program | 6,143,243 | |
| Computing Activities in Education and Research | 15,042,905 | |
| Science Information Activities | 10,694,898 | |
| International Cooperative Scientific Activities | 2,179,996 | |
| Research Applied to National Needs | 33,955,291 | |
| Intergovernmental Science Program | 800,000 | |
| Institutional Support for Science | 34,392,183 | |

| | | |
|---|---|---|
| Science Education Support: | | |
| Innovative Curricula and Alternative Instructional Modes | 19,430,569 | |
| Science Teacher & Leadership Training | 31,452,756 | |
| The Institutional Implementation | 11,456,167 | |
| Science Students | 36,471,739 | |
| Subtotal | | 98,811,231 |
| Planning and Policy Studies | | 3,219,556 |
| Program Development & Management | | 21,768,818 |
| Subtotal | | 494,408,290 |
| Unobligated balance carried forward to Fiscal year 1972 | | 10,355,742 |
| Total | | 504,764,032 |

## *Trust Fund*

Special foreign currency

| | |
|---|---|
| **Receipts** | |
| Fiscal year 1971 appropriation | 2,000,000 |
| **Obligations** | |
| Total obligations for fiscal year 1971 | 2,000,000 |
| **Receipts** | |
| Unobligated balance brought forward from fiscal year 1970 | 5,649 |
| Donations from private sources | 175 |
| Total availability | 5,824 |
| **Obligations** | |
| Total availability | 5,824 |
| Less unobligated balance carried forward to fiscal year 1972 | 4,801 |
| Total obligations | 1,023 |

# *Appendix D*

## *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 two patents by the U.S. Patent Office covering inventions arising out of Foundation-supported activities on each of which the U.S. Government has received a nonexclusive, irrevocable, nontransferable, royalty-free, worldwide license:

Patents No. 3,530,373, entitled "Methods and Apparatus for Pulsed Nuclear Magnetic Resonance of Solids" and No. 3,530,374, entitled "Pulsed Nuclear Magnetic Resonance of Solids," were issued on September 22, 1970, on inventions made by John S. Waugh in the course of research supported by a grant to the Massachusetts Institute of Technology. The inventions relate to a method and the apparatus for investigating solid substances through the adaptation of coherent radio frequency modulators.

# Appendix E

## *Publications of the National Science Foundation Fiscal Year 1971*

1 NATIONAL SCIENCE FOUNDATION GUIDE TO PROGRAMS (NSF 70-14).
2 UNITED STATES-ITALY COOPERATIVE SCIENCE PROGRAM (NSF 70-15).
3 RESOURCES FOR SCIENTIFIC ACTIVITIES AT UNIVERSITIES AND COLLEGES, 1969 (NSF 70-16).
4 SCIENCE DEVELOPMENT PROGRAMS (NSF 70-17).
5 COURSE AND CURRICULUM IMPROVEMENT PROJECTS (NSF 70-18).
6 UNITED STATES ANTARCTIC RESEARCH PROGRAM PERSONNEL MANUAL, 1970 (NSF 70-19).
7 *Mosaic*, Vol. I, No. 3 (NSF 70-20).
8 FACILITIES INFORMATION FOR THE SCIENCE DEVELOPMENT PROGRAM (NSF 70-21).
9 RESEARCH AND DEVELOPMENT IN STATE GOVERNMENT AGENCIES, FISCAL YEARS 1967 and 1968 (NSF 70-22).
10 DIRECTORY OF FEDERAL R&D INSTALLATIONS (NSF 70-23).
11 SCIENTIFIC AND TECHNICAL PERSONNEL IN THE FEDERAL GOVERNMENT, 1968 (NSF 70-24).
12 DEEP SEA DRILLING PROJECT (NSF 70-25).
13 SCIENCE RESOURCES STUDIES HIGHLIGHTS: "Federal Support to Universities and Colleges, Fiscal Year 1969" (NSF 70-26).
14 FEDERAL SUPPORT TO UNIVERSITIES, COLLEGES, AND SELECTED NONPROFIT INSTITUTIONS, FISCAL YEAR 1969 (NSF 70-27).
15 SCIENCE RESOURCES STUDIES HIGHLIGHTS: "Federal Funds for R&D Continue to Remain Level" (NSF 70-28).
16 RESEARCH AND DEVELOPMENT IN INDUSTRY, 1968 (NSF 70-29).
17 SCIENCE FACILITIES BIBLIOGRAPHY (NSF 70-30).
18 GRANTS FOR IMPROVING DOCTORAL DISSERTATION RESEARCH IN THE FIELD SCIENCES (NSF 70-31).
19 GRANTS FOR IMPROVING DOCTORAL DISSERTATION RESEARCH IN THE ENVIRONMENTAL SCIENCES (NSF 70-32).
20 ENGINEERING RESEARCH INITIATION BROCHURE, 1971 (NSF 70-33).
21 GRANTS FOR IMPROVING DOCTORAL DISSERTATION RESEARCH IN THE SOCIAL SCIENCES (NSF 70-34).
22 INVENTORY OF COMPUTERS IN U.S. HIGHER EDUCATION, 1966-67, UTILIZATION AND RELATED DEGREE PROGRAMS (NSF 70-35).
23 REGIONAL COOPERATIVE COMPUTING ACTIVITIES PROGRAM (NSF 70-36).
24 INTERNATIONAL DECADE OF OCEAN EXPLORATION (NSF 70-37).
25 FEDERAL FUNDS FOR RESEARCH, DEVELOPMENT, AND OTHER SCIENTIFIC ACTIVITIES, FISCAL YEARS 1969, 1970, 1971, Vol. XIX (NSF 70-38).
26 SCIENCE RESOURCES STUDIES HIGHLIGHTS: "Impact of Changes in Federal Science Funding Patterns on Academic Institutions" (NSF 70-39).
27 GRADUATE STUDENT SUPPORT AND MANPOWER RESOURCES IN GRADUATE SCIENCE EDUCATION, Fall 1969 (NSF 70-40).
28 *Mosaic*, Vol. I, No. 4 (NSF 70-41).
29 PUBLIC UNDERSTANDING OF SCIENCE (NSF 70-42).
30 SCIENCE RESOURCES STUDIES HIGHLIGHTS: "Growth Rate of R&D Activities in Independent Nonprofit Institutions Slackened During 1966-69" (NSF 70-43).
31 SCIENTIFIC, TECHNICAL, AND HEALTH PERSONNEL IN THE FEDERAL GOVERNMENT, 1969 (NSF 70-44).
32 SCIENCE RESOURCES STUDIES HIGHLIGHTS: "Local Government R&D Activities Double from 1966-69 But Remain Small" (NSF 70-45).
33 NATIONAL PATTERNS OF R&D RESOURCES 1953-71. FUNDS AND MANPOWER IN THE UNITED STATES (NSF 70-46).
34 SCIENCE RESOURCES STUDIES HIGHLIGHTS: "Industrial R&D Spending, 1969" (NSF 70-47).
35 IMPACT OF CHANGES IN FEDERAL SCIENCE FUNDING PATTERNS ON ACADEMIC INSTITUTIONS, 1968-70 (NSF 70-48).
36 SCIENCE RESOURCES STUDIES HIGHLIGHTS: "Federal Funds for Academic Science, Fiscal Year 1969" (NSF 70-49).
37 REVIEWS OF DATA ON SCIENCE RESOURCES, No. 19, "Salaries and Selected Characteristics of U.S. Scientists, 1970" (NSF 70-50).
38 ENVIRONMENTAL SCIENCE—CHALLENGE FOR THE SEVENTIES (NSB 71-1).
39 TWENTIETH ANNUAL REPORT, 1970, NATIONAL SCIENCE FOUNDATION (NSF 71-1).
40 GRANTS AND AWARDS, 1970, NATIONAL SCIENCE FOUNDATION (NSF 71-2).
41 NATIONAL SCIENCE FOUNDATION DATABOOK (NSF 71-3).
42 GRANTS FOR COMPUTING ACTIVITIES (NSF 71-4).
43 UNITED STATES-JAPAN COOPERATIVE SCIENCE PROGRAM (NSF 71-5).
44 RESEARCH AND DEVELOPMENT IN LOCAL GOVERNMENTS, FISCAL YEARS 1968 & 1969 (NSF 71-6).
45 FEDERAL FUNDS FOR ACADEMIC SCIENCE, FISCAL YEAR 1969 (NSF 71-7).
46 *Mosaic*, Vol. II, No. 1 (NSF 71-8).
47 SCIENTIFIC ACTIVITIES OF INDEPENDENT NONPROFIT INSTITUTIONS, 1970 (NSF 71-9).
48 GUIDELINES FOR SUBMISSION OF SPECIAL FOREIGN CURRENCY AWARDS FOR RE-

SEARCH, SCIENCE EDUCATION, AND RELATED ACTIVITIES (NSF 71–10).

49 SCIENCE RESOURCES STUDIES HIGHLIGHTS: "Immigrant Scientists, Engineers, and Physicians Increase in Fiscal Year 1970" (NSF 71–11).

50 SCIENCE RESOURCES STUDIES HIGHLIGHTS: "Secondary School Science Teachers (Experience and Employment)" (NSF 71–12).

51 SCIENCE EDUCATION: THE TASK AHEAD FOR THE NATIONAL SCIENCE FOUNDATION (NSF 71–13).

52 SCIENCE RESOURCES STUDIES HIGHLIGHTS: "Recent Trends in Enrollment and Manpower Resources in Graduate Science Education" (NSF 71–14).

53 SCIENCE RESOURCES STUDIES HIGHLIGHTS: "Federal Support to Universities and Colleges, Fiscal Year 1970" (NSF 71-16).

54 PUBLICATIONS OF THE NATIONAL SCIENCE FOUNDATION (NSF 71-17).

55 RESEARCH AND DEVELOPMENT IN INDUSTRY, 1969 (NSF 71-18).

56 SCIENCE RESOURCES STUDIES HIGHLIGHTS: "Federal R&D Expenditures Related to Budget Functions" (NSF 71-19).

57 SCIENCE AND ENGINEERING DOCTORATE SUPPLY AND UTILIZATION, 1969-80 (NSF 71-20).

58 INITIAL REPORTS OF THE DEEP SEA DRILLING PROJECT, Vol. IV (NSFSP-4).

59 INITIAL REPORTS OF THE DEEP SEA DRILLING PROJECT, Vol. V (NSFSP-5).

60 INITIAL REPORTS OF THE DEEP SEA DRILLING PROJECT, Vol. VI (NSFSP-6).

# *Appendix F*

## *National Research Centers*
## *Contractors*

**Associated Universities, Inc. (AUI)**
Gerald F. Tape, President

National Radio Astronomy Observatory
David S. Heeschen, Director

AUI Member Universities:
Columbia University
Cornell University
Harvard University
The Johns Hopkins University
Massachusetts Institute of Technology
University of Pennsylvania
Princeton University
University of Rochester
Yale University

**Association of Universities for Research in Astronomy, Inc. (AURA)**
Rupert Wildt, President

Cerro Tololo Inter-American Observatory
Victor M. Blanco, Director
Kitt Peak National Observatory
Leo Goldberg, Director

AURA Member Universities:
University of California
University of Chicago/University of Texas
Harvard University
Indiana University
University of Michigan
The Ohio State University
Princeton University
University of Wisconsin
Yale University

**Cornell University**
W. Donald Cooke, Vice President for Research

National Astronomy and Ionosphere Center
Frank D. Drake, Director, Ithaca, N.Y.
Tor Hagfors, Director, Observatory Operations, Arecibo, Puerto Rico

**University Corporation for Atmospheric Research (UCAR)**
Walter Orr Roberts, President

National Center for Atmospheric Research
John W. Firor, Director

UCAR Member Universities:
University of Alaska
University of Arizona
University of California
The Catholic University of America
University of Chicago
Colorado State University
University of Colorado
Cornell University
University of Denver
Florida State University
Harvard University
University of Hawaii
University of Illinois at Urbana-Champaign
The Johns Hopkins University
University of Maryland
Massachusetts Institute of Technology
University of Miami
University of Michigan
University of Minnesota
University of Missouri
New York University
State University of New York at Albany
University of Oklahoma
Pennsylvania State University
Saint Louis University
Texas A&M University
University of Texas
University of Toronto
University of Utah
University of Washington
University of Wisconsin

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