NATIONAL SCIENCE FOUNDATION

# Program Activities of the National Science Foundation

# SUPPORT OF SCIENTIFIC RESEARCH

The National Science Foundation provides support for basic research across the full spectrum of the physical, life, and social sciences, primarily through grants to colleges and universities. Such grants are made not only for specific research projects, but also for problems broad in scope that often require collaboration of investigators in varied disciplines.

In addition to grants for the actual conduct of research, the Foundation also provides assistance for the construction of facilities essential to the progress of the national research effort. These include graduate research laboratories, major items of research equipment, and specialized scientific facilities, such as oceanographic vessels and nuclear accelerators.

Three national research centers have also been established by the Foundation—National Radio Astronomy Observatory at Green Bank, West Virginia; Kitt Peak National Observatory at Tucson, Arizona; and the National Center for Atmospheric Research at Boulder, Colorado. Their facilities are available to all qualified scientists, and are operated by non-profit corporations under contracts with the Foundation.

The Foundation has also been assigned the responsibility for the support and administration of a number of national research programs which involve the cooperation and participation of scientists of colleges and universities, other private institutions, and various Government agencies. These projects include the U.S. Antarctic Research Program, Project Mohole, the Indian Ocean Expedition, and the Weather Modification Program.

The Foundation's support of research is administered by the Division of Mathematical, Physical, and Engineering Sciences, the Division of Biological and Medical Sciences, the Division of Social Sciences, the Office of Antarctic Programs, and the Office of Institutional Programs.

## Basic Research Projects

### CURRENT RESEARCH IN THE MATHEMATICAL, PHYSICAL, AND ENGINEERING SCIENCES

The mathematical, physical, and engineering sciences are concerned with man's physical environment and encompass a wide variety of disciplines. Support is provided for research ranging from studies of dis-

tant galaxies to the rocks within the earth's crust, from the movement of air masses to that of ocean currents, from subnuclear particles to the particles in the ionosphere that cause the aurora borealis, and from the complex equation of turbulent flow to the mechanisms of chemical reaction. Knowledge gained in one field often finds application in other fields, with mathematics providing the basic language common to all fields. Facilities and research tools needed vary considerably from pencil and paper to oceanographic vessels to high energy accelerators to giant radio telescopes.

Because of the broad spectrum of subject matter covered, the Division of Mathematical, Physical, and Engineering Sciences is organized along traditional disciplinary lines paralleling the departmental organization of the universities where the research is accomplished. The Division, therefore, has six programs—Astronomy, Atmospheric Sciences, Chemistry, Earth Sciences, and Physics—and one section, Engineering Sciences, under which are a number of separate programs.

In addition, the Division is responsible for a number of national programs—Project Mohole for drilling under water through the crust of the earth into the mantle, Weather Modification, and for the physical science aspects of the International Indian Ocean Expedition. It is also responsible for three national research centers, managed for the Foundation by university corporations—Kitt Peak National Observatory, National Radio Astronomy Observatory, and the National Center for Atmospheric Research.

### *Astronomy*

The astronomy program supports research dealing with all types of celestial phenomena—the solar system, stars, comets, galaxies, interstellar gas and dust, etc. Progress in this field has become ever more rapid because of the development, in recent years, of radio telescopes, the use of high-altitude balloons and space vehicles for observation, and the development of electronic-image intensification which increases manyfold the efficiency of existing optical instruments. Automation techniques are being used increasingly in both optical and radio astronomy making data collection much faster and easier. The establishment of two national observatories by the Foundation has made available essential facilities to the nation's astronomers which were beyond the financial capacity of any one university.

The newly developing field of neutrino astronomy which owes its existence to developments in nuclear physics is one that should have considerable impact on our understanding of the important role played by the exclusive neutrino, the least of all nuclear particles (without mass and

without charge), in the evolution of stars and especially supernovae. Neutrinos are created in the nuclear fires that generate the energy inside stars, travel with the speed of light, and have a mean free path many times the size of the entire universe. Neutrinos are byproducts of thermonuclear reactions in stars, such as the well-known proton-proton reaction and the carbon cycle which both form helium out of hydrogen by fusion.

Although the neutrinos thus produced pass through the star without interference, they carry away only a small percentage of the energy (3 to 7 percent). But if the neutrino flux of a star, e.g., our own sun, could be detected, their energies and numbers would provide a direct verification of the reactions in the solar nuclear furnace. Detecting neutrinos is extremely difficult, because of the very slight interaction with matter. However, equipment for observational neutrino astronomy is under design by several investigators who plan to measure the sun's flux and the neutrino flux from supernovae.

An entirely new neutrino mechanism (electron-positron annihilation) occurs in the very hottest stars where the central temperature is 600 million degrees Kelvin or more. In these stars the neutrino process dominates all other modes of energy loss, and it provides a radically different view of how a star becomes a supernova. This means that such an extreme star can lose all its energy through neutrino emission in a few days, and that is about as good a description as can be given of a supernova.

Briefly, the new theory of supernovae has the following aspects. With the central energy radiated away so drastically, the star has to contract very fast. This quickly heats the central regions as well as the outer layers and in a short time all the nuclear fuel in the star is ignited, causing an explosion like a huge hydrogen bomb of stellar dimensions. At the same time a shock wave, produced at the center accelerates outwards. When this shock wave collides with the surface of the star the whole menagerie of elementary particles can be produced. Most of them soon decay into protons, electrons, and neutrinos with energies of 10–20 billion electron volts. This may be the mechanism for the creation of cosmic rays which later are accelerated again by collisions with interstellar magnetic fields. Even in the present state of detector technology, the neutrino flux of a galactic supernova can be detected.

### *Atmospheric Sciences*

The atmosphere is a thermally active hydrodynamic system, compressible, non-homogeneous, viscous, and constantly in motion in non-

linear response to a complex of internal and cosmic forces. It interacts with the earth and ocean at its lower boundary and with the solar atmosphere at its outermost reaches. It is driven by sources and sinks of thermal energy which are caused by the variable reaction of the atmosphere to the sun's radiant energy, the latent heat involved in phase changes of water substance, the photochemical processes at upper levels of the atmosphere, and the transfer of heat to and from the underlying earth and ocean. An understanding of this exceedingly complex system is the goal of the Atmospheric Sciences program. Such understanding will surely assist in placing weather forecasting on a firmer scientific basis and may eventually provide man with the ability to control the weather.

Photochemical and electrical phenomena are being measured by Foundation grantees; the energy processes that influence the behavior of the atmosphere at the upper levels are being described; and light is being shed on the manner in which the upper atmosphere links solar activity with terrestrial phenomena. The ability to observe atmospheric changes from meteorological satellites is being rapidly exploited; also measurements employing indirect probes and isotope tracer techniques are demonstrating their effectiveness. For the first time, an adequate description of the atmosphere by physically significant measurements is within our grasp. Such quantitative measurements are contributing greatly to the rapid developments in theory and understanding of the phenomena observed. Two examples may be cited:

First, the brilliant work in closing the gap between the theory of fluid motions and the reality of nature as revealed in the synoptic representation of large-scale atmospheric motion systems. The successful blending of mathematical and physical insight, the power of the high-speed computer, and the ability to simulate atmospheric movement in rotating hydrodynamic tanks are contributing greatly to the determination of a valid explanation of the general circulation of the atmosphere.

Second, progress toward a physical explanation of condensation and precipitation phenomena. The physics of the condensation process, by which the phase transition from vapor to liquid or solid, in the presence of nuclei, now appears to be amenable to solution. The principal processes by which millions of cloud droplets come together to form precipitating elements are being treated quantitatively and the dynamics of cloud and the role of electrical field have been brought under serious study. Much remains to be done, but the rate of scientific progress following the classical work in modifying natural clouds has clearly demonstrated that important advances can result from an augmented effort in the field of cloud physics.

One of the key factors limiting expansion of research in the atmospheric sciences is the lack of sufficient numbers of trained investigators. Because research in the atmospheric sciences requires an interdisciplinary approach, not only are meteorologists needed but also chemists, physicists, mathematicians, and engineers. The Foundation, through its many support programs, is assisting in the augmentation of the needed manpower by providing new opportunities for attracting and training able and creative young scientists in this field.

The Weather Modification program is managed as an integral part of the Atmospheric Sciences program (see page 52). The National Center for Atmospheric Research, also supported through this program, is described on page 56.

### *Chemistry*

Chemistry support is extended largely to research in organic chemistry, physical chemistry, inorganic chemistry, and analytical chemistry. Research in theoretical inorganic chemistry continues to grow, especially in coordination chemistry dealing with chelated metal ions because of their increasing importance in biology and medicine and for industrial applications; also in boron chemistry because of the possible value of boron for synthetic fuels and thermally stable inorganic polymers.

Unfortunately interest in inorganic chemistry, particularly synthetic inorganic chemistry, appears to be declining in this country. Because of the vital importance of research in this area, the Foundation with the advice of the scientific community established an ad hoc Committee on Inorganic Chemistry. As a result of their recommendation, a summer institute was held, as part of the Foundation's education program, this past summer for college teachers and undergraduates. An exchange program is being planned which will permit prominent European synthetic inorganic chemists to spend a year or two in academic institutions in this country teaching and conducting research and which also will permit prominent American physical inorganic chemists to do the same thing in European institutions. NSF is also providing increased support for inorganic chemistry. A Foundation-supported grantee prepared a number of hexacoordinated silicon compounds and from one of them a thermally stable phthalocyaninosiloxane polymer. This polymer exhibits exceptional stability and may find application as a high-temperature resistant material because the silicon-oxygen bridges are shielded within the center of the molecule.

In organic chemistry, more than half of the grants were for physical organic research—a concentration that has been aided by the availability of modern instrumentation. The projects include studies on the

mechanisms, kinetics, and equilibria of reactions. Others were for synthetic studies and investigations of new chemistry and new reactions; synthesis and structure determination of natural products; and stereochemical and conformational analysis studies. Of particular interest was the synthesis for the first time of dilithium pentalenide, the first derivative of the pentalenyl dianion. This work may pave the way to pentalene itself, a bicyclic unsaturated compound that is of considerable theoretical interest.

Research in analytical chemistry continues to place major emphasis on the use of instrumental methods and a physical chemical approach to the solution of research problems. Radiography and chromatography are the areas of greatest current interest. Successful separation of inorganic substances, especially metals, has been achieved through extension of the gas-liquid chromatographic process. A Foundation grantee has accomplished a quantitative separation of volatile chlorides of tin and titanium. If it proves to have general applicability, this technique may be of tremendous assistance in the solution of such difficult problems as the separation of the rare earth metals.

In physical chemistry, there was increased support for radiofrequency and microwave spectroscopy, statistical and quantum mechanics, and catalysis and adsorption. Continuing support has been provided for research in the areas of thermodynamics, thermochemistry, reaction kinetics, colloid chemistry, optical spectroscopy, photochemistry, polymer chemistry, and crystal structure.

### *Earth Sciences*

The Earth Sciences program supports basic research in geology, geochemistry, geophysics, and oceanography, as well as in such related fields as hydrology and soil science. In the solid earth sciences (geology, geochemistry, and geophysics) much of the support went into geochemical studies, particularly isotope research that was focused on geological problems. Increased interest was evident in geophysics, especially paleomagnetism and heat flow. Emphasis on the marine sciences was continued with increased support for physical oceanography, marine geology, chemical oceanography, and submarine geophysics.

In geochemistry the use of potassium-argon isotopes to date prehistoric man showed that man as a tool maker was 1,750,000 years old, almost twice as old as previously believed. In another geochemical study, samples from Gatun Lake (Panama Canal Zone) dated by radiocarbon yielded results suggesting a rapid rise in sea level in the period from 11,000 to 7,000 years before the present, followed by a much slower rise since then. These data are consistent with the evidence compiled in the tem-

perate zones about the melting of the ice of the last great glaciation 11,400 years ago.

Research on tektites, which have become objects of more extensive study with the advent of the Space Age, was continued to determine whether these glassy bodies originated on the earth or came from outer space. Recent work has shown or confirmed the following: (1) Tektites are not fragments of larger pieces, but are essentially the same size and shape as when they were formed. (2) The mineral composition, magnetic properties, and low water content all indicate high temperatures of formation. (3) Strain patterns are similar to those found in other small bodies that are known to have cooled quickly from a molten state. (4) The similarity of tektites in any one area suggests that each particular group is related to an individual tektite shower that might have resulted from sudden impact of a meteorite or other body. (5) Laboratory analyses of $Al^{26}$, produced by exposure to cosmic radiation, showed that tektites contain about as much of this element as do other terrestrial materials. The low exposure of tektites to cosmic radiation is thus consistent with a terrestrial mode of origin, but does not rule out completely an extraterrestrial origin.

Geologic research involved a wide variety of studies including mineral research, physical and biostratigraphic studies of sedimentary rocks, studies of pollen, petrographic research, studies of glacial ice structures, and paleoclimatic and paleontological research. Based on mineralographic and X-ray study, one grantee has investigated the little known and very complex, manganese ore minerals. In yet another study, paleobotanical data show that the Sierra Nevada came into existence as a major topographic barrier at the end of Pliocene time. Miocene floras of deciduous hardwood species, collected from rocks that are today between 5,000 and 9,000 feet high, resemble modern forests in areas where relief is generally less than 2,000 feet. Therefore, most of the summit areas must have been relatively low in Miocene time. Paleoclimatic data is also consistent with this interpretation.

In oceanographic research a grantee has discovered that the "tongue" or radula of certain mollusks have "teeth" composed of magnetite, a magnetic oxide of iron, and that the radula of some snails have "teeth" of goethite, a hydrated iron oxide. These discoveries illustrate the complex nature of oceanographic studies and open up new avenues of research. There is, for example, a biochemical problem of how iron, a trace element in sea water, can be metabolized and concentrated within the organisms so as to be precipitated in concentrations up to 65 percent iron oxide. There is also the geochemical problem of the fate of these skeletal minerals after death of the organism and the problem of stability

of goethite which is not generally found in marine sediments and of the instability of magnetite, usually considered to be resistant to natural chemical dissolution processes.

Notable also in oceanographic research was a Great Lakes study in which drilling operations from a floating barge penetrated hundreds of feet of sediments and showed bedrock valleys to be present more than 1,000 feet below sea level.

### *Engineering*

During the year the status of the engineering sciences was strengthened by the establishment of the Engineering Section which supersedes and absorbs the Engineering Sciences program. Within the Section there are now programs in engineering chemistry, energetics, mechanics, materials, and systems.

Also, the National Science Foundation has adopted a policy which clarifies the engineering research supportable by the Foundation by indicating that intellectual pursuits at educational institutions intended to advance significantly the basic engineering capabilities of the country are eligible for support by the National Science Foundation as basic research in the engineering sciences. Such work must be of a true scientific nature and not routine engineering practice, and must meet the usual NSF standards of originality and excellence.

This action recognizes that, in addition to the basic engineering science research in the classical disciplines stemming from the physical sciences, meritorious research along the following lines has been and will continue to be important: the development of principles and techniques in systems engineering design, the development of principles and a philosophy for creative engineering, interdisciplinary research such as biomedical engineering, the principles of generation and control of energy systems and information systems, and the analysis and synthesis of processes and systems which contribute to the mastery of the environment.

A variety of engineering research has been supported by the Foundation. There is a noticeable growth trend in the broad area of plasma dynamics. Several projects have been motivated by the interest in space research. In many cases, the results of a particular basic research study may have future application in space activities as well as in other situations. For example, research on combustion, two-phase flow, heat transfer, materials, structural mechanics, and control systems could have space implications. One NSF-supported study of the effect of low-gravity environment upon fluid configuration in containers has indicated that short-duration experiments under low-gravity free-fall conditions may lead to false conclusions. Short-duration, low-gravity experiments

show, for example, that the air in a container partially filled with water takes the form of a bubble in the center of the container. A theoretical analysis (later partially confirmed during a space flight) indicates that this condition will not prevail for a long-term experiment, and the air would again be in contact with the wall. However, the liquid configuration may be quite different from what would be expected under normal conditions. The results of this research could help lead the way to improved design of liquid-containing systems for use in space vehicles.

A significant advance over previous methods in chemical process control engineering has resulted from research conducted during the past year under an NSF grant. These researchers have developed a system for the control of a continuous chemical reaction which self-adjusts so that optimization of cost or yield of product may be achieved directly and continuously. Analysis of the response of the product yield to a small periodic change in a process variable, such as temperature or flow rate, provides the basis for automatic adjustment of the variable in such manner that the process operates at maximum yield or minimum cost. It is feasible to apply the control system to a catalytic reaction where catalyst activity is changing in an unknown manner. So far the system of control has been applied only to a simple chemical reaction.

### *Mathematical Sciences*

Research in mathematics is extremely diversified, varying from abstract symbolic logic to quite concrete applied mathematics. New fields evolve continuously, and the old classifications become blurred by the emergence of such hybrid subjects of study as algebraic geometry, differential algebra, algebraic topology, topological dynamics, and differential topology. Even describing the subject matter of these varied disciplines is difficult because of the relative unintelligibility of most of modern mathematics to scientists well informed in other fields, yet all the physical sciences, and increasingly the biological and social sciences as well, are dependent on mathematics. Solutions to many of the problems which arise require some of the most advanced mathematical techniques presently available.

Among the significant results of Foundation-supported research this year are two cases of verification of conjectures that had been outstanding for many years. At a time of intense activity, new problems are followed by their solutions with great rapidity, and it is sometimes hard to gauge the difficulty of results, because results often appear deceptively simple in hindsight. It is therefore particularly heartening to see old problems that have tried the talents of generations of mathematicians yielding along with newer ones before the current concerted effort.

In the field of algebra, group theory has assumed a central role, and it has accordingly been the subject of a great deal of research over the years. Yet some of the most refractory problems are still to be found in the theory of finite groups, where, as in number theory, it is easy to make plausible conjectures that are very difficult to prove. One such conjecture, that all groups of odd order are solvable was confirmed this year.

In the field of topology, successful inroads have been made upon another famous conjecture. Around the turn of the century the great French mathematician, Henri Poincaré, observed that every closed, simply connected, two-dimensional manifold is a two-sphere, i.e., the surface of a three-dimensional ball, or something which can be obtained from it by stretching and shrinking without tearing or cutting. He was guided by a remarkably fine geometric intuition to conjecture that the analogous result holds true in the next higher dimension. More daring moderns have conjectured that analogous results hold true in all higher dimensions. The former is the original Poincaré conjecture; the latter, the generalized Poincaré conjecture. Strangely enough, the original conjecture still resists proof, as does the next higher case, but this year two independent proofs have been given for all dimensions thereafter. Together these two breakthroughs have set the stage for much further progress in differential topology.

### *Physics*

At present, physicists are concentrating primarily on research into the properties of the solid state, of elementary particles, of nuclear structure, and of atoms and molecules. Consequently, most of the Foundation support for physics is provided in these subdisciplines.

With the availability of increased funds for physics research in the past year, university physicists have begun more and more to look to the Foundation for assistance. Support of solid state physics has shown a particularly large rate of expansion. In addition, the Foundation established a program of support for nuclear research facilities, and also was able to approve a number of grants of sufficient size to constitute the principal support for major research groups. Such support is exceptionally expensive considering that the overall cost of conducting a single significant experiment in high energy physics is roughly estimated at $250,000.

The major accomplishments in physics during the past twelve months have largely consisted of discoveries in elementary particles. Our Nation's considerable investment in multi-BeV accelerators has contributed greatly to advances in this branch of physics; both the number of known

particles and our knowledge of their interactions have increased to a marked degree in recent months. The most exciting discovery, perhaps, was that of two distinct kinds of neutrinos, one associated with electron interactions, and the other with muon interactions. It seems to be a major step toward understanding how the muon and electron can appear to be identical even though the muon is 200 times heavier.

While NSF has not supported high energy accelerator laboratories directly, the "users" program provides an appreciable and rapidly growing measure of support for elementary particle physics. This program consists of making grants in support of university physicists who cooperate in conducting experiments at large accelerator laboratories, and who later carry out analysis and interpretation of resulting data at their home institutions. Through this program, NSF sponsorship has played a role in recent important developments of elementary particle physics. An example is the work of a group that analyzed the interactions of positive pions with deuterium, and became among the first to discover a new particle, the Eta meson, and to confirm the existence of the Omega meson.

Notable work was done during the past year in low temperature physics, particularly in work on the physical properties of liquid helium (at temperatures 2.2° above absolute zero). It has been known for some time that two types of waves can propagate through a liquid of this nature, which is described as being made up of two interpenetrating components—one a normal fluid, the other a superfluid without viscosity. A pressure wave, known as "first sound", propagates by oscillating the two fluid components in phase with one another. A thermal wave propagation, known as "second sound", involves out-of-phase oscillation. Several years ago a grantee predicted the existence of another form of wave disturbance in films of liquid helium. Termed "third sound", it would be one in which the superfluid component oscillates while the interpenetrating normal component remains fixed. Within the past year this investigator has demonstrated the existence of "third sound", and has measured its velocity as a function of the film thickness. It may be noted that this work presents one of those gratifying but infrequent cases where an investigator has carried out experimental confirmation of his own theoretical conceptions.

In atomic and molecular physics, one of the advances reported may supply the basis by which space scientists may determine the quantity of hydrogen in the atmosphere of the various planets of the solar system. Through the use of precision infrared spectroscopy, an important new band (the "forbidden" 1–0 band) has been observed. It is ten times

brighter than had been predicted. The intensity of the band is proportional to the amount of hydrogen between the source and the observer.

## CURRENT RESEARCH IN THE BIOLOGICAL AND MEDICAL SCIENCES

Developments in the biological and medical sciences over the past several years have moved with such rapidity and been of such major importance as to constitute a revolution. The emphasis in the biological field has shifted markedly from studies of the whole organism to investigations at the cellular and subcellular levels. The chemical and physical aspects of life processes have become much more clearly understood, in part through the application of outstanding technological advances, such as those made possible by the electron microscope, for example, and important breakthroughs in our knowledge of the hereditary processes. Much fuller understanding of the nature of life itself is now foreseeable, and the implications of this progress in terms of man's welfare are great.

The impact of this revolution on biology as a whole is profound, also. The biochemical and biophysical discoveries in biology at the molecular level, the startling advances in knowledge of gene-chromosome relationships, and the use of computer techniques have enriched the whole discipline. It is significant that the biological scientist today, whether he is working with the intricacies of the life processes going on within a single cell or with the whole organism or a community of organisms, is calling more and more for an interdisciplinary attack on his problems.

In performing its primary task of supporting basic research in the biological and medical sciences, the Division of Biological and Medical Sciences is organized on a functional basis which covers the total spectrum ranging from classical biology to the most modern experimental problems. The Division covers this spectrum under the following eight programs: Molecular Biology, Genetic Biology, Developmental Biology, Metabolic Biology, Regulatory Biology, Environmental Biology, Psychobiology, and Systematic Biology.

Support is provided primarily for research on an individual project basis, but occasionally, where feasible, it has been extended to cover broader coherent areas of research activity of several outstanding scientists. Such grants have been made, for example, in support of research programs in molecular genetics, somatic cell genetics, and evolution. Foundation assistance is also provided for specialized biological facilities, such as oceanographic research vessels, field stations, controlled environ-

ment installations, natural history museums, as well as for the acquisition of complex equipment needed for modern research.

Encouragement is also given to the development of research programs in neglected biological areas or in those showing particular promise. An example is tropical biology, which is at the same time both a neglected field and one of special promise. The Foundation is encouraging a noticeable upturn of interest in the New World tropics on the part of biologists in a number of American institutions.

### *Molecular Biology*

The Molecular Biology program is concerned with investigation of biological systems at the molecular level. This involves the isolation, determination of structure, and the study of the reactivity of the compounds which make up such systems. It deals with research into the manner of organization of these molecules into the more complex aggregates which are the basis of biological structures; also with the dynamic aspects of the interactions between molecules which permit biological systems to persist in the face of their inherent instability, to reproduce themselves, and to maintain the same structure over many generations while concomitantly evolving into new forms over longer periods of time.

Molecular biology is concerned primarily with providing the means for the solution of biological problems rather than the solutions themselves. It is interdisciplinary in nature, not only within the biological sciences but also between the biological and physical sciences. It provides the meeting ground where the new approaches and techniques of chemistry, physics, and mathematics are applied to biological research.

Molecular biology has achieved some of its objectives, e.g., the delineation of the major aspects of structure of such biological macromolecules as DNA and protein, thereby contributing to the significant recent advances in understanding genetics and protein synthesis. Nevertheless, these advances have served only to emphasize the need for more detailed understanding of these molecular components. Consequently, the general areas of research support continue to be much like those making up the program in the past.

Certain research deals with the isolation and characterization of proteins, lipids, carbohydrates, nucleic acids, and with the investigation of some new types of compounds. One investigator has been developing information about the sulfolipids, which appear to play an important role in the structure of biological membranes. Another research effort is directed toward improving methods for investigating the precise sequence of bases in nucleic acid structures.

A second area of research deals with the nature of interactions between molecules of the same kind or between molecules of different kinds. Biological structures are aggregates of molecules, whose association must be directed by quite specific types of interactions at a molecular and electronic level. Other highly specific reactions are involved in the action of hormones, enzymes, or antigen-antibody reactions. One investigator has developed a new reagent for investigating the active site of trypsin, a protein-digesting enzyme. Another has been able to separate an antibody molecule into component subunits and then recombine them to obtain active antibody again.

A third major category of grants supports studies of subcellular structures. Attempts are being made to understand the molecular organization of such complex cellular structures as membranes, mitochondria, microsomes and ribosomes, lysosomes, walls, and muscle fibrils. One example, also related to functional behavior, would be studies of mitochondria and the chemical factors which influence the contraction of the mitochondrial membrane. Other studies are concerned with the optical properties of muscle and still others with refinement of techniques of electron microscopy.

A fourth broad area relates to the interactions of living systems with energy. These range from studies of the basic biophysical process of photosynthesis to studies of the mechanisms of specific and active transport of molecules and ions through membranes. Answers are being sought in part by the study of biological systems and in part by the study of appropriate chemical systems. Some current studies deal with visual pigments, their modification by light, and attempts to relate these processes to the generation of the nerve impulse. At another extreme, an investigator has obtained evidence that the transport of sugar and of sodium across the intestinal membrane may be linked processes.

The investigation of biological problems at the molecular level has depended upon the application of new and more powerful methodology and instrumentation. Support of further developments in polarization microscopy, the perfection of a magnetically suspended ultracentrifuge rotor, the use of lasers in photoreactive processes, and the application of temperature-jump methods to very rapid biological reactions are all in keeping with this effort to maintain a rapid advance in the application of new technologies to biological problems.

### *Genetic Biology*

The Genetic Biology program supports a variety of research projects, including preliminary and general investigations, studies of the nature

and action of the genetic material, research in quantitative and mathematical genetics, and evolutionary studies.

The preliminary and general studies are concerned with establishing the existence of a genetic basis for observed variation, finding new hereditary traits, and the location of genes on the chromosomes.

Investigations of the transmission, chemical nature, and action of the genetic material comprise a large segment of the research now supported by the genetics program. A major breakthrough has resulted in the determination of the genetic code for certain amino acids (protein building blocks). Long strides have been made in studies on the details of gene-enzyme relations and the mechanisms of information transfer in micro-organisms. The techniques involved in answering the many unsolved problems in these areas are becoming clearer and the program is making great efforts to support this area while maintaining a balance in its support for all areas of genetic biology.

The extension of the detailed analysis of mutant protein structure to higher organisms and the correlation of these with specific changes in the hereditary material are important recent developments.

The course of genetic biology is also being profoundly influenced by investigations on the way in which certain elements within the genetic material function as regulators of the activity of "structural genes." A synthesis of knowledge is taking place concerning seemingly diverse phenomena in bacteria, higher plants, and insects which have in common controlled changes in gene activity. In addition, detailed morphological and biochemical studies of development in different genetic types are continuing. There appears a reasonable hope that these diverse approaches will lead to a new and highly fruitful attack on one of the most important problems in modern biology—differentiation.

Investigations of the nature of the hereditary material itself are being integrated in many cases with studies of gene-protein relationships and "regulatory" genetic elements. However, studies of genetic fine structure by means of rare recombinational events and investigations of the mechanisms underlying irradiation and chemical mutagenesis are continuing on a wide variety of organisms.

Studies on quantitative genetics and studies of continuous variation are still an important part of the program. These studies involve inbreeding, outcrossing, and selection. Mathematical theory and statistical methods relate to quantitative genetics; some studies require applications of electronic computers.

Projects on the genetic basis of evolutionary phenomena provide the remaining grants made in this program. Such studies are concerned with genetic differences between species and natural populations and

include investigations of chromosome and gene variation, reproductive isolation, and hybridization. Grants in this area support studies on a wide variety of animals and plants—protozoans, marine invertebrates, insects, fishes and amphibians, a few lower plants, and numerous seed plants.

### *Metabolic Biology*

Investigators supported through this program study the biochemical reactions by which the substance of living organisms is built up and broken down. Generally speaking, they observe the activities of enzymes and the changes which these organic catalysts bring about in the biochemical materials on which they act. Typical of the problems they are interested in: What happens to such a material, and what are the effects on the host organism of the new substance produced from it? What brings about an increase or decrease in the amount of a particular enzyme or the rate of its activity? Where in the cell do these changes take place?

Of continuing importance are complete determination of the sequences of enzyme action which lead to a given end product and show how a given biochemical is used in the living cell. For example, although it has long been known that sulfur and nitrogen are metabolized by certain bacteria, the enzymes involved and the intermediates formed in the process are only being determined now.

An integral part of metabolic processes is the conversion of energy to a usable form during the breakdown of foodstuffs. Thus, one grantee is trying to explain the reduced utilization of the sugar, glucose, when body temperature is lowered, as during surgery. Another investigator is studying the changes in size, characteristics, and activity of the subcellular elements, mitochondria, in relation to the ion absorption capacity of plant storage tissue during washing. It is on mitochondria that respiration (oxidation), one of the main energy-producing activities of the cell, takes place.

Significant research is being done on control of the operation of metabolic pathways by hormones, substrates, environmental factors, subcellular organization of enzymes, and biochemical intermediates. These factors may act in various ways; for example, by affecting permeability of the cell wall, by inhibiting enzyme activity through the socalled feedback mechanism, or by competing with the normal substrate for the active site on an enzyme. Another factor which controls metabolism—parasitism—is being intensely studied at present. Included are studies of infection by such organisms as rickettsiae and viruses which have few or no enzymes of their own. The investigators are

striving to determine such things as the materials which a parasite requires from its host cell and the effect of the deoxyribonucleic acid (DNA) or ribonucleic acid (RNA) of the parasite on the replication of these substances in the host cell.

The synthesis of protein, particularly enzyme protein, is naturally of great interest. One NSF-supported researcher is conducting studies of the structure of the enzyme, alkaline phosphatase, in the bacterium *E. coli* as it is affected by mutational changes in the bacteria. Another's work is concerned with genetic and nongenetic mechanisms which control the rate of synthesis of the enzyme, beta-galactosidase.

In some of these projects, a possible medical application is apparent. For example, a grantee is studying the production and destruction of histamine, the substance which gives rise to allergic symptoms. Another is trying to synthesize a compound which will prevent the abnormal glycogen storage in the liver due to absence of a certain enzyme concerned with conversion of glycogen to glucose.

### *Developmental Biology*

Developmental biology as a substantive discipline bridges a complete gamut of conceptual levels ranging from the whole organism, through its organs, cells, and intracellular constituents, down to the molecular level. At each of these levels, our concept of differentiation has a very different emphasis. As one NSF grantee has expressed it, in the whole organism (holodifferentiation), emphasis is on increasing heterogeneity—the origin, localization, and amplification of differences within an originally relatively homogeneous system. The early embryo acquires its heightened diversity and complexity through such processes as polarization, regionalization, and organogenesis. "In the process there are drastic changes of properties at all subordinate levels—cell groups, individual cells, cell organelles, states of molecular aggregation, molecular species. When the focus drops to the cell—cytodifferentiation—emphasis is on change of cell properties, appearance of 'new' cell types. 'Holodifferentiation' connotes diversification, 'cytodifferentiation' connotes change and stabilization of cell properties—frequently with decreasing rather than increasing diversity within the cell. Subcellular differentiation, on the other hand, emphasizes specialization, the concentration of diverse activities toward particular ones—especially those which lead to new synthetic products, sometimes 'exported' as secretion, sometimes accumulated as 'structure' between or within the producing cells. The general term 'differentiation' denotes any of these things at all of these levels, but it has special and different connotation with respect to each.

"In studying most biological phenomena, approaches are made at several levels, and questions frequently arise as to the relationship between the conclusions drawn at each of these levels. But in development the organism passes from level to level, and the conceptual problem, in part, precisely is to understand the process of conversion of properties at one level into those of the next." (Grobstein. 1962 *Amer. Scientist.* 50: 46–58.) However, it must be emphasized that although embryos invariably progress from one level to another, each of the three levels requires separate conceptual and technological approaches and that extrapolation of knowledge from the molecular level to the supracellular level must be done either with great caution or not done at all.

Investigations of differentiation at the molecular level, many of which are supported by this program, frequently attempt to elucidate mechanisms whereby enzymes, mucopolysaccharides, or morphogenetically characteristic proteins are regularly "caused" to appear within the cell during the course of development. The recent elaboration of the gene information theory (DNA–RNA–protein) has done much to clarify the role that has been and will be played by the embryologist. Integration of knowledge about differentiation at the molecular and supracellular levels must ultimately be based upon a reverse-information theory whereby the receptive cell (including its genome) receives messenger service both directly and indirectly from neighboring cells and tissues. Such a concept of information circulation is helpful because it formulates the old embryological principles such as "organizer" and "inductor" in today's more specific language, and it postulates that the DNA–RNA–protein doctrine is actually one segment of a cycle that extends from the DNA strand into the cytoplasm (genetic information) and ultimately into extracellular spaces. Feedback of developmental information arising from cell interactions occurs in the opposite direction. Many studies aimed toward elucidation of this information circulation are currently supported by this program.

### *Regulatory Biology*

The Regulatory Biology program deals with research on the whole organism and its organ systems. Consequently, proposals submitted to this program originate from a very broad spectrum of the basic scientific disciplines. Not only are the classical areas of general and plant physiology represented, but such fields in the agricultural sciences as horticulture, agronomy, soil science, plant pathology, and veterinary medicine. Also, basic research in the field of the medical sciences, such as

pharmacology, surgery, pathology radiology, neurology, microbiology, and endocrinology, is supported.

One area of support in particular is deserving of special mention—neurophysiology. Some of the advances made here by Foundation-supported investigators have been so great that what was originally pure exploratory research has now become an area of tremendous scope involving many disciplines.

Recent findings deal with the: (1) anatomy and functional organization of the nervous system, (2) nature of the origin and output of rhythmic impulses, (3) regulatory role played by feedback circuits and of central autogenic discharges, (4) nature of coding mechanisms in receptor and central neurons and its implications, (5) the nature of the nerve impulse, as well as chemical characteristics of the nerve cell, (6) central mechanisms controlling food intake, (7) interrelations with the endocrine system, and (8) neural control of behavior. They strongly suggest that continued support of a broad and concerted attack, involving many biological and physical disciplines, will soon result in outstanding discoveries regarding brain function.

Studies of the symbiotic relationships between animals are also being supported through this program and are being made by zoologists, medical scientists, and agricultural scientists. Of all such relationships the most fascinating and least understood is parasitism. While most animal parasites belong to the invertebrate phyla, these organisms affect practically all species of vertebrates investigated. The origin and evolution of parasitism is a matter of speculation. From the standpoint of natural selection it seems possible that out of populations of free-living forms in a common environment, altered individuals have emerged and associated together as host and parasite. In other words, certain invertebrates with parasitic potentials found vertebrates with host capacities. An NSF grantee has advanced a relatively new concept with respect to the origin and evolution of host-parasite relationships, the concept of acquired immunological tolerance. He was stimulated by the observation that if foreign antigens are allowed to make suitable contact with a test animal during an early period of life, this animal will acquire an immunological tolerance to a later contact with this antigen. If a vertebrate can be induced to regard invertebrate protoplasm or metabolites as compatible rather than foreign substance, then, in the absence of host reactivity, the invertebrate will be placed in a more advantageous situation to become a parasite.

## *Psychobiology*

This program is concerned with studies of the integrated behavior of organisms, human and animal, and of the physiological and neurological processes underlying behavior. About 20 percent of the grants awarded in 1962 were for studies of animal behavior invloving fieldwork or a combination of field and laboratory research. Most of the remaining grants were for experimental laboratory studies—half with human and half with a variety of other laboratory animals.

Within the studies of animal behavior, the topics of widest interest are social behavior and communication. A number of the investigators conduct parts of their studies in the field, but then transport animals back to their laboratories for controlled experimentation and breeding. Examples of such studies include one on the behavior of Iguanid lizards and giant tortoises on the Galapagos Islands (techniques used include time-motion analyses, the use of models, and controlled contact of individuals) and one on the behavior of tree shrews, man's most primitive mammalian relatives. Other studies use physiological and experimental techniques to elucidate various aspects of the social behavior of ants and termites, including their communication and orientation. The variables controlling the evolution and maintenance of mimicry in butterflies are also being investigated. Studies are being made of the visual acuity of the dolphin beneath the water and in the air above, and of the social organization and behavior of primates in outdoor enclosures.

The more conventional laboratory studies deal with a much narrower range of species than do the field studies, because attention is directed to generalizations about such topics as learning, conditioning, sensory processes (chiefly vision), motives or drives, and social behavior. Examples include studies of the motor conditioning of dogs, the development of social behavior in rats, the visual system of the goldfish, central changes occurring under various conditions that produce impaired attentive behavior in monkeys, behavioral changes as a function of infusing micro-amounts of alcohol into the cerebral spinal fluid of rats, and the relationship between intensity of illumination and schooling behavior in fresh water fishes.

Laboratory studies of humans show interest in conditioning and learning, including verbal learning and concept formation. Examples are the processes followed by people in solving mathematical problems, the relationship between experimentally acquired verbal skills and performance in the identification of concepts, and the effect of various kinds of sensory deprivation upon different kinds of productive mental activities where intelligence is not a factor.

## *Environmental Biology*

The Environmental Biology program is concerned with research dealing with the interactions of organisms with each other and with the physical, chemical, sociological, and other biological features of their environment. In terms of disciplines, this covers plant and animal ecology, including those areas sometimes identified more specifically as environmental physiology, paleoecology, palynology, limnology, biological oceanography, macro- and micro-bioclimatology, phytosociology, animal community and population dynamics, bioenergetics, life history studies, orientation and behavioral studies, environment-controlled distribution of organisms, biological productivity, and certain features of mycology and parasitology.

The following samples of research currently being supported will give an idea of the diversity of research which falls within the purview of the program.

One grantee who has established that alder trees contribute significantly to the natural productivity of lakes is now continuing his efforts to establish the role of trace elements in limiting the basic productivity of high altitude lakes. A number of studies of the factors which control bird migration are being supported by the program. One, in particular, deals with the further investigation of the environmental and behavioral influences associated with pre-migratory restlessness and navigation ability of birds. In a ready-made outdoor laboratory, the basic biological interactions of plant and animal communities of an isolated island have been under investigation. Earlier investigations, which were concerned with the major predator (wolves) and prey (beaver) animals in relation to vegetation and other ecological factors, are to be supplemented by a thorough examination of the role played by the other major animal population which is preyed upon (moose).

Research with a somewhat different objective is being supported to increase the geographical scope of certain moisture computations and thus lay the groundwork for the preparation and production of new and more realistic world maps revealing classification of climates based upon distribution of vegetation and soils. This investigation will be followed by scientists and national leaders who have become aware of the importance of more exacting investigations of the inter-relationships of plants and animals (including man) and macro- and micro-climatic conditions.

Support of biological oceanography continues to be one of the major activities of the program. A grant to continue and expand concerted investigations of the metabolism and food relations of certain marine zooplankton with respect to features in their life cycles exemplifies one

type of assistance provided to the currently extensive U.S. effort. A purely basic investigation on the ecological implications of root grafting and the exchange of food and auxin between vigorous and suppressed tree "partners" may provide fundamental information useful in the interpretation of the role of root grafts in the transmission of diseases of economic importance, such as the Dutch elm disease. An attempt to correlate certain aspects of population genetics with population ecology should provide basic information on the evolutionary potential of a population and the closely intertwined genetic and ecological influences on natural selection. Specifically, the investigation will be concerned with the role of genetic variation in the population development of *Tribolium castaneum* (flour beetle).

The physiological adaptations of animals in counteracting extremes of environment is an area which is just opening up to study. At the forefront of such investigations is an analysis of the influences of ambient temperature on the physiological activities of reptiles which are active in nature at body temperature equaling or exceeding those of birds and mammals in comparison to such influences on reptile species in which heat resistance is much less highly developed.

Representative of a number of studies on the interpretation of vegetation and climate in earlier geological periods is a grant for the investigation of the early climatic and vegetational history of unglaciated humid and arid tropic regions. A major related objective in these African studies is an analysis of the development of equatorial lakes as ecological systems on the basis of chemical and biological information to be derived from examination of sediments and fossil materials contained in cores taken from such lakes.

The increasing cooperation of scientists trained in different disciplines in the biological sciences is exemplified by an interdisciplinary study designed to elucidate the subtle interactions which occur in a host-parasite relationship with a "controlled environment ecosystem." The investigators, in this case, use the host animal as an ecosystem in which the various genetic, physiological, nutritional, and other influences can be regulated to reveal the response in the parasite populations.

## Systematic Biology

The field of systematics focuses attention on organisms themselves—their kind and diversity, and relationships among them. In order to understand organisms the systematist gathers, utilizes, and interprets data from comparative morphology, comparative physiology, comparative biochemistry, and comparative psychology, as well as from biogeography and ecology. Systematists are concerned with the origin of

species and units of classification, and with the processes that govern their origin. This interest in evolutionary processes allies them with geneticists and ecologists, on the one hand, and with comparative morphologists, anatomists, and paleontologists, on the other. The formal classification of organisms and study of the methods and theoretical bases of classification fall within the scope of systematics. Systematists thus provide for the use of other biologists an organized arrangement of all forms of life.

A consideration of the range of projects that are supported by the program for Systematic Biology suggests something of the breadth and depth of systematic biology. Projects are diverse in regard to organisms, to habitat and geographic area, and to geologic time interval. The methods and approaches of systematists are likewise varied. An appreciation of this diversity can be gained from the following sample of projects being supported by this program: marine algae of Puerto Rico; moss flora of the Pacific Northwest; cytology and morphology of palms; cytogenetics of speciation in pines; biometric studies of butterfly weed; fossil and modern fern spores; fossil forests of Panama; revision of North and South American tortricid moths; ingestive and digestive organs of carabid beetles; paleontological studies of insect-bearing amber; larvae and juveniles of Western Atlantic flying fishes; biochemical systematic studies in the Leguminae, functional morphology of squamate reptiles; protein structure as evidence of relationships in birds; variability and evolution of dental and osteometric traits in rodents; principles of numerical taxonomy.

Representative of the sort of problem attacked by systematists is a grant-supported project for investigation of a glacial refugium (area not glaciated) on Kodiak Island. Two investigators had come independently to the conclusion, one on geological and the other on botanic grounds, that a major refugium existed on Kodiak Island during part of the Pleistocene. These scientists have been joined by two entomologists and a parasitologist, and the team is engaged in sampling the living biota of the refugium and surrounding areas and in searching for fossils from critical areas. The soil fauna will be of special interest, because soil-bound insects and other organisms often reflect accurately the history of a biota. Analysis of the collections will be aimed at evaluating the impact of this major glacial refugium on the regional flora and fauna.

Among the reports of results received during the past year from grantees, two may serve to illustrate further the scope of research supported by this program. Speciation of western newts has been the subject of a report by one grantee. Hybrids between species of these newts

have been produced artificially, no hybrids being known in nature. Fertility of these hybrids and viability of the second generation offspring were generally high. Results of the breeding experiments thus suggest that speciation in western newts and preservation of the distinctness of species have been achieved through behavioral and other isolating mechanisms without development of basically incompatible genetic backgrounds. Characteristics which distinguish between species of western newts seem to be referable to a very limited number of genes. Important information on terrestrial vertebrate fossils from the Permian period (200 million years old) has been reported by another grantee. Previously the history of Permian terrestrial vertebrates was based in large part on early Permian fossils from North America and later Permian fossils from Russia and Africa. The picture was incomplete, however, due to a temporal gap between early and late Permian faunas. New discoveries in North America have brought to light faunas that are helping to bridge the former gap. These discoveries are shedding light on such phylogenetic problems as the evolution of mammal-like reptiles, those reptiles from which the mammals took origin, as well as Old and New World faunal resemblance; and on understanding of intercontinental correlation and of vertebrate faunal arrays characteristic of ancient terrestrial environments.

## CURRENT RESEARCH IN THE SOCIAL SCIENCES

The expansion last year of the social sciences to full-fledged divisional status signified the importance attached by the Foundation to the social sciences. In the same way, the inclusion of the behavioral sciences within the purview of the President's Science Advisory Committee signified recognition on a national scale of the importance of the scientific study of behavior; the issuance of its publication "Strengthening the Behavioral Sciences" was a most significant event with clear implications for the future conduct of the Foundation's programs in support of behavioral science. It seems quite evident that the Foundation's encouragement of the social and behavioral sciences contributed greatly to the position expressed in the Committee's report.

The Division of Social Sciences is organized into four programs: *Anthropological Sciences*—including physical anthropology, archaeology, linguistics, and social and cultural anthropology; *Economic Sciences*—including econometrics, mathematical economics, economics of science and technology, economic and social geography, research of basic scientific nature on other economic topics, as well as research involving development or use of theories and methods of a non-mathematics char-

acter; *Sociological Sciences*—including demography, social psychology, sociology, psycholinguistics, and the sociology of science; and *History and Philosophy of Science.*

## Anthropological Sciences

From the methodological point of view, the research supported includes accumulation of basic data (often from societies or groups under the threat of exinction in the near future), the investigation of ongoing social and biological processes, the recovery of past cultural events for the elucidation of time-ordered processes, and the development and testing of new research techniques. Perhaps the outstanding contribution of the program in the past and present has been the support of broadly oriented, coordinated studies of the many social and natural variables which interact to produce the cultural configuration of a particular society.

Each of the societies, past and present, in which man has lived represents an experiment in cultural adaptation, and, as modern societies are altered by contact with western civilizations, living evidence of man's variability is disappearing. Several studies supported by the program combine the coordinated approach with the realization that truly primitive peoples are fast vanishing and that it is urgent to collect data about them. In New Guinea, regions along the upland rivers and in high-altitude rain forests have been relatively undisturbed by influence from more complex societies and are just being opened to anthropological research. Careful investigation of demographic features, of systems of land use, and of concomitant social features will provide the foundation for important analyses of cultural adaptations of a primitive horticultural population to its environment and of cultural changes related to the forced elimination of certain aspects of former adaptations. For example, cross-cultural studies suggest that headhunting raids of primitive groups may have the functions of population dispersion, adjustment of male-female and age ratios, and prevention of over-exploitation of resources resulting from population growth. If warfare has similar functions in New Guinea, careful observation of the early effects of administrative suppression of headhunting should reveal either ready development of functional alternatives or anxiety and disorganization. Another research project having as its focal point the aboriginal peoples of New Guinea seeks through the study of population genetics, linguistic interrelationships, and cultural and psychological variation and change to clarify the interrelationships of language, culture, and biological properties.

Experimental investigation of ethnological problems is not possible

because of the difficulties inherent in trying to control cultural variables. However, fortuitous circumstances in the Pacific make possible the study of continuities and change in five matched pairs of population units that have been forced to move from their homelands. These societies provide, in effect, natural experiments. In some instances the population unit was, before and after its removal, a single relatively self-contained and autonomous community; in others it became such only after members of different but related communities were assembled and transported to their new home. All have been relocated because of impending threats, such as over-population or natural disaster, or for political reasons, or both. The study of the outcomes of these several relocations differs from many other studies of change and stability in which the focus is more narrowly upon the transformation of single cultural traits, institutions, or complexes. Its results will contribute to the understanding and the theory, not only of cultural change, but also of community stress and viability, cultural diversification, environmental adaptation, and resettlement planning for future displaced populations in the Pacific and elsewhere.

The Pacific area is also being investigated archaeologically. Because of their extreme isolation in prehistoric times, the islands of the Pacific form a unique situation for the study of man and his culture. The project will provide the time-space framework for future investigations in Polynesia by giving special attention to prehistorical ecology. By uncovering what lies beneath the surface in east-central and western Polynesia, the origins of the Hawaiian, central Polynesian, and Maori cultures may be traced and cross-oceanic influences determined.

Support for anthropological linguistics covers projects on the languages of the Taos and Sioux Indians, and on Cherokee documents written in the Sequoyah syllabary. Testing of the lexicostatistical classification of related languages involves machine calculation of the percentages of cognates in each of many 100 word lists collected in Malayo-Polynesian languages. Classification of a large number of languages and study of significant indices of relationships will test the postulate that languages which exhibit significantly higher percentages of cognates in a basic vocabulary list are most closely related to each other. Statistical runs on Indo-European language relationships will further test the methods of lexicostatistical classification.

### *Economic Sciences*

One of the youngest of the Foundation's programs, support of basic research in economics is developing rapidly both in size and in variety of projects.

A sampling of the grants made this year illustrates a variety of research methods. One theoretical analysis is directed toward discovering bargaining solutions for noncooperative games, and another will attempt to extend the usefulness of general equilibrium analysis in international trade. Still other research seeks resource allocation mechanisms of improved informational efficiency, combining welfare and organization theory. Several investigators will employ experimental techniques as yet less utilized in economics than in other social sciences or, of course, the natural sciences. One project of this kind will use experimental competitive markets; another will attempt by experimental means to amplify a simultaneous theoretical attack (along Bayesian lines) on statistical decision theory.

Simulation, a new technique made possible by the speed of the modern computer, may provide economics with a semiexperimental approach to certain classes of problems. The method is being employed, with the aid of grants, by several investigators. One economist is using this device to "shock" a basic econometric model which previously was incapable of generating economic fluctuations.

Research on the economic causes and effects of scientific and technological change is sponsored not only because of the special interests of the NSF in the area but also because of their significance in the American economy and their relationship to the theory of economic development. One grantee, who has undertaken a detailed study of patents in railroads, petroleum refining, and other fields, has reported evidence suggesting the historic shifts in inventive attention are intimately associated with unfolding economic needs and opportunities arising out of a changing social order. These research results would modify the familiar belief that technological progress is an independent cause of socioeconomic change. Though "cultural lags" (instances in which social arrangements are made obsolete by technological changes) undoubtedly exist, there also are chronic tendencies of technology to lag behind demand—"technological lags."

Sometimes new technology enters the economy through new capital formation, and even where this is not the case the investment rate is both a determinant of economic growth and a cause of economic fluctuations. To gain knowledge of this subject, grants have been made to several investigators. One will combine empirical and theoretical methods in attempting to explain inventory fluctuations, important causes of post-war business fluctuations in the United States. Foundation support will enable another economist to attempt to link capital theory and investment theory using randomly affected lags.

## *Sociological Sciences*

Social scientists have long been aware of the limitations of research results based on small and fortuitious samples of Americans in some readily accessible locality. Several grants have been made by the program in previous years for studies involving comparative data from more than one nation. For example, one study involves the automobile industries and workers of Lansing, Michigan, and Turin, Italy. These two communities are similar in being dominated economically by the automobile industry, but differ in cultural setting. Comparisons will be made concerning the informal social structure of the factories, the occupational involvement and job satisfaction of employees, and the social integration of the communities and neighborhoods. These comparisons will help clarify which generalizations about American industrial plants and communities are culture-bound and which are more widely applicable.

A sociologist who has developed a theory of societal structure, is engaged in a test of aspects of his theory in Tokujawa, Japan. The theory was developed largely from studies in the United States, and a test in a very different culture, such as Japan, will challenge the generality of the theory.

A number of new grants during this fiscal year greatly extend the effort to differentiate between culture-bound generalizations about the U.S. and those that hold more broadly for social organizations and behavior. A grant was made to a team of investigators for a study of the effects of various child-rearing practices in the United States, Switzerland, and the Soviet Union. Many aspects of the personality and behavior of children will be studied in relation to the extent of training in the family, in boarding schools, and in semi-autonomous peer groups.

The International Sociological Association and UNESCO have cooperated in organizing a major cross-cultural study of mass communication. The study will examine, by careful objective methods, the content of motion pictures in at least 10 countries in Europe, Asia, and North and South America. Emphasis in the study is placed up the portrayal of film heroes, who are regarded as idealized images of the prevalent cultural values and also as an influence that may shape cultural values. Exactly comparable procedures of analysis will be used in all countries with NSF providing support for the United States portion.

These studies are examples, among others, of a strong trend in sociological research toward generalizing American studies by obtaining comparable data from other countries. This type of research should help clarify the extent to which findings of United States sociology are culture-bound.

The closely related effort to obtain more representative behavioral data within the United States has not progressed as far. One major difficulty in obtaining a representative United States sample for many kinds of studies is the massive cost and time commitment involved. It is not possible for each researcher, individually, to build up the elaborate research organization necessary for this purpose, and the duplication involved would be prohibitively expensive in any case. Hence, a special grant was made to the National Opinion Research Corporation to establish a national survey research facility with its services available to researchers all over the country. A periodic survey, on a carefully drawn representative sample, will be conducted to which individual researchers may append questions so as to obtain data needed for various studies. This will make it possible, at more modest cost, for an individual researcher to test hypotheses on a sample that gives surer grounds for inferring generality of his results.

One of the objectives of the program is to encourage studies that use a variety of methods, experimental and nonexperimental, in a concerted attack on some defined substantive area. Most proposals still use only experimental methods or only survey methods. An illustration of a more varied approach is a major project directed at empirically based formal theory of authority structures in organizations. The empirical aspect of the project makes use of surveys and observations in two large organizations—an industrial plant and a medical center—and simple laboratory experiments that are constructed as analogs of authority structures found in the large organizations. Survey data and observations in outside "real" organizations will be used to suggest hypotheses and designs for experiments, new independent variables that should be introduced in the laboratory, and changes in the theoretical models. Thus, the strategy is to work back and forth between the restricted but well-controlled environment of the laboratory and the richer, less-controlled environment of real organizations. In this way, it is hoped precise, mathematically expressed theory will be developed that can predict the more controlled experiments while still maintaining maximum relevance to the richer, uncontrolled real organizations.

A second major program objective is the development of more formal, empirically relevant theory. Several studies are aimed at developing mathematically based theory. One investigator has developed a complex model of interaction and discussion preceding an individual's decision, and is developing other models that may represent a variety of social processes, such as addiction, fashion, technological replacement, and social mobility. All of these models will be realized in computer programs.

A mathematically trained sociologist is undertaking research on intergenerational social mobility, with theories expressed in a mathematical model based on the theory of restricted permutations. The model is aimed at inferring causes of observed inequalities of mobility rates in different social strata. Preliminary research, applying the model to data from Denmark and Great Britain, suggests that, within the rather stringent assumptions of the model, occupational inheritance adequately explains observed unequal opportunities for mobility. Work is progressing toward relaxing the assumptions of the model and extending it to deal with such matters as social mobility through marriage, effects of innovations on mobility, and the chain of job changes precipitated by a single change.

A third investigator is conducting research aimed at analyzing social structures with computers and then simulating them in computer programs. Characteristics of persons at each point in a structure are programmed and the characteristic functioning of the structure is then determined. Also various theoretically significant elements of a social process (e.g., worker-management relations, communication nets, status systems) are programmed and stable states (if any) of these theoretical processes are determined by computer runs. The results from computer simulations are compared with data from studies of such varied topics as rebellious behavior in high schools, interaction in three-person groups, reward and participation in formal organizations, and the like.

Improved research methods, as has been pointed out, are of critical importance, and NSF has supported a number of projects which involve methodological innovations or developments. A recent grant will assist research on the role of reinforcement in the development of group structure. An ingenious experimental approach is employed in which groups are brought together for a discussion, with members being differentially reinforced for leadership behavior or some other selected class of role behavior. Reinforcement is given to each member without any member's knowing when others are reinforced. The design is unusual (for an experiment on this topic) in that there are no confederates in the experiment—all of the subjects are naive. Thus, the experimenters can alter behavior of a selected group member for experimental purposes without the directing and possibly distorting effects of programmed behavior by an experimental confederate in the group. The development of the technique may be quite valuable in experimental studies of small groups, social perception, role differentiation, and other areas.

Another grant in this area concerns the methods and costs of survey research. An attempt will be made to assess the costs involved in the various operations and methods of data collection and analysis currently

in use. The aim is to determine which methods will yield the highest quality data for the lowest possible cost. The findings of this research should go a long way in encouraging the best use of financial and methodological resources in survey research.

### *History and Philosophy of Science*

Support for the history of science ranges from studies of the works of individuals to studies of whole eras of scientific development. The latter often furnish the framework for the former, and thus support of both types is vital to the advance of the history of science. However, if the type of request received by the Foundation is indeed a valid indicator of research trends, historians of science have become increasingly interested in the broad aspects of scientific development. Projects supported by the program range in time from the early Greek mathematicians to the development of biological theory in modern Russia. Periods of greatest activity are, of course, of most interest. For example, science flourished in France and in England during the eighteenth and nineteenth centuries, and three grants awarded during fiscal year 1962 take this period of efflorescence as their major focus. One is concerned with the communities of intellectuals in England which encouraged and influenced the development and exchange of scientific ideas. Another will study scientific developments in Revolutionary and Napoleonic France, when analytical and celestial mechanics, chemistry, comparative anatomy, and experimental and clinical biology assumed essentially modern form in the hands of the great French scientists. The third links the exceptional scientific productivity of French pharmacology with the nineteenth century applications of chemistry to fields such as biology, hygiene, therapeutics, and toxicology.

Projects concerned with the influence of individuals on the course of scientific development include one in which the writings of Ptolemy will be translated and critically analyzed. A similar treatment of the writings of Erwin Schrödinger will result in a monograph which will deal not only with his development of wave mechanics but also with his interpretation of quantum mechanics and analyses of Darwinian and Greek philosophical concepts.

Although the philosophical foundations of science are a subject of basic importance to both the scientist and the philosopher, there are few workers in this field, a condition that is reflected in the relatively small number of grants awarded for philosophy of science. One researcher is receiving support for his continuing efforts to develop a new theory of probability based on the concept that all non-deductive inference is probability inference. The system constitutes an inductive logic,

constructed on the basis of symbolic logic and measure theory. It also embraces a new theory of statistical inference, estimation, and amount of information. Thus the project belongs to the boundary region between logic, mathematics, and methodology of science.

An investigation of meaning, belief, and behavior is concerned primarily with a method for the semantic analysis of meaning. Another grant, for a joint research program of five eminent philosophers of science, is concerned with the basic concepts of current atomic and quantum theory, including the theory of measurement. Because of the diversity of views of the five participants, the joint effort will be mutually stimulating and may result in new understanding of the logical bases of physical theories, probability, induction, and statistics.

Because the philosophical bases of geology have until now been largely ignored in modern texts and anthologies of the philosophy of science, a grant has been awarded to prepare an annotated bibliography and index of philosophical concepts pertaining to geology, to be drawn from existing geological literature.

## SIGNIFICANT RESEARCH DEVELOPMENTS

GENETIC CODE DETERMINED FOR PRODUCTION OF SPECIFIC AMINO ACIDS IN ENZYME MOLECULE—One of the most dramatic developments in biology today is the unraveling of the genetic code for the amino acids. During the last year, evidence has accumulated that the coded information for each amino acid in an enzyme molecule consists of triplets of the smallest subunits (nucleotides) of DNA (the hereditary material). Moreover, it has been possible to specify the nucleotide composition of the coding units for specific amino acids. The initial "cracking" of the code came from an *in vitro* system in which relatively simple combinations of amino acids were formed. In a brilliant combination of genetic experiments and biochemical studies, an NSF-supported investigator extended genetic coding to gene-enzyme relationships in a living system.

These experiments were conducted on normal and mutant forms of an enzyme, tryptophane synthetase, from the bacterium *Escherichia coli.* They indicate that genetic mutations which affect the same coding unit result in replacement of the same amino acid. If different sites within the same coding unit are changed by recombination in genetic experiments, different amino acids replace the original one in the enzyme. Moreover, each amino acid replacement observed so far can be explained as the consequence of a single nucleotide change in the corresponding coding unit, as worked out from the simpler, *in vitro* system.

The significance of these pioneering experiments extends beyond the

present accomplishments. They indicate the road which will undoubtedly lead to the answering of many unsolved problems concerning the operation of the genetic code in directing enzyme synthesis.

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GENETIC CODE PROBABLY NOT UNIVERSAL BECAUSE OF EVOLUTIONARY CHANGES IN TRANSLATION MACHINERY—One of the general assumptions of investigators studying the mechanism of heredity has been that the genetic code is universal, i.e., that the meaning of a coding unit will remain the same for all organisms. However, this view assumes that the complex "translation machinery" for the information coded in DNA will remain permanently unchanged. Recent evidence has shown that mutations can occur in this translation machinery, which, in effect, alter the interpretation of the coded information.

The suggestion that such mutations do occur came from studies of certain mutants at a single "locus" of the T4 bacteriophage which infects the bacterium *Escherichia coli*. It has been found that these mutants, which all involve a simple change within one coding unit, may be inactive in infecting one strain of the bacterium, but may be active in an altered strain. The most reasonable explanation is that the altered bacterial strain carries a mutation in the translation machinery for the genetic code which changes the interpretation of the phage mutant coding unit from "nonsense" to an order for a specific amino acid. This would appear to be a very simple case of an inherited change in the translation machinery.

The discovery that mutations in the translation machinery probably occur led to a preliminary testing of the similarities and differences in the translation mechanisms from three widely separated forms—a bacterium, yeast, and rabbit. These tests involved isolating the essential ingredients of the translation machinery from the organisms involved and forming "mixed" *in vitro* systems. The ability of these systems to translate for specific amino acids was tested. Striking quantitative differences were found with certain amino acids. In these cases the "mixed" systems were much less effective in translating for the amino acid than the control systems where all the ingredients came from one organism.

Thus, differences in the translation machinery do exist and must be taken into account, although the fact that the mixed systems function at all suggests that the variability may be limited.

* * *

DNA OF VIRUS FORCES INFECTED CELL TO SYNTHESIZE VIRAL RNA RATHER THAN NORMAL RNA—For a number of years, evidence has

been accumulating that a virus which infects a cell takes over much of the machinery of the cell and uses it for its own reproduction. This has been shown very directly for the synthesis of ribonucleic acid (RNA) by an NSF grantee. Following virus infection, the cell stops making the RNA which it needs for its own survival and makes a new kind of RNA which is concerned with virus multiplication. Such new RNA has been isolated in purified form and its chemical structure shown to be different from that which the cell would normally make.

Since the virus used was of the deoxyribonucleic acid (DNA) type, these studies are also of great importance in the field of genetics. The virus can be regarded as a kind of counterfeit gene which not only is accepted as legal tender but drives the genuine currency out of circulation. The experiments very clearly support the current hypothesis that the DNA of the gene controls the synthesis of RNA which acts as the messenger to convey information to the cell as to what to make. However, they go farther and provide direct evidence for the theory that this messenger RNA is formed by using the DNA of the gene as a pattern. The RNA is not a copy of the DNA, but has more the relation of a print made from a photographic negative. Physico-chemical studies show that the new RNA formed under the influence of the virus DNA matches the DNA in this sense.

* * *

ISOLATION OF CELL-FREE EXTRACTS THAT FIX NITROGEN OPENS COMPLEX ENZYME SYSTEM TO BIOCHEMICAL ANALYSIS—Next to photosynthesis, by which atmospheric carbon dioxide is fixed, biological nitrogen fixation is the most important process in the incorporation of inorganic elements into the economy of the living cell. The basic process involved here is entry of molecular (atmospheric) nitrogen into a cell and its conversion to ammonia by reduction (addition of hydrogen). Ammonia nitrogen is then converted into various inorganic and organic substances such as nitrites, nitrates, and amino acids. Two NSF grantees are trying to unravel the biochemical details of these complicated processes.

Using whole-cell preparations of such nitrogen-fixing organisms as bacteria found in the roots of leguminous plants, they have confirmed the cell's need for the trace metal cobalt for maximum growth when any of several inorganic substances are used as the nitrogen source.

The isolation by these investigators of cell-free extracts which fix nitrogen opens the complicated enzyme system operating here to direct biochemical attack. It has been impossible, so far, to isolate and purify the individual enzymes involved, for these have proven to be very labile

and very oxygen sensitive. However, the complex has been obtained in two parts, namely a nitrogen-activating portion and a pyruvate-metabolizing portion.

Pyruvate metabolism must take place concurrently for nitrogen fixation to occur. Apparently pyruvic acid serves as an energy source and as a hydrogen donor for the reduction of nitrogen. The intermediates formed from pyruvate have already been determined through the use of cell-free preparations. A very careful search has also been made with such preparations for intermediates between nitrogen and ammonia. The fact that free intermediates were not found, even when using whole cells, lends credence to the idea that nitrogen remains bound to an enzyme during its reduction. Various other facets of the fixation process, such as enzyme inhibition and the influence of atmospheric nitrogen pressure, have also been studied. It is interesting to note that light had no influence on nitrogen fixation in cell-free preparations of a photosynthetic bacterium.

* * *

TECHNIQUE DEVELOPED FOR IDENTIFYING AND CHARACTERIZING SUBSTANCES WHICH INFLUENCE CELL DIFFERENTIATION DURING EMBRYONIC DEVELOPMENT—Embryonic development starts with the fertilization of a single egg cell. Through cell division, growth, and differentiation, the embryo develops into an amazingly complex organism composed of a great variety of highly specialized cells, such as liver, bone, lung, and nerve. The differentiation of the original fertilized egg cell into these various specialized cells is controlled by the chromosomes in the nucleus through blocking and/or triggering chemical reactions.

An NSF grantee experimenting with frog embryos injected albumin extracted from the nuclei of liver cells into recently fertilized frog eggs. He found that these cells divided and the embryo developed normally up to the gastrulation stage when cell differentiation begins. At that point cell division and development stopped—the embryo died.

He then went one step further and through microdissection removed the nucleus from a cell of one of the albumin-injected embryos just prior to cessation of development. The nucleus was transplanted into a newly laid unfertilized egg from which the native nucleus had been removed. This combination grew normally up to the gastrula stage and, as previously, stopped. These tests were repeated and the "blocked" nuclei were transplanted through seven generations of embryos. In each generation, development stopped at the same embryonic stage.

The conclusion is both inescapable and highly significant. The original macromolecules of albumin (contaminated with a small amount

of RNA) produced an effect in the nuclei, or in the adhering cytoplasm, that persisted and consequently blocked development at a specific stage of embryogenesis. Such developmental blocks have been demonstrated repeatedly, but for the first time an approach has been developed that permits chemical characterization of specific molecules influencing a replicating system in the embryo.

* * *

HEAVIEST RAINFALLS OCCUR IN FIRST AND THIRD QUARTERS OF LUNAR CYCLE—Statistical proof of the existence of a lunar effect on precipitation has been obtained by an NSF-supported researcher. He investigated the dates of excessive precipitation—wettest days—throughout the United States over a period of about 90 years. When these wettest days were plotted against the angular difference between the sun and moon, there was a conspicuous departure from the expected normal distribution.

The dates of extreme precipitation were recorded near the middle of the first and third quarters of the lunar cycle. The second and fourth weeks of the cycle were correspondingly deficient in heavy precipitation. The dates of the most extreme widespread rainfalls in the history of official U.S. meteorological observation were three times as frequent during the cyclic peak periods as during the cyclic trough periods.

It is not yet possible to advance a physical explanation for this phenomenon.

* * *

NEW FIELD OF CHEMISTRY MAY OPEN AS RESULT OF SYNTHESIS OF FIRST AROMATIC SILICON COMPOUND—An overwhelming percentage of all the chemical compounds occurring naturally or produced in the laboratory have the element carbon as their fundamental building block—gasoline, protein, sugar, plastics, rubber, etc. This results from the unique character of the carbon atom; it can join with other carbon atoms for open chains or for closed rings. Carbon chemistry is called organic chemistry, and the completely unsaturated ring compounds are called aromatic.

Silicon with a chemical structure similar to carbon has in the last decade or so been substituted for carbon in a number of chain compounds, such as the silicones, which have proven of great industrial value.

During the past year, a most significant discovery was made by an NSF grantee—the synthesis and characterization of the anion of silacyclopentadiene, the first aromatic compound containing silicon. This successful laboratory development paves the way for the synthesis of

other aromatic silicon compounds, such as silabenzene, the silicon analog of benzene. A complete new field of chemistry with great potential thus becomes possible.

* * *

QUANTITATIVE DETERMINATION OF RELATIONSHIP BETWEEN MACHINABILITY AND PHYSICAL PROPERTIES OF MATERIALS MAKES POSSIBLE A MORE EFFICIENT AND ECONOMICAL MACHINING PROCESS—An NSF grantee has derived and experimentally verified a mathematical correlation between machinability and the physical properties of materials. He has found that he can evaluate or predict the quantitative measure of machinability, that is, the cutting speed in feet per minute that the work material may be moved by the cutting tool for a specified tool life (the length of time for the tool point to be worn away). The application of this mathematical correlation in place of expensive and time-consuming experiments will permit a more analytical approach to the problem of improving composition, choosing appropriate heat treatments, and recommending the best processing methods to ensure the most economical machining in metal-working industries. The machinability of a material is defined by three physical properties: (1) the percent reduction of area in a tensile test, (2) the Brinell hardness, and (3) the thermal conductivity. The derived relationship has been verified with experiments on a variety of different metals and alloys.

* * *

SURFACE TEMPERATURES OF PLANETS OBTAINED AT NATIONAL RADIO ASTRONOMY OBSERVATORY—The surface temperature of Venus is far hotter than the boiling point of water, while that of Saturn is below the freezing point. Very accurate observations of radio radiation from these planets, at a wavelength of 10 cm., have been made at the National Radio Astronomy Observatory, Green Bank, W. Va., to provide new values for the temperatures of these two planets. Convincing evidence was obtained that the temperature of Venus is a rather surprising $610°K \pm 50°K$, or about 340°C. The comparable values for Saturn were $196°K \pm 60°K$, which is well below the freezing point of water.

## National Research Programs

These programs include scientific research endeavors that are best planned, coordinated, and funded on a national program basis because of the scope of the projects. Such factors as geographic location and

need for coordinating the research efforts of various Federal agencies and/or universities are involved.

## U.S. ANTARCTIC RESEARCH PROGRAM

The United States Antarctic Research Program (USARP) enables scientists of the Nation's colleges, universities, and research centers to carry out a wide variety of basic research in Antarctica in all the sciences.

Biological investigations are concerned with studies of the life of the land area as well as marine biology in the surrounding oceans. In the earth sciences, research is being carried out in geology and glaciology, including seismic, gravity, and magnetic observations to determine thicknesses of the ice cap and rock strata. Meteorology and upper atmosphere physics programs cover studies of aurora, cosmic radiation, and similar phenomena. Aboard the USARP research vessel *USNS Eltanin* extensive programs are carried out in meteorology, upper atmosphere physics, biology, oceanography, and submarine geology.

The National Science Foundation plans, manages, coordinates, and funds the USARP through its Office of Antarctic Programs. The Foundation arranges for long-range and yearly scientific programs, and provides management and coordination for research programs in the field as well as in United States laboratories.

Serving in an advisory capacity to the Foundation is the Committee on Polar Research of the National Academy of Sciences. This committee represents the United States on the Scientific Committee on Antarctic Research (SCAR) of the International Council of Scientific Unions (ICSU). The Department of Defense provides logistic support to the scientific program in Antarctica.

### *International Antarctic Activities*

*Antarctic Treaty*—The international cooperative scientific effort that proved so successful in enhancing the knowledge of the geographical and geophysical aspects of Antarctica during the International Geophysical Year prompted the 12 nations cooperating subsequent to the IGY to sign the Antarctic Treaty in June 1961. The treaty provides that the Antarctic shall be used only for peaceful purposes and that freedom of scientific investigation shall continue in this spirit of international cooperation. Under the Treaty the United States participates in exchanges of scientific personnel and information with other nations.

*Scientific Exchange Program*—The scientific exchange program with the Soviet Union, begun during the IGY, continues. In the present

program in which personnel are now wintering over in the Antarctic, a U.S. biologist from Ohio State University has joined the Soviet expedition and is carrying out biological studies in the vicinity of Mirnyy Station. A Soviet scientist spent the 1961–62 austral summer at McMurdo studying meteorological data. Plans are also being explored with the Soviet Union to expand U.S.-Soviet Antarctic cooperative research activities between respective research vessels, for the exchange of additional scientific personnel between the expeditions and for better exchange of data and results. Arrangements are also being considered whereby scientists of Japan, Norway, Belgium and Chile may cooperate with U.S. scientists on an exchange basis.

*Joint Scientific Program*—A variety of joint activities are carried out cooperatively by the United States with other countries signatory to the Antarctic Treaty. With Australia and Argentina, the United States maintains programs at Wilkes and Ellsworth Stations respectively as cooperative stations. Scientific personnel are provided by both parties to this agreement. Australia and Argentina provide the logistic support at these stations and the United States provides scientific equipment and some personnel.

New Zealand provides the United States with a staging point for Antarctica which is helpful to the United States in maintaining its activities. In return for this service, the United States assists New Zealand by providing transportation of supplies and personnel for New Zealand to McMurdo Sound for the New Zealand Scott Base. This cooperation with New Zealand includes also the joint maintenance of scientific programs at the U.S. Hallett Station.

Australia has provided the United States with support of scientific parties on Macquarie Island, making possible certain programs in cosmic ray studies and biological observations. During the past year, Chile supported U.S. geologists in the Palmer Peninsula area. The United Kingdom provided support by which U.S. ornithologists carried out observations near South Georgia. Also, U.S. oceanographers cooperated with research personnel from Argentina in an oceanographic study of the Drake Passage.

### Scientific Programs

During the 1962 fiscal year the Foundation supported 45 active field projects. Seventy-one per cent of the field projects represented work conducted by university groups. The following table shows the distribution of effort by discipline in terms of identifiable projects and people.

| Program | Active field projects | Number of people |
|---|---|---|
| Biology | 17 | 25 |
| Geology | 8 | 31 |
| Geophysics | 1 | 10 |
| Glaciology | 3 | 15 |
| Gravity | 1 | 1 |
| Meteorology | 2 | 35 |
| Oceanography | 3 | 6 |
| Seismology/Geomagnetism | 1 | 6 |
| Upper Atmosphere | 8 | 31 |
| Cartography | 1 | 8 |
| Total | 45 | 168 |

## BIOLOGY

Of the disciplines listed, biology has shown the most continued growth in programs and workers. The total of 17 active programs is being conducted through 9 universities involving a total of 25 scientific workers. Biological research was largely concentrated at McMurdo Station because of the well-equipped biological laboratory essential for the development of many of these field studies.

Three phases of Stanford University's continued investigations of the marine biology of McMurdo Sound were brought close to termination. Data collected over the past three years has provided information on the ecology of marine benthic communities, ecology and physiology of plankton, and the relation of invertebrate reproduction to biochemical aspects of food reserve cycles. Studies of fish metabolism and growth continue, utilizing tanks, aquaria, and metabolism chambers available at the McMurdo laboratory.

Functional morphology and histological work on the pycnogonids, or sea spiders, was carried out by scientists from the University of the Pacific. The Virginia Fisheries Laboratory shore-based marine program of parasites from fish, mainly the Nototheniidae, was completed this year with collections from Wilkes Station.

Two microbiological programs were undertaken in the McMurdo and Hallet Station area. An Ohio State University group made an ecological survey of soil bacteria at several different locations during the summer, with particular attention to quantitative reactions of the nitrogen cycle. In the wintering University of Texas program, aerobiological

studies, viability and longevity studies, microbiology of an Antarctic saline pond, soil microorganisms, and skin flora of the isolated wintering personnel were included. An interesting result of culturing samples of 50-year-old yeast and tinned foods cached at Captain Scott's base camp was the surprising number of contaminant microbes that were still viable. The presence of microorganisms in soils was found to be highly variable, some soils yielding almost no organisms while others gave several hundred thousand per gram.

Interesting results were obtained by the University of California researchers studying the summer energy budget of Antarctic ponds and lakes in the dry valleys. Positive photosynthesis was evident in the dry-valley lakes beneath as much as 15 feet of ice, confirming similar findings in studies of plankton productivity under arctic sea ice. In the lakes studied, high light intensity is severely inhibiting for algae during midsummer. Productivity in the littoral zone, however, was appreciable higher than that recorded in the deeper parts of the lakes. Physical limnological and geochemical work was done at these lakes by the University of Kansas resarchers, who spent the field season mapping the lake bottoms, obtaining temperature profiles and water samples, and attempting to measure thermal conductivity of the bottom material. Both lakes showed high stratification, with relatively pure water just under the ice changing to much warmer, highly saline water near the bottom. More accurate measurements in Lake Bonney this year showed a bottom temperature of 77.9 degrees Fahrenheit.

In a botanical program, an Ohio State University investigator initiated a long-term study of algae, moss, and lichen growth rates at Hallett Station, by staking out numerous plots and thoroughly mapping the vegetation. The plots will be resurveyed in the coming seasons. Growth rate of individual lichen plants proved too small for determination in a single summer period.

The USARP bird-banding program by Johns Hopkins University was active at Hallett and McMurdo Station areas and on Bird Island near South Georgia in the Falkland Islands. At Bird Island two men began a long-term study of albatrosses by banding 10,196 birds and taking samples of stomach contents and blood sera. Routine banding, census-taking, and observing previously banded birds continued on the continent. In a homing experiment one of six skuas transported to the South Pole from the nesting area at Cape Crozier, returned from the Pole, having covered a distance of 825 miles. This is believed to be the longest distance ever covered in an experimental demonstration of homing by oceanic birds.

A Bernice P. Bishop Museum report on the zoogeography of Pacific and Antarctic insects summarizes the results of three years of insect trapping and collecting on the continent and from airplanes and ships within the limits of sub-Antarctica. Of the 50 recorded species of terrestrial arthropods of Antarctica, about one-half are biting lice on birds or suckling-lice on seals. The other half are ticks, mites, springtail fleas, and chironomid flies. Free-living insects and mites are found on exposed rock surfaces, generally associated with lichens, algae, or mosses, and usually hide in the plants or below the rocks. The researchers consider that a majority of the insects probably represent post-Pleistocene immigration, although the possibility that some are relics from an ancient temperate fauna cannot be discounted.

## EARTH SCIENCES

Four major geological parties continued investigations of the vast ice-free mountain ranges of West Antarctica and the Transantarctic range. The first visit to the Sentinel Range of the Ellsworth Mountains, perhaps the most extensive of the world's unvisited mountain ranges, was made in the 1961–62 summer by a University of Minnesota party. Most of the rock outcrops visited are metasedimentary with large sills of basic igneous rock. Stratigraphic units of the northern part of the Sentinels included thick sequences of graywacke, slate, quartzite, and possibly tillite—all without fossils. A party from the U.S. Geological Survey completed work on the Thiel Mountains forming the easternmost range of the Transantarctic mountains that has been investigated. These mountains consist of a large flat-topped massif joined by an escarpment to a group of high nunataks. The most widespread rock is a quartz monotite porphyry. Flat-lying sedimentary and metasedimentary rocks, chiefly quartzite and argillite, are exposed in several of the peaks. A unique "siderolite" meteorite, in two pieces totaling about 70 pounds, was found by this party. Ohio State University completed the study of the Central Horlick Mountains where several sections in the highly fossiliferous Beacon formation were studied. The carboniferous tillite formation was about 800 feet thick, and some fossil assemblascs were located in the Horlick formation of the lower Devonian rocks between the tillite and the basement rocks. A coal bed about 10 feet thick was located in this area.

A series of previously unknown mountains and nunataks was discovered by the University of Wisconsin Ellsworth Land Traverse, at the base of the Peninsula. The locations of the outcrops, the configuration of the ice surface, and the seismic depths of the buried rock surface suggest that these nunataks are on an extension of the Peninsula Moun-

tains. Near the Chilean Base O'Higgins another group from the University of Wisconsin investigated the stratigraphic and tectonic relationship of the peninsula area to the Andean Cordillera.

Three geological projects were active in the McMurdo Sound area. An Ohio State investigator worked on the glacial morphology of the dry valleys, collecting samples of algae which may be used to date recent glaciations. Soil scientists from Rutgers University determined in initial pedological reconnaissance that genetic soils do exist in Antarctica, most of them forming in an abiotic system though chemical and physical weathering was common. Findings of the University of Wisconsin geologists working with sand and ice-wedge polygons corroborated tentative conclusions that patterned ground is ubiquitous in the ice-free areas of the continent and should be useful for dating recent glaciations.

During the University of Wisconsin traverse, gravity measurements, magnetics recordings, seismic soundings, and glaciological studies were carried out in an area at the base of the peninsula. A large area north of the Ellsworth Mountains was found to have bedrock lying below sea level. Thus, a sub-ice channel between the Ross and Weddell Seas appears to be a reality, though this channel follows a circuitous route northeast and east of the Ross Sea skirting the northern edge of the Ellsworth Mountains. Another geophysical program of the University of Wisconsin was the interstation gravity network in which observers with portable gravimeters flew from place to place with resupply flights, making a total of 32 gravity ties from McMurdo Station to numerous inland points. The U.S. Coast and Geodetic Survey has been carrying out seismic studies since the International Geophysical Year, and following recommendation of SCAR, is now issuing quarterly reports on the earthquake epicenters located by the Antarctic station seismograph network.

## UPPER ATMOSPHERE PHYSICS

Logistically and scientifically the highlight of the 1961–62 summer season was the establishment by air of a temporary station (Sky-Hi) near 75° S, 77° W, about 1400 miles from McMurdo Station and 600 miles east of Byrd Station. This was operated for approximately two months by upper atmosphere physicists. Studies of the ionosphere, geomagnetic variations, and very-low-frequency emissions showed results at considerable variance with those from the Byrd Station. Analysis of comparative data from Ski-Hi and its magnetically conjugate station near Quebec, Canada, by the National Bureau of Standards revealed a number of interesting items. Ionospheric absorption events were well correlated in time and intensity at the two ends of the field line though an exception to this was a sudden-commencement magnetic

storm followed by a major absorption event at the southern end only. The amplitude of the absorption events at the two ends of the field line were unexpectedly equal. New information on the size of the conjugate area in Canada was gained by operating 3 riometers simultaneously at 80-km spacings. Very-low-frequency events were generally, though not always, similar at both conjugate points. The VLF emissions offer clear evidence of an acceleration mechanism which is apparently capable of continuously perturbing a small fraction of the existing ionosphere particles and then causing their dumping in the upper atmosphere approximately equally at each end of a magnetic field line. This site complements the present United States Antarctic station network as it is the only one lying outside the auroral zone. Plans are under way to make this facility a year-round base—the Eights Station—which will play a large role in the coming studies during the International Quiet Sun Year, 1964–65.

In the aurora and airglow program of the Arctic Institute of North America, research with auroral spectra has shown close correlations between auroral displays and variations of cosmic noise absorption measured at a frequency of 30 mc. Analysis of data from Byrd and Ellsworth Stations indicates further that auroral emissions have a high magnetic dependence in the auroral zone.

Other ionospheric physics programs included the investigation of whistlers and other VLF radio noise emissions by Stanford University, the U.S. Coast and Geodetic Survey's operation of magnetic recording stations, cosmic ray counting by the Bartol Research Foundation and the University of Maryland, and the vertical incidence ionosphere soundings by the National Bureau of Standards.

## METEOROLOGY

Surface and upper air observations were continued in the meteorological field where radiometersondes were introduced, obtaining radiation parameter variations with altitude. Also a new program was initiated at McMurdo by Texas Western College for the explorations of the temperatures and winds at high altitude with meteorological rockets. At the U.S. Weather Bureau in Washington, several analysis studies using glacial, oceanographic, and meteorological data are under way. The meteorological feasibility of transosondes (constant-altitude balloons) is also being investigated. Winter radiation and heat exchange measurements at the South Pole in the 1961–62 summer provided information useful in a more accurate estimate of the continent's heat exchange. It appears that the atmosphere provides about twice as much heat to the snow surface during the polar night as during the six months

of light, and that the light season warming of the air is not the result of warming from below but rather the result of vertical and horizontal atmosphere movements and direct atmospheric absorption of solar radiation.

## SHIPBOARD PROGRAMS

During the year the USNS *Eltanin,* a 266-foot former ice-strengthened cargo ship, was converted to an Antarctic research ship. Shakedown cruises in the North Atlantic were completed in early 1962 and the ship started her first Antarctic cruise out of Valparaiso, Chile, in early summer 1962, working in the western Drake Passage and the Bellingshausen Sea. Thirteen research agencies are represented aboard the *Eltanin.*

Upper atmospheric physics work on the *Eltanin* includes operation of an airglow photometer and a riometer by the University of Alaska, Bartol Foundation's high-counting-rate plastic scintillator and meson telescope, a VLF–ELF and HF radio noise study in eight frequencies in the transmitting band by the U.S. Bureau of Standards. More emphasis will be placed on conjugate point studies when the route of the ship becomes conjugate to accessible land sites of northern United States, Canada, and Alaska.

The marine science activity includes Lamont Geological Observatory's current measurements by standard dynamic methods and by current meters on an anchored buoy system, and primary productivity studies. The University of Southern California biology program covers the biota of deep basins and trenches, deep benthic fishes, mid-water fauna, and surface primary productivity.

The California Institute of Technology has a grant to investigate the biogeochemistry of skeletal carbonates in a paleoecological study. Bernice P. Bishop Museum is using the ship as a moving platform for insect-trapping nets in an effort to learn more about insect transport to the continent from southern islands.

The U.S. Navy Hydrographic Office oceanographic work, concentrated on the *USS Burton Island,* included all standard physical oceanographic observations plus bottom coring, sediment grabs, plankton tows, and geomagnetic recording. Florida State University continued examination of ocean bottom cores. The Texas A & M researcher measured surface current profiles in the Drake Passage aboard an Argentine vessel. A grant to the Lamont Geological Observatory (Columbia University) provided support for a systematic oceanographic survey in the Drake Passage and in the South Antillean Sea on the *R/V Vema.*

In the United States, continued effort goes into the reduction and

analysis of the data from the Antarctic. While most university research is undertaken by the field investigative groups, separate grants have been made for studies in meteorology, upper atmospheric physics, and glaciology. Support for the team approach to some of the major problems has been assisted by funds for continuation of polar centers at two major universities. To encourage analysis and presentation of data and to fulfill international obligations of data exchanges, plans are in hand for an antarctic monograph series, an antarctic series of folios, antarctic bibliography, and periodic publications of general interest regarding the nature, extent and personnel involved in antarctic research.

### CARTOGRAPHY

The year 1962 was a notable one for Antarctic mapping. New field control techniques were tried and proved successful. Substantial progress was made in the preparation of maps in the 1:250,000 series and a new continental map was produced. United States Geological Survey topographic engineers, working with the Army helicopters supported by the Navy, successfully completed Topo North and South, a 1,100-mile topographic traverse in the mountains between Cape Adare and the Beardmore Glacier using electronic distance-measuring devices. The use of this technique resulted in the establishment of field control making possible the mapping of a 100,000-square-mile area. Another important development was the testing and proving of a technique to use daylight stars as a basis for position determination.

A new 1:5,000,000 scale map of Antarctica was produced by the American Geographical Society, undoubtedly the best map of the continent to date. Preparations were started that will result in the printing of a 1:3,000,000 scale map of Antarctica in four colors.

Compilation was completed and a contract was let by the Geological Survey for the preparation of a two-layer plastic relief model of Antarctica. Support was continued to the Office of Geography of the Department of Interior which is actively engaged in the naming of geographic features in Antarctica, coordinating this effort with similar groups in other countries.

Arrangements were begun for the production of an Antarctic Map Folio Series. Each folio, representing a special field of activity, will include maps, narrative, graphs and photographs to be used as a working tool for scientists.

## INTERNATIONAL INDIAN OCEAN EXPEDITION

The International Indian Ocean Expedition (IIOE) is a scientific project of broad scope and magnitude designed to investigate one of the

world's least-explored oceans. The Indian Ocean's 28 million square miles cover about 14 percent of the earth's surface and are surrounded by some of the world's most densely populated countries, yet between 1873 and 1957 fewer than 30 vessels carried out oceanographic investigations in its waters. Although there is intriguing evidence that the biological productivity of the ocean is high—higher than either the Atlantic or Pacific, almost half of its area has not ever been sampled biologically, and while a possible food resource washes over their doorsteps, many inhabitants of the surrounding region suffer from severe dietary protein deficiency.

The Indian Ocean is of great interest also to physical scientists. The basin's structure is virtually unknown. Moreover, as it is landlocked in the north, west, east, and cut off by equatorial currents on the south, the northern half of the Indian Ocean is the only body of water where there is a complete seasonal reversal of the prevailing wind. It is, therefore, a huge natural laboratory for observing the effects of wind stress on oceanic currents.

The above features and the lack of scientific attention to them are evidence of the need for a thorough exploration and analysis of the ocean's contents, structure, and relationship to the atmosphere above it. This need will be met by the 25 nations and 44 vessels participating in the IIOE; from 1962 through 1965 they will conduct broad systematic surveys as well as detailed individual investigations in such varied fields as biology, geology, chemistry, geophysics, bathymetry, and meteorology.

### *History and Organization of the U.S. Program*

Initiated in 1958 under the auspices of the International Council of Scientific Unions and its Special Committee on Oceanographic Research, the IIOE is now coordinated by the Office of Oceanography of UNESCO. Initial planning for this country's participation was performed by the Committee on Oceanography of the National Academy of Sciences. United States participation was approved by the President in June 1960, and the National Science Foundation has been assigned full scientific responsibility for the U.S. program. NSF has encouraged research institutions in this country to submit proposals for projects connected with the IIOE, and in some cases has transferred funds to enable other Federal agencies to carry out urgent, related programs.

Although the participating scientists represent more than 100 colleges and universities, the actual conduct of the expedition is centered in those few institutions experienced and qualified in the logistics of ship

operation. Thus, the biological sciences program is coordinated through the Woods Hole Oceanographic Institution; the physical sciences program is managed by the Lamont Geological Observatory, the Narragansett Laboratories of the University of Rhode Island, Scripps Institution of Oceanography, and Woods Hole; and the meteorological efforts are under the direction of the University of Hawaii, cooperating with Woods Hole and the Universities of Michigan and Washington.

Taking a leading part in the U.S. program will be *Atlantis II,* one of only two major vessels under the U.S. flag especially designed for research tasks. The former Presidential yacht *Williamsburg,* now renamed the *Anton Bruun,* will also be operated as a public vessel by Woods Hole; aboard this ship much of the biological work of the expedition will be carried out.

### *Scientific Programs*

The study involves three major programs: biological, physical, and meteorological. The biological program is designed to increase knowledge of the abundance and distribution of living organisms and to gather information leading to a better understanding of the biological resources of the Indian Ocean. All U.S. ships will be equipped to sample plankton and observe surface biological phenomena; some will measure primary productivity as well.

The physical oceanography program will include chemical and isotopic analyses of water samples, measurement of current flow at various depths, and geophysical studies to aid in comprehending the nature of the sea floor and the crustal structure.

The meteorological studies will be concerned with the interactions between the ocean and the atmosphere. Essential to this will be a large-scale circulation study employing not only standard wind and weather observations from ship and shore stations and from two special Weather Bureau aircraft, but also new and special devices including an extensive series of meteorological rockets.

## PROJECT MOHOLE

The ultimate objective of Project Mohole is to drill through the crust of the earth beneath the ocean to provide the first samples and direct measurements of the deep crust and the underlying mantle. The project, which is supported and administered by the National Science Foundation, is a cooperative plan by scientists throughout the country, organized under the National Academy of Sciences' AMSOC Committee.

Probably no single project within the scope of present technological capabilities would provide more information on a number of critical

questions in geophysics. Samples of the deep crust and upper mantle would, for example, (1) render much more accurate the determinations of various rock layers, (2) establish the chemical composition and mineralogy of the top of the mantle to aid experiments in high-temperature, high-pressure mineralogy, (3) help determine possible causes of the anomalously high heat flow from the floor of the ocean, (4) provide data about the original isotopic composition of primordial lead and uranium, and (5) increase understanding of early stages of earth history.

Samples of material obtained from crustal layers, if the hole were drilled at sea, would provide a nearly continuous sedimentary record from the floor of the ocean down through the first rocks deposited in that part of the ocean basin. In addition, much evidence of the evolutionary process would be provided by fossil remains in the various sedimentary layers.

The rapid development of deep-drilling techniques by the petroleum industry in recent years has indicated the possibility of drilling to the mantle through the oceanic crust. Beneath the continents the Mohorovicic discontinuity, the boundary between the crust and its underlying mantle, lies at depths of from 25 to 40 kilometers (3 to 5 miles). Thus, drilling to the "Moho" at sea would take advantage of the fact that the crust is much thinner under oceans than continents.

Drilling in deep water from unanchored vessels had never been attempted until the experimental drillings, conducted by the AMSOC Committee with Foundation support, off La Jolla, California, and Guadalupe Island, Mexico, in early 1961. These tests proved the feasibility of drilling at sea using a specially conceived dynamic positioning system that enabled the drilling vessel to maintain station with its own power for prolonged periods under severe wind and wave conditions. Drilling at La Jolla, on the edge of the San Diego Trough, took place in 3,000 feet of water. Five holes were drilled, one to 1,035 feet, obtaining important scientific results in the form of the first samples of oceanic sediments from significant distances below the sea floor. Five holes also were drilled in 11,700 feet of water at Guadalupe to a maximum of 601 feet into the bottom. Samples were obtained for the first time of the second layer of the oceanic crust, found to be basalt at that site. The success of the operation resulted in further AMSOC recommendations to attempt the second phase of drilling all the way to the upper mantle.

Under Foundation support and administration, the second phase of Project Mohole was begun with the selection of Brown and Root, Inc., Houston, Texas, as the prime contractor for management, operations, and logistic support. Detailed engineering and feasibility studies are

in progress. The project is expected to require between 3 and 5 years to complete.

## WEATHER MODIFICATION

The National Science Foundation has supported a special program of research in the field of weather modification over the past four years, following passage of Public Law 85–510 of July 11, 1958. By that law, NSF was directed to "initiate and support a program of study, research and evaluation in the field of weather modification."

Since then the Foundation has not only supported a significant program of weather modification research, but in a larger sense it has maintained a central position of leadership in stimulating adequate and pertinent research throughout the scientific community, in the universities, and within the various laboratories of the Federal Government. Following the usual pattern of Foundation operation, the program is administered principally through grants and contracts with universities and other research groups. At the Government level this includes joint research efforts in the various Federal agencies concerned with weather modification, for example, the NSF-Weather Bureau-Navy hurricane modification program.

Under the NSF program a full range of laboratory and field experimental work along with theoretical studies is being pursued under the direction of research physicists, chemists, mathematicians, and engineers, as well as meteorologists. The problems of weather modification are interdisciplinary in nature and trained scientists from many fields find challenging and worthwhile problems to undertake. The program is managed as an integral part of the much broader program for atmospheric sciences, for weather modification is inseparable from the field of meteorology as a whole.

Under the NSF Weather Modification program some 37 individual research studies are now underway, mostly at university research centers. They range from a carefully designed field research effort at the University of Arizona where the objective is to determine whether aerial silver-iodide seeding can modify the cumulus clouds that form over the Santa Catalina Mountains of southeastern Arizona, to a planning conference at the South Dakota School of Mines and Technology where scientists and educators outlined a program of weather modification research for the Black Hills area of South Dakota. Other projects supported include a U.S. Weather Bureau investigation of the number and variation of freezing nuclei in the atmosphere and their relationship to global patterns of heavy rainfall, and a series of experiments by scientists from

Arthur D. Little, Inc. and the University of Illinois to find out how artificially induced electrical space charges affect the growth of cumulus clouds during the summer over an extensive weather station network in central Illinois.

Countries other than the United States are also conducting research and attempting to develop methods and techniques of weather modification suitable to their problems. For the first time all the known activity throughout the world was described and published in the NSF Third Annual Report on Weather Modification. The material for each of the national program reviews was supplied for the most part by scientists conducting research work in the countries themselves. Information on the USSR and Communist China was derived from scientific articles published in the open literature.

In fiscal year 1962, fifteen grants totalling $1.3 million were awarded for research in weather modification. The fourth annual report on weather modification, covering fiscal year 1962 activities, will be released shortly.

## National Research Centers

Major national research centers are maintained by the Foundation in three important and rapidly developing fields of science—optical astronomy, radio astronomy, and atmospheric sciences. These centers have been established to provide essential facilities that U.S. colleges and universities, for reasons of cost or location, could not provide. Government installations funded through the Foundation, the three centers are managed by independent nonprofit corporations made up of groups of universities; they are available to all qualified United States scientists, and to visiting foreign scientists, subject to priorities based on scientific merit and feasibility of the proposed research. The centers provide facilities for both staff scientists and for university scientists who wish to supplement their campus-based research.

### KITT PEAK NATIONAL OBSERVATORY

A considerable amount of major construction was completed during the fiscal year at this optical observatory, including most notably the 300-foot solar telescope, largest and most advanced such telescope ever built. The first solar image, 34 inches in diameter, was obtained on October 31, 1962, just two days before the dedication of the instrument. (See photo, page 68.)

This instrument has been named the Robert R. McMath Solar Telescope, in memory of the famous University of Michigan astronomer who, as first chairman of the Association of Universities for Research in Astronomy, Inc. (AURA)—the organization that operates Kitt Peak for NSF—was largely responsible for conceiving and bringing to fruition this project. The structure consists of a 110-foot high pedestal, a 500-foot inclined tunnel, much of which is underground, and an underground observing room with 70-foot deep pit for vacuum spectrographs. The telescope is equipped with preliminary optics including a 63-inch quartz flat for the heliostat and a 63-inch concave aluminum image-forming mirror with a 300-foot focal length.

Ten months of polishing and figuring on the primary mirror for an 84-inch stellar telescope came to a successful end during the year, and the mounting for the instrument was installed in the dome atop Kitt Peak. The mirror has been shown in shop tests to be extremely accurate—good to 1/20 wavelength up to its extreme edge. Additions to the Tucson headquarters building of the observatory were also finished during the year, and occupied by the solar and space divisions. A public highway to the observatory, designed and built under the auspices of the U.S. Bureau of Public Roads, was also completed.

The 36-inch telescope was during fiscal year 1962 the major instrument in operation at Kitt Peak. It has been used primarily for photometric studies. A 16-inch telescope was also installed on the peak, and is now in regular use in programs of photoelectric photometry.

Time for observing runs on the 36-inch telescope was scheduled for 13 visiting astronomers and 5 graduate students (202 nights), with staff astronomers and assistants assigned 153 nights. Among the programs carried out by visiting scientists were the observation of nearly 100 calibration stars and 20 galaxies in 12 spectral regions as part of a University of California project; the establishment of photometric standards by an astronomer from The Observatories, Cambridge, England, in regions of the Praesepe and Coma clusters; and photoelectric photometric observations by a visitor from the Institute for Advanced Study, Princeton, New Jersey. Close cooperation was maintained with visiting astronomers from the nearby University of Arizona, with four projects being carried on at Kitt Peak during the year by members of the Steward Observatory staff.

Spectroscopy and photometry occupied the major portions of the observing time of the staff astronomers. In addition, the Observatory's digital computer was used in an investigation of optical designs for telescope mirror systems and for astronomical instrumentation. A new

spectral atlas is being compiled jointly by a Kitt Peak astronomer and an astronomer from the Steward Observatory of the University of Arizona.

Preliminary design and engineering studies of a 150-inch reflecting telescope are under way, and a program of rocket astronomy using Aerobee-borne photometers and spectrometers is planned. Instrument packages are also being prepared for inclusion in deep space probes of the National Aeronautics and Space Administration.

## NATIONAL RADIO ASTRONOMY OBSERVATORY

Located at Green Bank, West Virginia, this scientific laboratory is presently operating a 300-foot radio telescope (completed in September 1962), an 85-foot fully steerable radio telescope, and several smaller instruments including a 40-foot automated dish, a 20-foot telescope, a 12-foot telescope, and a 120-foot standard-gain horn antenna. A 30-foot instrument is used for continuing interference measurements. Construction of a 140-foot fully steerable radio telescope was resumed in May 1962, with award by Associated Universities, Inc., which operates the facility for NSF, of three contracts for fabrication and erection of components for the instrument.

In September 1962, Dr. D. S. Heeschen was appointed Director of the Observatory. Dr. Heeschen had previously served as Acting Director following the retirement of Dr. Otto Struve in December 1961.

Successful completion of the 300-foot "transit" telescope has given scientists at NRAO the world's largest movable radio telescope. Not a fully steerable dish, the parabolic reflector can be moved in a north-south direction only. Observing procedure is to point the instrument at the area of sky to be studied, and allow rotation of the earth to carry the radio source through the telescope's beam. During this "transit", the data are automatically recorded on paper charts, printed out, and punched at high speed onto tapes for subsequent analysis in a digital computer.

Test observations with the telescope began September 20, 1962, and were so successful that a full program of research was immediately started. For the first series of observations, instrumentation has been installed to make possible the recording of two radio frequencies simultaneously.

The 40-foot transit telescope was completed during the winter, and regular daily observations began in March 1962. The telescope, receivers, and calibration signals are all automatically controlled by a digital control system.

Research programs carried out by the observatory staff included planetary observations (Venus, Saturn, Jupiter) galactic studies, atmospheric effects, and work on information theory.

The full time scientific staff of the observatory reached 10 on June 30, 1962, with additional staff in engineering, operation of telescopes, research assistants and technicians, operation, maintenance, clerical, and administrative employees. Approximately 30 graduate and undergraduate students in astronomy, mathematics, physics, electronic engineering, and related fields spend an average of three months each at the Observatory during the year, in addition to the frequent visits by established scientists for research purposes utilizing the NRAO facilities.

## NATIONAL CENTER FOR ATMOSPHERIC RESEARCH

During fiscal year 1962 the National Center for Atmospheric Research, at Boulder, Colorado, made a vigorous beginning toward fulfilling its role in the advancement of atmospheric science research. Operated for the Foundation by the University Corporation for Atmospheric Research, it is designed as a center for interdisciplinary investigation of fundamental processes in the atmosphere, including influences on it from below (the ocean and ground surfaces), and from space (particularly the sun).

As an institution in which men with many varying scientific specialties work in close cooperation and proximity, NCAR hopes to achieve substantial progress in improving existing theory concerning the atmosphere and its behavior, essential prerequisite to a better understanding of the factors affecting changes of weather and climate over various time periods. Such a theory is also essential to a realistic assessment of the extent to which weather modification or control may be possible. Long-range research programs now under way at NCAR may also produce theoretical bases that will assist researchers in attaining solutions of other atmospheric problems.

The research program of NCAR is pursued in two closely affiliated laboratories: the Laboratory of Atmospheric Sciences, which was established during fiscal year 1962, and the High Altitude Observatory, which was founded in 1946 and merged with the University Corporation for Atmospheric Research in December 1961. Within these laboratories, research efforts are organized around the work and interests of individual senior program scientists.

In the Laboratory of Atmospheric Sciences, research efforts under the direction of seven senior scientists and their assistants are now under way.

The laboratory's research is divided into four broad problem-area categories: dynamical aspects; thermodynamical, chemical, and physical aspects; interaction between the atmosphere and the underlying ground or ocean surface; and interaction between the terrestrial atmosphere and astrophysical phenomena. During the summer of 1962 a visitor program was carried out, with 18 scientists participating.

The High Altitude Observatory brings to NCAR an outstanding group of scientists whose chief research efforts, on solar-terrestrial effects, will complement and extend the work of the Laboratory of Atmospheric Sciences. HAO has a staff of about 75 persons, of which 15 are independent program scientists at the Ph. D. level or equivalent, and an additional 35 in the scientific and professional category. HAO operates an observing station at Climax, Colorado, a radio astronomy observing site north of Boulder, and a central headquarters on the campus of the University of Colorado. It is supported by a variety of private and Government sources.

The Center moved into new temporary quarters in Boulder in May 1962, in a building leased from the University of Colorado. Architectural plans are being prepared for construction of a permanent facility on the Table Mountain site just outside Boulder. This beautiful site of 570 acres was donated to the Foundation by the people of the State of Colorado, through their State legislature, as a permanent site for the NCAR headquarters.

The first of the NCAR national programs, the scientific balloon program, is approaching a level of operation where it can make significant contributions to a national scientific need. A year-round facility devoted exclusively to scientific balloon flights has been constructed at Palestine, Texas, and is known as the National Scientific Balloon Flight Station. Completed during the summer of 1962, it will be the location of the STRATOSCOPE II balloon-borne telescope flights of Princeton University in 1963 and following years, as well as other scientific balloon projects now planned by a number of institutions. The station was established as an integral part of a program to stimulate improvement in balloon technology for use in scientific experiments, and to make balloons more readily accessible to scientists who need their unique ability to float a large platform for heavy instruments at high altitudes over a long period of time.

A two-story prefabricated operations and laboratory building and asphaltic concrete launching area was completed during 1962, and a "Stratoport" erected to house the Princeton University 36″ Stratoscope telescope.

# Facilities

## GRADUATE-LEVEL RESEARCH FACILITIES

Graduate laboratories are used principally by faculty members and their research associates for the conduct of their scientific investigations. They have a further important use in that they serve the needs of graduate and postdoctoral students working on thesis or independent research problems. A considerable portion of the research supported by the Federal Government is conducted in these laboratories. Therefore, with the increasing level of Federal research support being provided, and the growing need for scientific knowledge and research training that results from investigations being conducted in these laboratories, it is of utmost importance that they be maintained at maximum productivity.

Most of the laboratories for graduate-level research, however, are outmoded and overcrowded. The rapid technological advances of the last few years, the tremendous increases in the volume of research being conducted, and the growing numbers of students striving to enter graduate training in the sciences have combined to tax existing facilities far beyond their operational capacities. At the same time the financial resources of most institutions of higher learning are being strained to the utmost to meet the constantly rising costs of operating their total educational programs. The result is that these expanded facility needs cannot be provided from funds now available to the institutions; additional outside assistance is urgently required. The Foundation, through this program, is providing limited support to colleges and universities so that they can partially undertake the needed expansion and upgrading of these graduate facilities.

Initially, only university departments with on-going doctoral training in science or engineering were eligible for support. In January 1962, the program was expanded to include: (1) institutions offering the master's degree with the requirement of research participation and a thesis, and (2) non-profit research institutions having arrangements for graduate training with degree-granting institutions. Provision was also made for general purpose laboratory equipment in an amount not to exceed 10 percent of allowable construction costs.

In fiscal year 1962 a total of $26 million was awarded for graduate-level facilities.

In the life and social sciences, the major portion of the grants were made in the animal and plant sciences, while in the physical sciences by far the greatest share was for chemistry, physics, and engineering.

The number of proposals for new construction as compared to those for renovation shows a continuing upward trend. Facilities being planned seem to involve to a great extent construction of large buildings.

The size of requests cover a wide range from $1,100 for fixed equipment for a two-room botany laboratory and $2,000 for the remodeling of one room for work in atmospheric sciences to $2.2 million for construction of a building for the behavioral sciences and $3.1 million for an addition to a chemistry building.

Well over half of the 1962 fiscal year grants were for amounts of less than $50,000. The two largest grants were $1.6 million for the construction of a 7-floor life sciences building and $1.4 million for the construction of a 15-story behavioral sciences building.

## SPECIALIZED BIOLOGICAL AND MEDICAL SCIENCES RESEARCH FACILITIES

This program is designed to support installations that are unique in the sense of geographical location, purpose, regional usage, or a combination thereof, and that are not usually a part of the normal departmental organizational structure of colleges or universities. There is no fixed requirement as to the amount of funds which the institution must itself raise before becoming eligible. In some instances the Foundation provides the full cost.

The specialized facilities program provides support for: (1) maintenance of research materials, including museum research collections, genetic stock centers, and repositories for special research materials; (2) maintenance and operation of research installations, including field stations, marine biology stations, special university laboratories or institutes, and other private nonprofit laboratories; and (3) development of new facilities, including unique designs of existing types of facilities, special applications of such complex tools as computers and reactors, and new departures.

Twenty-eight grants totaling $3.1 million were awarded during 1962 in this program. The following are examples of the awards made. A grant was made to the University of Michigan to establish a major facility for research in animal biosystematics. The facility will consist of a 31,000-square foot wing addition to the existing Museum of Zoology. This wing will contain controlled environment, photo-period, and acoustical rooms, animal maintenance facilities, biochemical laboratories, and other special features designed to permit application of the latest techniques of biochemistry, physiology, genetics, and behavioral science to the field of systematics.

Two grants were made for special research facilities at the University of California, Davis, and at Washington State University. The first is for an animal centrifuge laboratory designed to permit study of chronic acceleration effects. The second is for a controlled-environment irradiation facility for the study of the effects of radiation on plant structure and function. Two biological field stations received grants for construction and improvement of their research facilities: Mountain Lake Biological Station of the University of Virginia and the University of Colorado Science Lodge. In both instances the additional facilities will permit a modest expansion of the research programs involving both local and visiting scientists.

Grants were made to small marine stations, the University of Florida Marine Station and the Walla Walla College Biological Station, for acquisition of motor boats in the 32 to 40-foot range for marine biological research. One will be newly constructed and the other converted from a fishing vessel.

In addition to such aid to small marine stations, two grants were made for the development of the biological phases of marine and oceanographic research. (For details see section on "Oceanographic Research Vessels and Facilities", page 61.)

## UNIVERSITY COMPUTING FACILITIES

This program provides partial support for the rental or acquisition of high-speed computers of advanced design at universities for use in basic research and available to all departments of the university. Computers are proving of ever-increasing value as tools for research and training in virtually every imaginable scientific field. The need for these tools is accelerating rapidly, for as the speed and power of computers rise, problems previously insoluble because of their complexity and magnitude become susceptible to solution.

The Foundation has made grants to assist our educational institutions to acquire computers of all sizes—from the small to the very large.

In selecting institutions to support under this program, the Foundation uses the following criteria: (1) weighing the capacities of the institution's staff to develop the proposed computing center as an important adjunct to basic research; (2) selecting institutions with due regard to achieving good geographic distribution in terms of the needs of the scientific community; and (3) requiring institutions to indicate a plan for self-support of the facility as well as to demonstrate a capacity to provide the other capital funds needed.

In fiscal year 1962, 11 grants were made totalling $2,975,000.

## UNIVERSITY NUCLEAR RESEARCH FACILITIES

Recent advances in the theoretical description of the atomic nucleus, together with recent design improvements in cyclotrons and Van de Graaff accelerators, have resulted in the development of a program for establishing and improving low-energy nuclear physics research facilities.

The theoretical advances have resulted in a need for refined measurements of energy levels, spin assignments, and other characteristics of the nucleus so that the synthesis of current theoretical models can be further advanced. Many of these refined measurements are now possible through extension of Van de Graaff accelerator ranges to particles with energies of up to 20 MeV (million electron volts), and improvements in cyclotron design to permit well-controlled beams up to 40 MeV. Until about five years ago Van de Graaff accelerators were restricted to energies less than 8 MeV.

This year the Foundation made a group of 8 grants, totalling $6.2 million, in furtherance of the new program. These eight accelerators are expected to play an important role in the Nation's effort in nuclear structure physics.

## OCEANOGRAPHIC RESEARCH VESSELS AND FACILITIES

The 210-foot research vessel, *Atlantis II*, launched in September 1962, is one of the very few designed specifically for oceanographic research. The ship, built with funds provided by the National Science Foundation, is to be used by the Woods Hole Oceanographic Institution. After a few trial cruises, it will be assigned for duty in the Indian Ocean as part of the International Indian Ocean Expedition.

Approximately $6 million was provided in fiscal year 1962 for smaller craft, shore facilities, and buoy systems. Grants were made to the Scripps Institution of Oceanography for a special biological research vessel and a related shore laboratory which will contain a circular towing tank for underwater studies of marine organisms and man, also for a hydraulic laboratory; to Johns Hopkins and Oregon State universities for oceanographic laboratory buildings; to A & M College of Texas for conversion of an Army freighter (FS) into an oceanographic research vessel; and to Woods Hole Oceanographic Institution for a laboratory of chemical and biological oceanography.

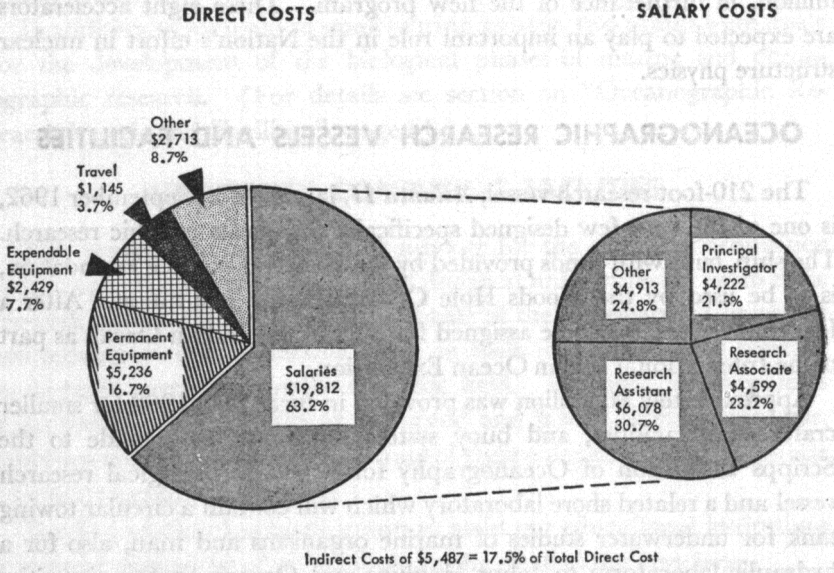
The USNS *Eltanin* joined the U.S. Antarctic Research Program during the fiscal year. Owned and operated by the Military Sea Transportation Service, the former cargo ship was converted by the Foundation into a multi-discipline research vessel. A description of its role in Antarctic research is described on page 47.

## Fiscal Analysis of Research Programs

Grants for support of basic research totaled 2,572 in fiscal year 1962 and were awarded to 381 institutions throughout the United States and its possessions. Research obligations amounted to $157 million—$96 million for research grants, $47 million for facilities, $10 million for national research centers; plus $4 million for the Indian Ocean Expedition and Project Mohole.

Research grants in 1962 averaged $36,822 for a period of slightly less than 2 years. Grants in the mathematical, physical, and engineering sciences averaged $41,616; in the social sciences, $34,389; and in the biological and medical sciences, $31,842.

The accompanying table summarizes the research grant program by subject categories. A detailed list of grants showing institution, principal grantee, title of project, duration and amount is given in Appendix C.




Note: Based on Average grant of $36,822.

**Figure 1.** ***Distribution of Research Grant Funds, by Type of Expenditure, Fiscal Year 1962.***

**Table 1.—*National Science Foundation Grants, By Fields of Science, Fiscal Year 1962***

| Field | Number | Amount |
|---|---|---|
| Biological and medical sciences: | | |
| Developmental biology | 83 | $3,012,300 |
| Environmental biology | 144 | 3,961,400 |
| Genetic biology | 80 | 3,149,212 |
| Metabolic biology | 119 | 4,365,850 |
| Molecular biology | 161 | 6,977,100 |
| Psychobiology | 98 | 2,545,700 |
| Regulatory biology | 150 | 4,599,600 |
| Systematic biology | 186 | 3,149,850 |
| General biology | 20 | 1,390,070 |
| Subtotal | 1,041 | $33,151,082 |
| Mathematical, physical and engineering sciences: | | |
| Astronomy | 73 | 3,332,600 |
| Atmospheric sciences (including weather modification) | 74 | 5,395,412 |
| Chemistry | 259 | 8,003,285 |
| Earth sciences | 171 | 6,313,130 |
| Mathematical sciences | 203 | 7,054,245 |
| Physics | 170 | 10,745,300 |
| Engineering sciences | 242 | 8,844,825 |
| Subtotal | 1,192 | $49,688,797 |
| Social Sciences: | | |
| Anthropological sciences | 94 | 2,184,545 |
| Economic sciences | 36 | 1,995,550 |
| History & Philosophy of science | 27 | 668,100 |
| Sociological sciences | 65 | 2,945,950 |
| Subtotal | 222 | $7,744,145 |
| Antarctic research (life & physical sciences) | 117 | 5,448,516 |
| TOTAL | 2,572 | $96,082,540 |

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# INSTITUTIONAL GRANTS

Institutional grants assist colleges and universities in developing and balancing their programs of research and education in the sciences. These grants provide flexible support, which enables institutions to move freely in the strengthening of neglected or emerging areas of their scientific activities and to correct imbalances that result from the large amount of Federal money granted for specific research projects.

The Foundation recognizes that a college or university is in the best position to determine the means by which it can strengthen its scientific endeavors and thereby contribute to the progress of science. Educational institutions must have independence of choice and economic capability in order to reach their educational goals. The responsibility for the administration of institutional grants, therefore, resides in the colleges and universities which receive them. With the limitation that they must be expended for science and science-related activities, institutional grant funds may be used at the discretion of recipient institutions.

Preliminary reports from the recipients of 1961 institutional grants show three main kinds of uses of the funds: (1) faculty research grants, (2) purchase of equipment for research and teaching, and (3) provision for institution-wide scientific needs. The reports testify to the value of the new program and commend the Foundation for its recognition of the principle of institutional freedom and its simplified procedures for the administration of the grants.

In 1962 colleges and universities receiving basic research grant payments from the Foundation during the year April 1, 1961–March 31, 1962 were eligible to apply for Institutional Grants. The following formula was used for computing grants made during 1962: 100 percent of the Foundation's basic research grant payments up to $5,000, plus 5 percent of such payments in excess of $5,000. The maximum grant to any one institution was limited to $50,000.

Grants totaling $3,730,634 were made to 302 institutions in 1962. Grants were made to colleges and universities in every State, the District of Columbia, and Puerto Rico. Seventeen of the grants were for the maximum amount. More than half (167) were for $6,000 or more.

NATIONAL SCIENCE FOUNDATION

# A Photographic Sampling of Foundation-Supported Activities

*Photo Credits*

Page 67: Shinya Inoué, Dartmouth College. Pages 68 and 69: NSF Photos. Page 70: Photographs copyright 1962 (c) Jerome Halberstadt. Page 71: NSF Photos from Archie Carr, University of Florida. Page 72: University of Wisconsin. Page 73: (Top) NSF Photo; (Bottom) Stanford University. Page 74: (Top) William Long; (Bottom) NSF Photo by Tom Nastos, U.S. Weather Bureau.

## Special Microscope Shows Living Cells in Process of Division

Mitotic division, the process whereby a cell divides and the genetic material is transferred from the old cell to the two new cells, is shown clearly in this remarkable plate obtained by an NSF grantee Shinya Inoué of Dartmouth College. Using a special polarizing microscope, the photo shows a living cell (isolated from the fruit of the African blood lily) actually undergoing nuclear division. The dark chromosome pairs that are just about to separate, and the bright spindle fibers that will pull the chromosomes apart, can both be clearly seen.

Time-lapse motion pictures of these cells taken through the polarizing microscope show how the molecules in the spindle fibers behave during cell division.

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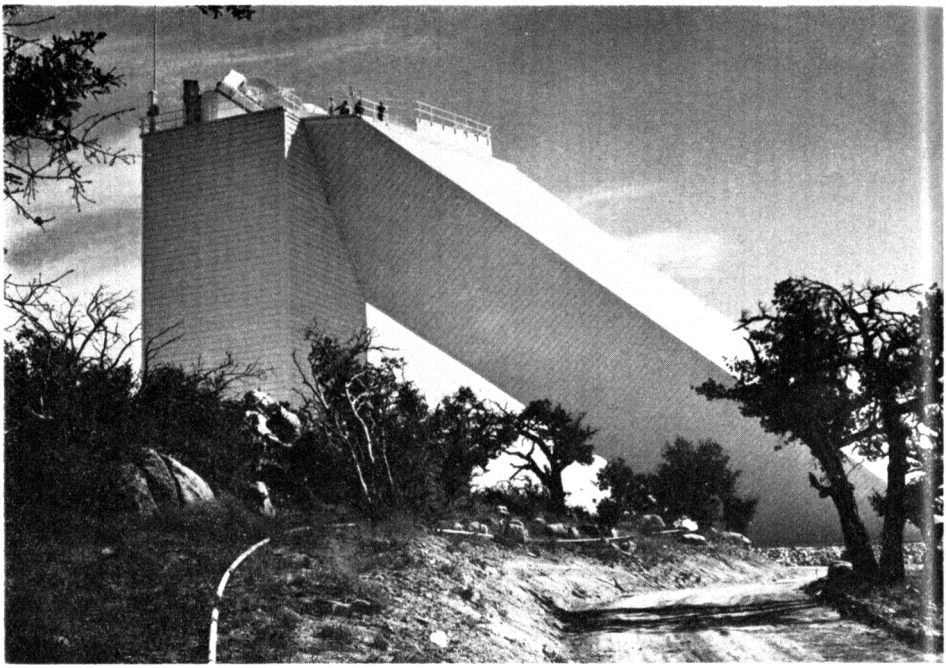
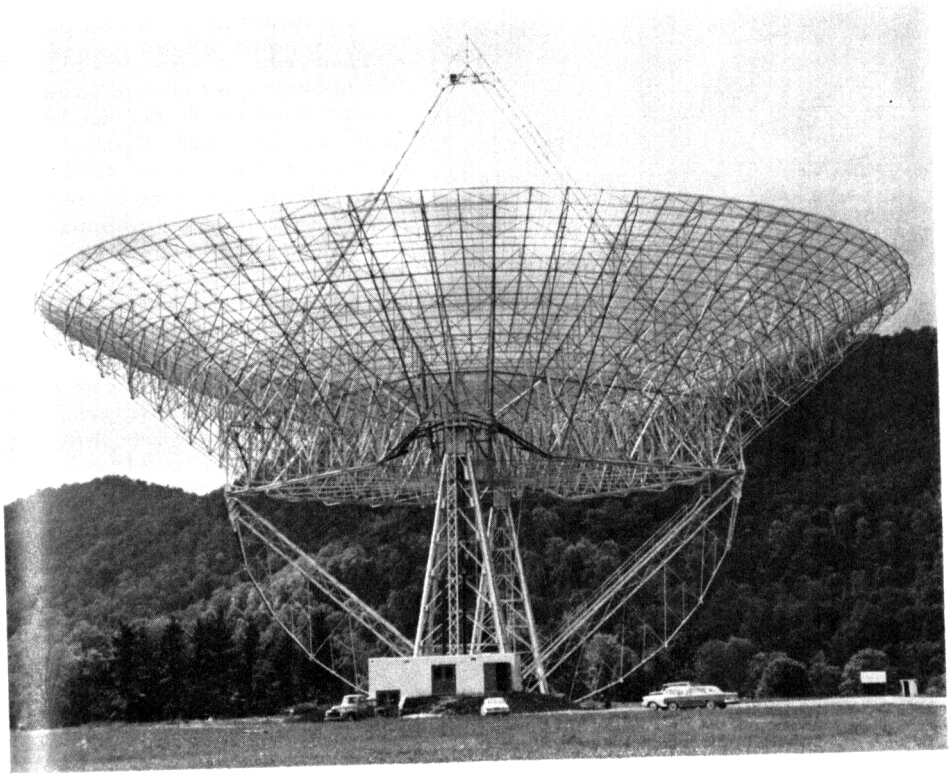




## Important New Research Tools for Astronomers

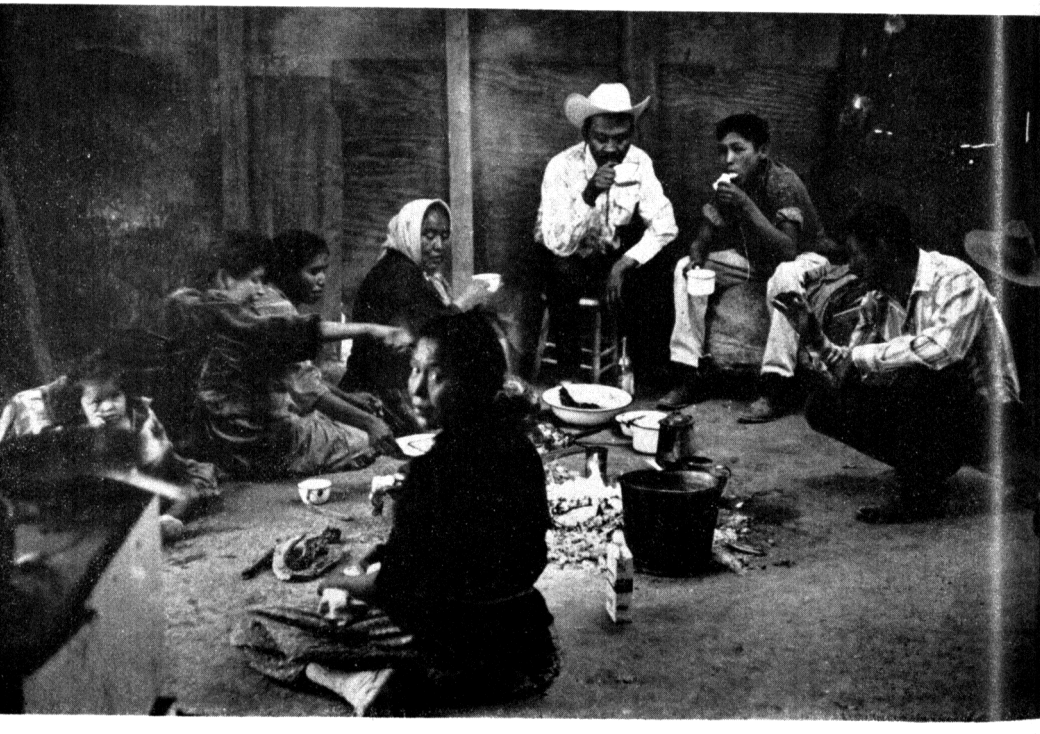
Completion of the 300-foot transit radio telescope (above) at the National Radio Astronomy Observatory in September 1962, was followed by a short testing period after which a full research program was immediately started. At present the largest movable radio telescope in the world, it is instrumented to record two radio frequencies simultaneously, and began observations on the planet Jupiter.

On Oct. 2, 1962, the 300-foot solar telescope at the Kitt Park National Observatory was dedicated (photos at left). Also the largest instrument of its type in the world, it produces images of the sun 34 inches in diameter in its underground observing room; one of the first of such images is shown in the lower photo, being observed by astronomers and visitors on dedication day. It is hoped that with this instrument, the true physical properties of the small-scale structure of the sun can for the first time be determined.

The National Radio Astronomy Observatory is located at Green Bank, West Virginia, and the Kitt Peak National Observatory is near Tucson, Arizona. Both are national research laboratories sponsored and funded by the Foundation. For further information, see page 53.

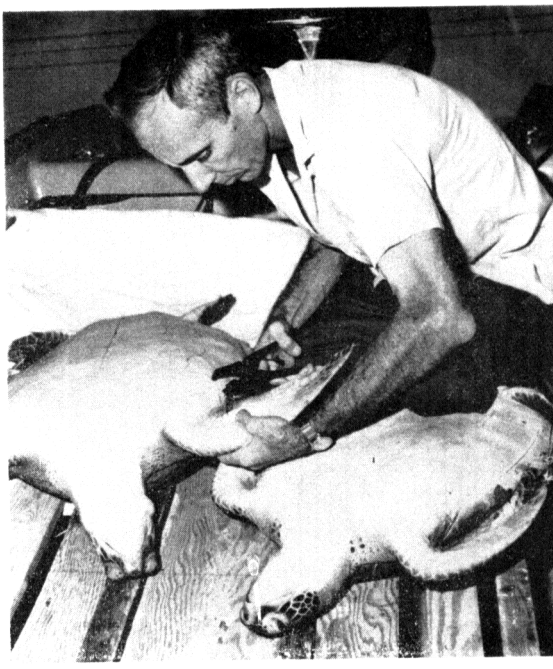
## Field Institute in Anthropology

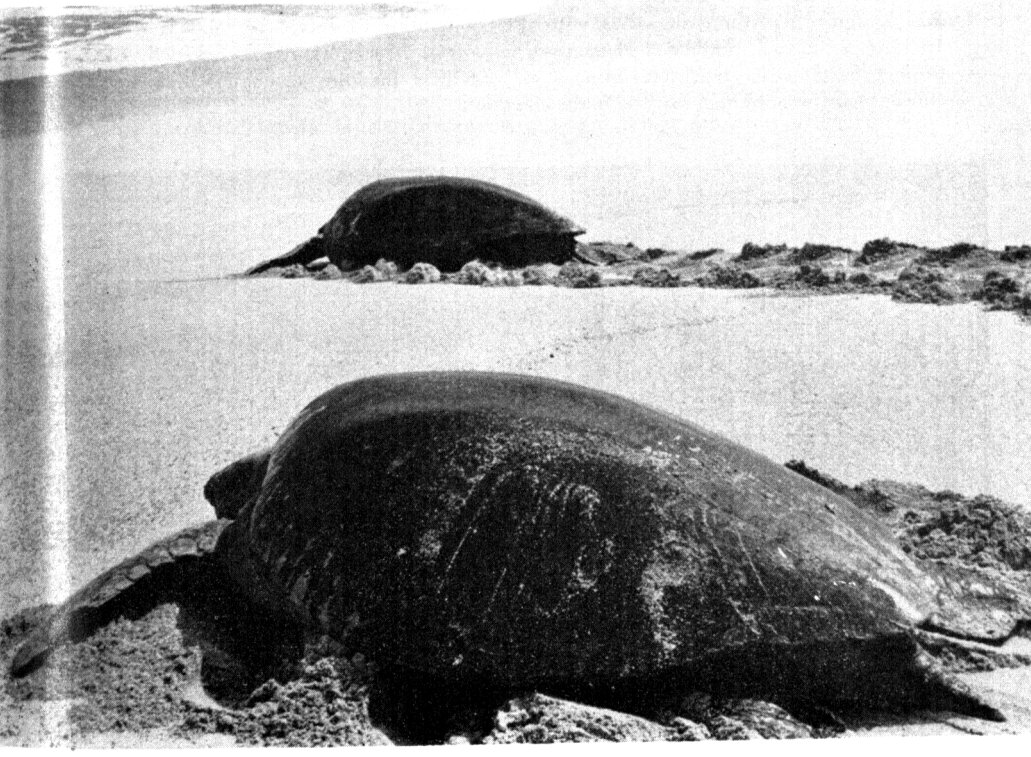
Photos taken in a New Mexico Navaho community, as part of a study conducted by the Harvard-Columbia Special Field Institute in Anthropology. Graduate students in ethnology and social anthropology spent three months under the guidance of a senior scientist, working on the history, habits, cultures, and religious ceremonies of Navaho, Zuni, Laguna, Acoma, and Hopi Indians. Interviews with the Indians, who received remuneration in return for their information and assistance, were carried on with the aid of an interpreter. These photos show preparation of a sheep hide (left) and a family group during mealtime.



## Sea Turtles Provide Clues to Understanding Animal Orientation

The marine green turtle appears to be one of nature's champion navigators. Turtle migration throughout the Caribbean, and between Brazil and tiny, isolated Ascension Island in the south Atlantic, probably involves celestial navigation. Work on the behavior, movement, and ecology of the five genera of sea turtles indicates that there is much to be learned about their highly developed travel-orientation senses. These photos show the NSF grantee tagging a year-old specimen (top right), and female green turtles trudging toward the sea after nesting, on Ascension Island.



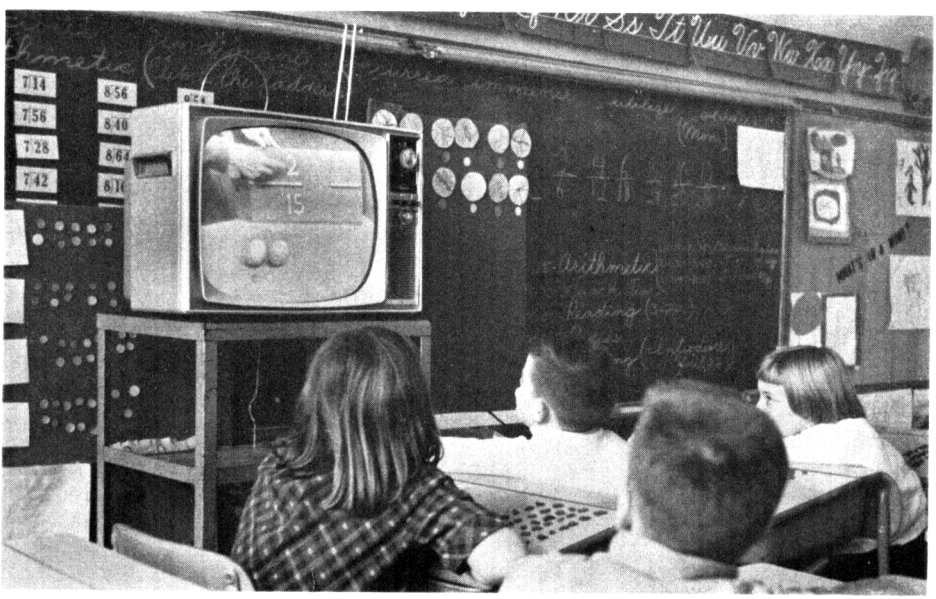


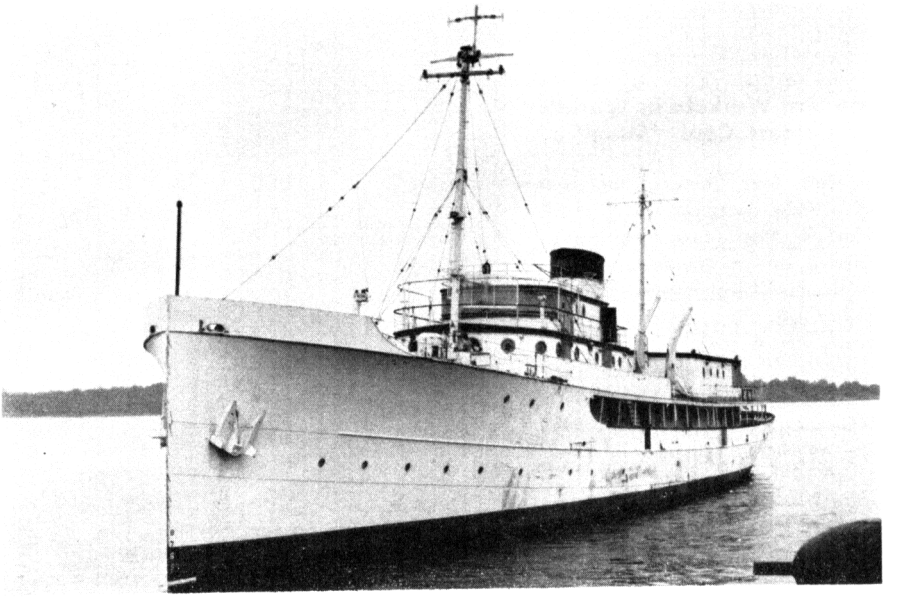

### Arithmetic by Television: Teacher

A Project Associate and Television Teacher presents sets of equivalent number pairs, for a fourth grade arithmetic class in Madison, Wisconsin. This is part of an effort to establish a sound basis for teaching a modern arithmetic curriculum in elementary schools through the use of television.

### Arithmetic by Television: Students

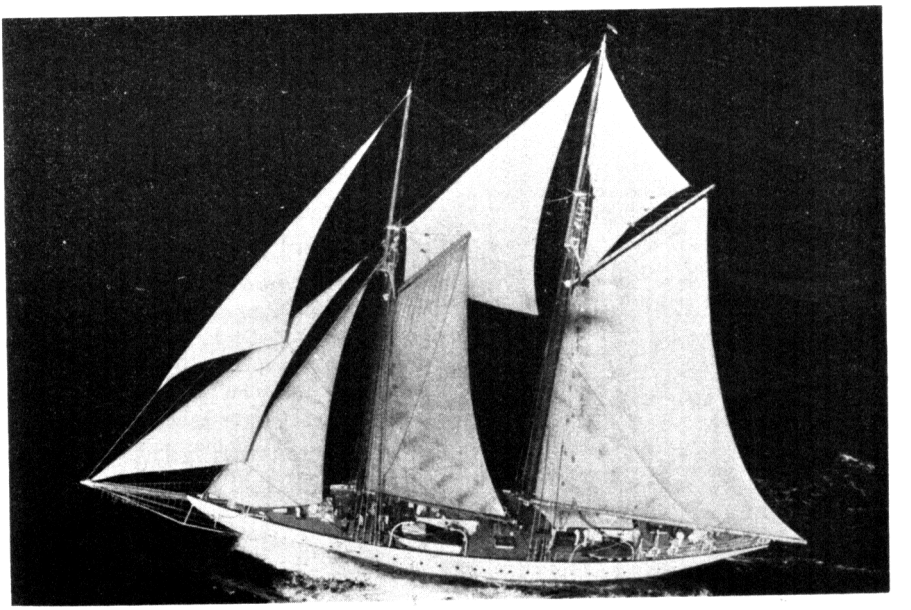
A fourth grade arithmetic class at Nichols School, Madison, Wisconsin, watches a television lesson in arithmetic. Sets of equivalent number pairs are being discussed. The program, an NSF-sponsored project of the University of Wisconsin, is also used in grades 5 and 6. Telecast in Madison and Milwaukee, it has also been used in Racine and other Wisconsin cities, with the cooperation of WHA–TV and WMVS. In view of the vast number of elementary schools and teachers, it is believed by the project participants that television is an excellent medium through which new concepts can be presented directly in the classroom.





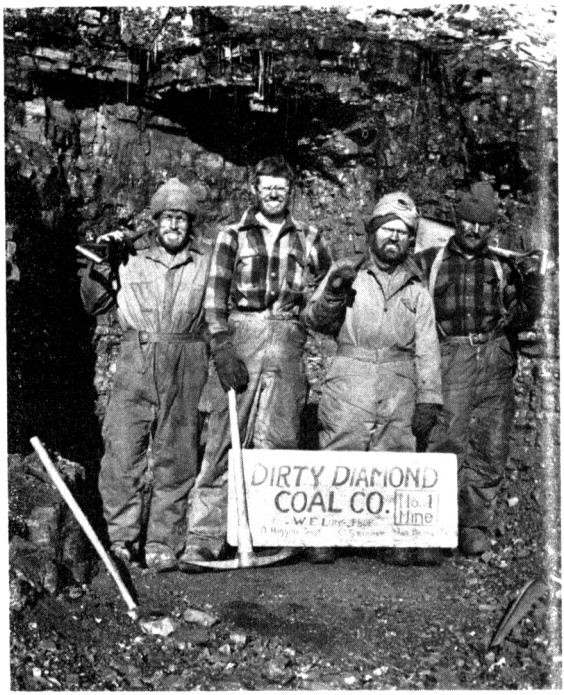
## Laboratory and Classroom Afloat

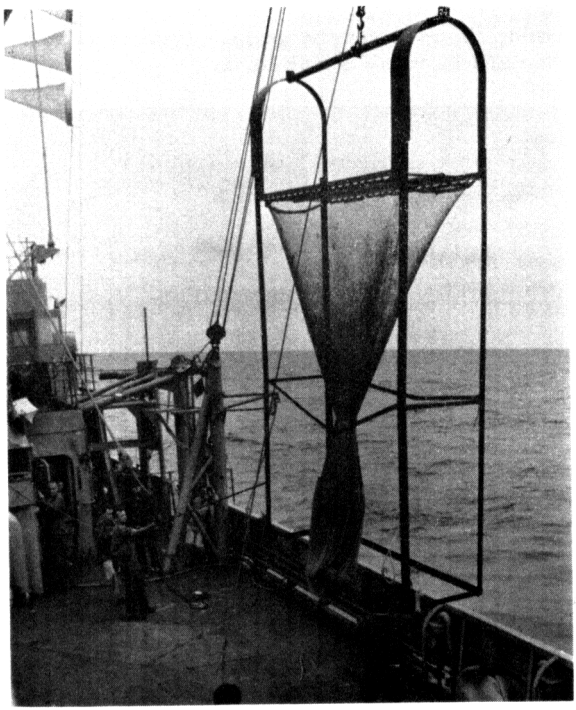
Formerly the Presidential yacht *Williamsburg*, the newly named *Anton Bruun* (above) has been made available to NSF as a floating biological research laboratory for the International Indian Ocean Expedition. The *Te Vega* (below), a 135-foot schooner formerly used in the West Indies as a pleasure yacht, has been chartered by Stanford University as a floating classroom for the graduate training-research program of the Hopkins Marine Station, with the aid of NSF grants.



## Modern Workers in World's Coldest Coal "Mine"

These four "miners," members of a field party in the Central Horlick Mountains, Antarctica, carried out a geological reconnaissance project as part of NSF's U.S. Antarctic Research Program. In a coal bed about 350 miles from the South Pole, they excavated to a depth of about 20 feet and recovered coal samples less weathered than any hitherto taken in the Antarctic.



## Antarctic Research at Sea

The USNS *Eltanin,* converted to a seagoing research laboratory, has begun a series of scientific cruises during which scientists from many different institutions and many different disciplines can undertake fundamental research. This photo shows a huge beam trawl hauled aboard, from a depth of 20,000 feet, to be emptied for specimens of ocean bottom sediment and marine life. The nets in upper left are part of another project, investigating air-borne insect distribution.

# EDUCATION IN THE SCIENCES

The Division of Scientific Personnel and Education continued in 1962 to support those activities which appear to have the greatest potential for improving science education in the United States. These include: further training of scientists and science students, supplementary training for teachers of science, mathematics, and engineering, improved course content and instructional materials, and various special projects in science education designed to assist individuals and institutions in improving their capabilites.

Continued and increased support was provided for established programs; new programs were introduced; the level of support was raised for promising experimental projects; and greater emphasis was placed on exploring and planning new approaches for existing institutions in upgrading science education. Approximately $88 million was obligated in fiscal year 1962 for education programs. Participation of institutes, teachers, and students in these programs increased considerably during the year. A total of 625 institutions, scientific societies, and comparable organizations were awarded grants to conduct such programs. Fellowships offered increased to 4,800. Approximately 40,800 opportunities for scientific study were made available at teacher-training institutes. A total of 15,000 undergraduate college and high school students participated in various NSF-supported training programs during the year.

Among the special projects in science education receiving noteworthy attention during the year was the new Undergraduate Instructional Scientific Equipment Program. This program was designed to assist institutions with the purchase—on a matching fund basis—of new and modern scientific equipment for improvement of science teaching at the undergraduate level. The demand for such funds far exceeded the supply.

The success of course-content improvement projects at the secondary school level has stimulated great interest in similar efforts for the elementary, junior high school, and college levels, and for certain specialized fields of science. The Foundation during 1962 has been conducting exploratory and feasibility studies before embarking on major programs in this area.

## Special Projects in Science Education

The Foundation's efforts in experimental testing and development of promising new directions in science education are centered in the activities of Special Projects in Science Education. Here new ideas are constantly being conceived, designed, developed, tested, and evaluated. Even those current activities which have become well established, with comparatively long histories and national acceptance, have either experienced major changes this year or will undergo major changes next year.

Four major program categories are administered under Special Projects in Science Education: Undergraduate Science Education Programs, Research Participation and Scientific Activities for Teachers, Specialized Advanced Science Education Projects, and Secondary School Programs.

### UNDERGRADUATE SCIENCE EDUCATION PROGRAMS

The several Undergraduate Science Education Programs offer unique opportunities to undergraduate institutions to improve the quality of education in the sciences. The three programs described below are intended to prepare the Nation's most able undergraduates to understand and contribute to the ever-expanding realm of science.

#### *Undergraduate Science Education*

The Undergraduate Science Education Program supports at colleges, universities, and non-profit research institutions a number of activities which have been designed to provide special opportunities for the scholarly development of outstanding undergraduates interested in the sciences. The program is aimed at developing new and expanded means for such undergraduates to advance in their understanding of science and in their ability to employ effective investigative procedures.

Through the research participation aspects of the program, able undergraduates are brought into direct contact with research and research scientists. It is intended that this research experience will stimulate the participant into developing fully his potential for scientific research and college teaching. The program also permits novel approaches to fostering independent study by individuals. It is recognized that regular undergraduate courses may not provide the high-ability undergraduate with the challenge or variety of experiences which he may gain from working independently.

In addition to the mathematical, physical, medical, biological, and engineering sciences, areas of the social sciences such as anthropology, sociology, psychology, and economics and the history of science are included in the program. During 1962 the interest in mathematics and the social sciences increased appreciably.

The growing interest of the academic community in the Undergraduate Science Education Program is evidenced in part by the increasing number of requests for support submitted to the Foundation. In 1962, 551 grants were approved, providing opportunities for 6,500 undergraduates.

With each year of operation, the evidence of this program's success becomes more convincing. Research reports by Undergraduate Science Education participants (as either sole authors or co-authors) have become a common occurrence in major scientific journals. It is also significant that two Undergraduate Science Education participants were named Rhodes Scholars in 1961 and that one of the top ten undergraduates in the country named by *Newsweek* in 1961 was an Undergraduate Science Education participant.

### *Undergraduate Instructional Scientific Equipment Program*

The Undergraduate Instructional Scientific Equipment Program, initiated in fiscal year 1962, was established to assist colleges and universities offering baccalaureates in the sciences by providing funds for the purchase of scientific equipment for undergraduate instruction. These funds, up to $25,000 per proposal, are granted on a matching basis. Proposals are allocated to institutions on the basis of the number of their science graduates, from one proposal for the smallest institution to six for the largest.

Priority was given to those teaching units where recognition of the need for improvement of the content and focus of undergraduate courses was accompanied by adequate staffing and supported by detailed and realistic planning. Need alone, unsupported by thoughtful assessment of the present and future positions of the disciplinary unit, did not qualify an institution for support.

The urgent need for this program and the great interest in it were evidenced by the fact that 783 institutions submitted a total of 1,127 proposals (over 70 percent of the eligible institutions applied) requesting over $16,000,000 in funds. Grants totaling $5,010,180 were made in support of 334 proposals from 263 institutions, representing approximately 30 percent of the requests for support.

### *Supplementary Training for Undergraduates*

Worthy projects which are directed toward the improvement of science instruction for undergraduates but do not follow the format of the Undergraduate Science Education Program are supported as supplementary training for undergraduates. Conferences to study undergraduate curricula requirements in particular disciplines, the provision of teaching experience for undergraduate science majors, and unusual faculty-student conferences represent the types of activities supported under this program.

Among the grants made last year was one in support of the Conference on Undergraduate Research in Mathematics. The Foundation has been informed that the Committee on Textbook Selection of the International Congress of Mathematicians selected this conference report for display at the International Congress at Stockholm.

## SPECIAL REPORT ON THE UNDERGRADUATE INSTRUCTIONAL SCIENTIFIC EQUIPMENT PROGRAM

Great advances in the state of knowledge in the sciences have motivated many educational institutions to re-examine their courses of study in undergraduate science. The need for this examination has been accentuated not only by an increasing number of student enrollments, but by recent developments such as:

(1) Increased quality of instructional materials available in science and mathematics at the secondary school level, accompanied by increased subject-matter competence among secondary school teachers of science and mathematics.

(2) Rapid expansion of the volume of scientific and technical knowledge—with the corresponding increase in the rate of obsolescence of college courses.

(3) Increased experience with various programs which demonstrate the capacity of able undergraduates to undertake significant responsibility for their own education—new or strengthened honors programs, undergraduate research participation activities, and other comparable "independent study" opportunities.

In institutions where planning and development in science education have occurred, it is not uncommon to find that substantial progress in the implementation of new procedures or in the improvement of old procedures is limited or restricted because the institution is unable to provide an adequate supply of new and modern undergraduate instructional scientific equipment. The Undergraduate Instructional Scientific

Equipment Program was designed to render assistance under these circumstances by providing funds for the purchase of the necessary equipment. These funds, up to a maximum of $25,000 per proposal, were granted on a matching basis.

During 1961–62, the first year of this program's existence, a total of 1,125 proposals were submitted by 783 institutions, requesting a total sum of $16 million. In all, 70 percent of the 1,110 eligible institutions submitted 74 percent of the 1,509 allowable proposals.

The magnitude of this program was far below the level which would be required to eliminate—or even alleviate substantially—the general shortage of instructional scientific equipment, a shortage which exists in some degree in every institution. Hence this program sought to identify situations in a state of "constructive ferment," where there was strong evidence of substantive improvement in some discrete aspect of the instructional program and where the improvement would be enhanced by the availability of suitable instructional equipment. As the announcement of this program stated, priority was given to those disciplinary units where recognition of the need for improvement of the content and focus of undergraduate courses was accompanied by adequate staff and supported by detailed and realistic planning. Need alone, unsupported by evidence of thoughtful assessment of the present and future position of the disciplinary unit, did not qualify an institution for support.

Grants totaling $5 million were made in support of 334 proposals from 263 institutions. Thus, approximately 30 percent of the proposals resulted in grants; 33 percent of the schools requesting grants received support at some level—in many cases substantially below the level requested.

Each institution was permitted to submit a maximum of from one to six proposals depending on the output of science baccalaureates during 1959–60. Funds were allocated in reasonable proportion to this output. The distribution by discipline was as follows:

| | | |
|---|---|---|
| Biology | 26 | percent |
| Chemistry | 24 | percent |
| Physics | 23 | percent |
| Engineering | 13 | percent |
| Computers | 7 | percent |
| Earth Sciences | 3 | percent |
| Social Sciences | 3 | percent |
| Mathematics | 1 | percent |

The equipment provided under these grants covered a wide variety of requests. Support for up to half of the cost of twenty small computers

was provided. Some institutions requested equipment to improve one detailed area, such as physiology or microbiology, while others sought improvement of the entire range of offerings in a broad area such as biology. Some sought to improve their undergraduate research facilities, while others concentrated on freshman and sophomore level needs.

While the massive national need for instructional equipment (estimated to be in excess of $300 million) cannot be eliminated by any modest program, the Foundation's Undergraduate Instructional Scientific Equipment Program provides a significant challenge and opportunity for institutions to develop further the quality of their undergraduate science programs.

## RESEARCH PARTICIPATION AND SCIENTIFIC ACTIVITIES FOR TEACHERS

Projects in this area cover a wide range of activities directed toward the improvement of subject-matter competence and scientific background of college and high school teachers, the promotion of interchange of ideas among college and high school teachers, and the development of cooperative programs among colleges and universities. These objectives are approached through research participation programs and through conferences and seminars, visiting scientists programs, and the support of "associations" of collegiate institutions.

### *Research Participation for College Teachers*

This program provides a means for college science teachers (including those junior college teachers who are qualified) to gain research experience during the summer. Teachers with limited opportunity to conduct research during the academic year are given a chance to obtain the stimulation and identity with science which research so effectively provides. Usually they participate as junior colleagues in research projects being carried on by experienced investigators.

The program is sufficiently flexible to meet several research needs of college teachers. Predoctoral teachers may commence projects leading to thesis research problems; others may complete such projects. Postdoctoral teachers are encouraged to participate, especially when their home institutions do not have adequate research facilities, and thus keep active in research. Postdoctoral participants, for the first time this year, outnumbered predoctoral participants.

A total of 51 grants were made, providing research participation for 427 teachers during the summer and 105 during the academic year.

### *Research Participation for High School Teachers*

This program provides a means for a limited number of qualified high school science teachers (and junior college science teachers not qualified for the companion Research Participation for College Teachers program) to gain research experience with competent investigators at colleges, universities, and nonprofit research organizations. This experience is expected to raise the level of the teacher's classroom instruction by improving his understanding of science and the scientific method. In some cases the teachers are able to carry out research which may lead to an advanced degree. An unexpected dividend derived from this program is the stimulus given to the college and university departments through the presence of the high school teachers. Provisions are made for a limited number of academic-year extensions to allow selected participants to continue their research at their home institution. In many cases the grantee institutions attempt to administer these funds on a matching basis in order to keep local school boards informed of the teacher's efforts to improve his professional qualifications.

The level of operation was intentionally kept at approximately that of last year because of the belief that there are only limited numbers of qualified high school teachers available to the program. There were 47 grants made in 1962, thus providing training opportunities for 370 participants during the summer and 115 during the academic year.

### *Supplementary Training for Science Teachers*

This program provides support for science teacher training projects which do not fit any of the Foundation's established teacher-oriented programs such as fellowships, institutes, research participation, or advanced science seminars. The Foundation has encouraged the development of novel approaches to improving the competence of science, mathematics, and engineering teachers—especially with respect to the subject matter they teach. The Supplementary Training program provides the administrative flexibility necessary to give these one-of-a-kind experimental proposals individual consideration. Through this mechanism it is possible to lend effective support to the Foundation's encouragement of imaginative and creative planning on the part of those concerned with the competence of science, mathematics, and engineering teachers. Eighteen grants were made.

### *Visiting Scientists Program*

The Visiting Scientists Program consists of two types of special projects: (a) the "college" projects concerned with visiting American scien-

tists and directed toward the small colleges and developing universities, and (b) the "foreign" projects concerned with visiting foreign scientists and aimed largely at the major graduate centers. Both kinds of projects are administered through appropriate professional societies, which select the lecturers and arrange itineraries.

It is the major objective of each of these programs to provide for students, undergraduate and graduate, respectively, the stimulus that comes from informal and personal contact with recognized scientists, and at the same time to provide for exchange of information between visitor and local staff, and for guidance to local staff and administration members on questions related to curricula and science education. The foreign visitor program is usually strongly research-oriented.

In the projects involving American scientists during fiscal year 1962 (i.e., during academic year 1961–62) 14 programs were in operation providing approximately 3,600 days of visits annually to some 1,400 science departments. In academic year 1962–63, the number of programs will increase to 17 or 18 and will provide approximately 3,900 days of visits. Current level of operations in the foreign scientists program supports about 2,200 days of visits annually.

## SPECIALIZED ADVANCED SCIENCE EDUCATION PROJECTS

Specialized Advanced Science Education Projects embrace two major functions that are linked with the general effort to improve the quality of education in the sciences. One function is programmatic in nature, involving administration of the Advanced Science Seminar and Public Understanding of Science programs; the other, which is less restrained by program boundaries and guidelines, is concerned with exploring and selecting new ideas, and devising methods of advancing science education.

### *Advanced Science Seminars*

Advanced Science Seminars are based on advanced treatment of subject matter. They frequently deal with interdisciplinary approaches, as in oceanography or space science, and are intended for specialists. Many are field station programs.

The varied format and specialized nature of the program are illustrated by a "Conference on Lunar Exploration" which was held at Virginia Polytechnic Institute, with the lecturers including the most distinguished space scientists in the country; a program in marine science supported at Woods Hole Oceanographic Institute in "Theoretical Studies in Geophysical Fluid Dynamics"; in marine biology at the Marine Science

Institute of the University of Texas; in "Nuclear Rocket Propulsion" at the University of Florida; field studies in anthropology in New Mexico under a grant to Harvard; and a program in "Dynamical Astronomy" at the Yale University Observatory. Participants in all of these seminars, together with 34 others, were college faculty, advanced graduate students, or a combination of both.

In several instances, courses designed solely for advanced graduate students were supported to meet a critical need during the summer months for distinguished graduate courses for participants selected on a national basis.

### *Public Understanding of Science*

The Public Understanding of Science Program is dedicated to the development of materials and programs that are designed to help intelligent non-scientists achieve an appreciation of science without attempting to train them to be scientists. The principal instrumentalities thus far supported include conferences between scientists and representatives of the mass media of communication, such as editors, science writers, and public information officers; the preparation of science films for educational television; and the planning of new educational television series. Through such individuals and devices the program aims to develop in the nonscientific public some appreciation of scientific methods and the significance of the term "research," of the element of uncertainty and limitations of science, as well as of its possibilities, and of the value of opinions voiced by scientists, both as experts in their fields and as citizens.

### *Science Education Developmental Projects*

The mission-oriented aspect of the Developmental Projects continues to search for and test appropriate means for providing comprehensive support of science in institutions that are striving to maintain or achieve educational excellence in the face of the expanding population of students. In practical terms this involves identifying competent scientists of catalytic temperament who, when given adequate support, can implement a master plan that works toward a synthesis of the best that American higher education is capable of offering. Accordingly, the Developmental Projects work closely with other organizational units of the Foundation in handling proposals that contain a master plan. These proposals usually cover a single department or disciplinary unit which, to be structured effectively, requires a range of kinds of support not offered by a single program or unit of the Foundation. Inclusive grants

of this type require, on the part of the Foundation, a degree of flexibility that programmatic activities seldom provide.

In fiscal year 1962 three grants were awarded in the developmental area: to Reed College for a summer program in inorganic chemistry for college chemistry teachers and undergraduate students majoring in chemistry; to the University of Oklahoma for the establishment of a training program in meteorology; and to the American Astronomical Society for a conference on graduate education in astronomy.

## PROGRAMS FOR SECONDARY SCHOOL STUDENTS

The talented secondary school student has, more often than not, remained unchallenged by traditional educational practices in the high schools. As part of the Foundation's broad program for education in the sciences, stimulation of the potential scientist during his formative years is considered an important function. Programs for secondary school students attempt to introduce students to new experiences which will draw upon their abilities to the fullest extent. Prominent among these are a variety of activities which bring them into contact with scholars, research scientists, and college-level science teachers. Substantive programs have been designed so that students may experience in some depth the fascination of advanced work in science or mathematics, taking care at the same time that such programs do not materially duplicate work available at either the high school or college level.

### *Summer Science Training Programs for Secondary School Students*

Now in its fourth year, the Summer Science Training Program for Secondary School Students (SSTP) provides opportunities for selected high-ability secondary school students to obtain a close and intimate view of an area of science, in direct association with qualified scientists, during the summer months. (In a few exceptional cases, programs are conducted on a part-time basis during the academic year.) Summer programs range in length from 5 to 13 weeks.

Individual programs are conducted by colleges, universities, and nonprofit research organizations. Instruction is at the college level. Offerings fall into two general types: (1) classroom instruction, with concomitant laboratory work and occasional field trips and (2) assignment of the student as a junior member of a team engaged on a *bona fide* research project. These categories are not exclusive; many programs combine elements of both types, and the difference is mainly one of emphasis. Both types have proved to be very effective in stimulating

interest in science careers, in improving study habits, developing more intelligent choices of optional subjects, and facilitating the student's later adjustment to college life.

During this fiscal year 154 grants were made in this program, providing instruction for 6,000 students.

### *Cooperative College-School Science Program*

The Cooperative College-School Science Program provides opportunities for higher educational institutions to present programs, as collaborative efforts with secondary schools, for the improvement of school science instruction. Projects typically group qualified secondary school students with teachers in intensive college-directed learning programs which may be course-oriented or provide research participation experience. The teacher participants serve as instructional aides, or in other suitable ways, thus gaining experience with advanced subject matter and with its impact on superior students. A desired result is that the teachers may develop improved science projects for capable students in their own schools.

A total of 34 grants were made in this program in fiscal year 1962. Projects supported involve 2,100 participants, 13 percent of whom are secondary school teachers. Seventeen of the projects are summer offerings and the remainder academic year or combined summer and academic year projects.

### *State Academies of Science*

The State Academies of Science Program provides support to State academies and comparable organizations, enabling them to carry out a variety of projects aimed at strengthening science education. Representing as they do the scientific community at State or local levels, and being conversant with local requirements, academies are well suited to present effective multidisciplinary programs operating over restricted geographic regions. Fifty-five grants were awarded in this program in fiscal year 1962.

An effort was made in the State Academies of Science Program in fiscal year 1962 to encourage the development of programs oriented toward college students and teachers. Such programs may provide meetings at which undergraduates present results of scientific research and may arrange visits of scientists to small colleges to advise students and teachers on current possibilities and requirements of graduate study. It is believed that these programs can effectively complement the Undergraduate Research Program of the Foundation.

### *Supplementary Science Projects for Students*

This program supports experimental projects, generally of a one-of-a-kind type.

Four grants were made for the following purposes: to the National Academy of Sciences for the distribution of a career information booklet on mathematics; to the National Science Teachers Association for the partial support of an American student delegation to the International Youth Science Fortnight in Great Britain; to Dartmouth College to support a program for the improvement of science education in the high schools of New Hampshire, to be conducted with the cooperation of St. Paul's School and the New Hampshire State Department of Education; and to the Council of Chief State School Officers for the preparation of a catalogue of instructional scientific equipment for secondary school use.

### *Holiday Science Lectures*

Patterned after the famous Christmas Lectures of the Royal Institution of London, the Holiday Science Lecture project is an effort to bring distinguished scientists to students all over the Nation in a five-day lecture series during Christmas and Easter vacations. The project was originally supported under a grant to Rockefeller Institute of New York City, and is now administered by the American Association for the Advancement of Science. During the past year, Dr. Paul Weiss lectured in San Francisco and Dr. Rene Dubos in Cincinnati, repeating the series which they had developed under the Rockefeller Institute grant. During the 1963 calendar year there will be six to eight lectures in a variety of disciplines presented in selected cities across the country.

### *Visiting Scientists (Secondary Schools)*

This special project enables professional societies in the basic disciplines—mathematics, chemistry, physics, and biology—to send distinguished scientists into secondary schools throughout the United States upon a school's request for such visitors. The visitors typically lecture on their scientific specialty, inform the students about opportunities in such fields of science, outline desirable educational programs for students wishing to enter scientific fields, confer with teachers and school administrators on new developments in curriculum and laboratory experiments, etc. The number of visits in any one State is small, for this is a national program which concentrates on those States where visiting scientists are not available under the State Academies of Science Program.

### *Traveling Science Libraries*

This program is conducted by the American Association for the Advancement of Science under grants from the National Science Foundation. Its primary purpose is to circulate to secondary and elementary schools, on a temporary loan basis, sets of selected books on science and mathematics. Also included in the program is the preparation and distribution of annotated book lists for the guidance of students and librarians contemplating the purchase of science books.

Initiated in 1955, the program was designed to serve secondary schools only and has been continuously supported through annual grants. Widespread distribution of the traveling libraries has so encouraged the acquisition of science books by school systems that further Foundation support of this phase of the activity is no longer necessary. Consequently, no grants were made in this program in fiscal year 1962, and the circulation of such libraries under previous grants was discontinued on June 30, 1962.

In the fall of 1959, circulation of a second group of science and mathematics books specifically selected to meet the needs and interests of elementary school students was initiated. In three years of operation the Traveling Elementary Science Library has reached 2,386 schools. Because of the many schools not yet served and the growing interest in science instruction in the elementary schools, this part of the program is being continued during academic year 1962–63.

## Course Content Improvement Programs

The Course Content Improvement Program of the Foundation is designed to bring scholarship of the highest order to the development of courses and instructional materials for all educational levels, reflecting contemporary scientific knowledge and points of view in science, mathematics, and engineering.

Continued large-scale effort of scholars and teachers is necessary if instructional materials are to keep pace with the rapid progress of science. Furthermore, the rapidly growing need for persons highly trained in science demands the efforts of our best teachers and scholars in providing the best course materials and course sequences they can devise. There has been a growing interest among scientists and teachers in collaborating in this effort.

A brief review of work being supported by the Foundation is given below followed by a more extensive report on work in physics.

## COURSE CONTENT IMPROVEMENT STUDIES IN MATHEMATICS, SCIENCE, AND ENGINEERING

This program has as its objective the production of improved up-to-date course materials for school and college programs in mathematics, science, and engineering. To this end, support is provided to leading scientists, assisted by teachers, for research and development work on course content. The material thus produced and information about its use are made widely available to schools and colleges. However, the material must make its way on its own merits and the decision as to its adoption is left entirely up to the judgment of the college or local school systems.

### *Elementary and Junior High Schools*

Small-scale projects aimed at developing, experimentally, appropriate sequences for elementary schools have been continued, in science at the University of California and the University of Illinois, and in mathematics at Stanford University. Webster College has received support for a project concerned with the development of elementary mathematics materials. The School Mathematics Study Group plans to complete a final revision of courses for grades 4–6 (during the summer of 1962) and to start work on mathematics for the primary grades.

A grant has been made to the American Association for the Advancement of Science (AAAS) for establishment of a planning and coordinating group to provide guidance and liaison among projects dealing with science for elementary schools. In order that a variety of materials and approaches may be available for schools, more than one major project is being supported. Both the AAAS and Educational Services Incorporated have received grants to conduct studies, with participation of scientists and teachers from various parts of the Nation, aimed at an exploration of the concepts and materials best suited for use in the elementary classroom.

### *Secondary Schools*

The table on the following page shows the status of the major study groups developing new course material for secondary schools.

Approximately 20 percent of the high school students enrolled in physics in the United States are now taking the Physical Science Study Committee (PSSC) course. In addition, as is indicated in the table, many teachers are using various parts of the course materials in their conventional physics course.

| Subject | Year Begun | Present Status | Use 1961–62 | |
|---|---|---|---|---|
| | | | Teachers | Students |
| Physics (PSSC).... | 1956 | Commercial version available. | 1,800–2,000 Partial Use by 1,000. | 80, 000 |
| Mathematics (SMSG). | 1958 | Definitive version available—Grades 7–12. | Unknown..... | 409, 000 |
| Chemistry (CBAP). | 1958 | Revised version in trial schools; commercial version, Sept. 1963. | 200..... | 10, 000 |
| Biology (BSCS).... | 1959 | Revised versions in trial schools; commercial versions, Sept. 1963. | 500..... | 50, 000 |
| Chemistry (CHEM Study). | 1960 | Revised version in trial schools; commercial version, Sept. 1963. | 124..... | 12, 000 |

Approximately 100 volumes of School Mathematics Study Group (SMSG) materials are in definitive form. The group plans to withdraw these books as soon as comparable volumes by individual authors are commercially available. Other SMSG activities this year include the production of additional books in a monograph series, programming of the ninth grade algebra course, an alternative geometry course, modification of the course for ostensibly less able students, and extensive evaluation studies.

A grant for an alternative sequence in mathematics has been made to the University of Illinois for the support of the University of Illinois Committee on School Mathematics, a pioneer group in mathematics reform, previously supported by the University of Illinois and the Carnegie Corporation. With this earlier support, materials were produced for grade 9–12 and have been tested in schools. On the basis of these tests, a new and improved approach—beginning with the 7th grade and continuing the sequences through the 12th grade—is planned.

The Chemical Bond Approach Project (CBAP) and the Chemical Education Material Study (CHEM Study) have continued testing in schools in preparation for producing final versions of the courses to be published commercially in 1963. The latter group has started production of a film series that is expected to number 20–30 films.

The Biological Sciences Curriculum Study (BSCS) continued testing its three approaches to biology and expects that commercial versions will be available in 1963. In addition to textbooks and laboratory manuals, the courses include a program of intensive laboratory work and research-oriented material for gifted students. Supplementary material being developed includes teachers' guides, a handbook for teachers, films on laboratory techniques, an annotated list of existing films suitable for use in the three courses, and a series of pamphlets on biological subjects for both teachers and students.

In addition to these major projects, smaller ones in other areas have been supported. Through a previous grant to the American Geological Institute, a sourcebook on geology and the earth sciences for elementary school and secondary school courses has been completed and is now commercially available. A grant was made to the American Anthropological Society for exploration of the use of anthropological materials in elementary and secondary schools and for the preparation (for use in the schools) of source material in anthropology in the form of bibliographies and pamphlets.

### *Colleges and Universities*

The success of the Committee on the Undergraduate Program in Mathematics and the Commission on College Physics in stimulating, coordinating, and disseminating information on work aimed at improving undergraduate instruction has led leaders in other disciplines to establish similar organizations. The Foundation now supports, in addition to the groups in mathematics and physics mentioned above, the Advisory Council on College Chemistry, the Geological Educational Orientation Study, and the Commission on Engineering Education. It is likely that groups in other disciplines will form in the coming year.

As an example of the type of activities of these groups, some of the accomplishments of the Commission on College Physics may be cited. The Commission instigated and assisted in a series of conferences on "The Curriculum for Undergraduate Majors in Physics." The Commission's Committee on Instructional Films and Apparatus initiated projects in these fields which are carried on at colleges and universities and by professional organizations. A series of paperback books for college use was begun as was a series of *Resource Letters* for college teachers. Each letter provides a guide to some of the literature, apparatus, and films available on a given topic for use by the instructor who is not an expert or specialist in that topic.

Panels of the Committee on the Undergraduate Program in Mathematics have prepared curriculum recommendations for the various

groups of students who take undergradutae mathematics, including prospective teachers. Suggested course outlines have been prepared with the hope that they will stimulate the writing of new texts. A consultants bureau has been established to bring information about the work of the committee directly to the colleges, and to provide first-hand information for the further work of the committee.

The Commission on Engineering Education will explore the curriculum needs in the rapidly changing field of engineering and will seek means for the continuing education of the engineering faculty staff.

A grant has been made to the National Academy of Sciences-National Research Council to support a study group on educational policy in agriculture aimed at an assessment of the needs for new courses and curricula in this field.

In addition to grants in support of the activities of coordinating and other study groups, a number of grants have been made for the development of specific courses and materials. Some of these are related to, or stimulated by, the "nerve center" groups, while others have arisen independently. Typical grants include those to the:

(1) University of Illinios—for the development of a research-oriented analytical chemistry course.

(2) American Society for Engineering Education—for a study of ceramic engineering curricula.

(3) Case Institute of Technology—for materials for dynamics instruction through the use of a personal analog computer.

(4) Cornell University—for an experimental teaching program in algebra.

(5) University of Maryland—for materials in mathematics for elementary school teachers.

(6) Educational Services Incorporated—for a text, laboratory experiments, and film on semiconductor electronics.

Work has continued at the Massachusetts Institute of Technology and at Washington University on the development of new approaches and materials for introductory college physics courses, and at Harvard University on the development of a new biology course. A group centered at the University of California has now produced the manuscript for two college-level resource books in anthropology entitled "The Teaching of Anthropology" and "Resources for the Teaching of Anthropology."

## SUPPLEMENTARY TEACHING AIDS

Under the *Science Teaching Equipment Development Program* support is provided for developing prototypes of new instructional equip-

ment. This year 43 grants were made, bringing the total number of projects supported under this program to 137. Several projects in chemistry and physics are designed to employ recent research developments as the basis for new experiments for undergraduates. The fact that almost half the proposals were in engineering indicates the serious attention now being given to the modernization of engineering laboratory experiments.

Support is also given to production of films designed to increase the effectiveness of teaching by bringing into the classroom phenomena not readily available through other means, presentations by outstanding teachers and scientists, illustrations of laboratory techniques, and films to be used primarily for teacher-training purposes. Film projects have been supported in a number of fields. Among these are the following grants:

(1) Iowa State University—for plant biology films for college courses.
(2) Indiana University—for developmental anatomy films.
(3) Educational Services Incorporated—for films on semiconductor electronics as part of the set of course materials previously mentioned; —for motion pictures as an instructional aid in fluid dynamics courses; —for films of demonstration and laboratory experiments for college and university physics courses.

Some of the film projects initiated in previous years have been continued during fiscal year 1962. These include the production of films and tapes of a mathematics course for educational television use at the University of Wisconsin. This course, at the fifth and sixth grade levels, is aimed at teacher education concurrent with classroom use. The television course "The New Biology" intended primarily for teachers has been shown this year on television networks and educational television stations. NSF supported production of films and tapes of this course for further educational use. Films recording the customs, technologies, and ceremonies of Indian tribes in the western United States continue to be supported by the Foundation as are films on archaeological research centered around archaeological salvage projects in reservior areas which will soon be flooded.

## SPECIAL REPORT ON STUDIES IN PHYSICS

Changes in education can now be added to the roster of events which have altered the face of physics in the twentieth century. Relativity, quantum mechanics, parity, strange particles, solid state, fission, fusion,

nuclear weapons, radar screens, automation—words like these evoke an image of a science changing rapidly in fundamental factual and theoretical content, technological product, and politico-social implication. Requirements for increasingly complex apparatus, teams of investigators, and real understanding of physics by more and more people at many levels in industry and government are further illustration of the profoundly different status of physics as compared with 60 or 30 or even 10 years ago.

In the middle 1950's scientists and educators began to see that events like these—in all fields of human endeavor and interest—made it essential that research-oriented scholars join forces in a continuing search for new ways of providing an educational program reflecting contemporary insights into modes of inquiry, ways of learning, and the evolving structure of subjects.

The first major frontal attack was on the problem of creating a better physics course for the high school. Previously physicists had merely complained about the inclusion of too much technology in physics courses, the failure to reflect the unity of physical thought, the tendency to compound a patchwork by inserting bits and pieces about recent developments. The most significant development came in 1956, when a group of physicists drawn from such research centers as Massachusetts Institute of Technology, California Institute of Technology, University of Illinois, Cornell University, Harvard University, and Bell Laboratories decided to work on the development of as good a high school program as they could devise. From the outset they recognized that they must bring in, as equal partners, exceptionally competent teachers and schoolmen who knew students and school situations. The result was the formation of the Physical Science Study Committee in the fall of 1956. The group set itself the goal of devising a one-year course in physics, to be taught at the eleventh or twelfth grade level, suitable at least for those students who normally take physics in high school. The course was to lead students to think their way through fundamental physics, drawing in appropriate ways upon all aids to learning—textbooks, laboratory work, supplementary readings, examinations, audiovisual aids, and—above all—teachers. As Dr. Jerrold Zacharias, Chairman of the Physical Science Study Committee, puts it: "The teacher will always be the best 'learning aid' of all."

In the summer of 1957 the Physical Science Study Committee brought several scores of physicists and teachers to Cambridge, Massachusetts, to begin the task of developing the new course. A very preliminary version was tried in eight schools by eight of the teacher-writers during the 1957–58 academic year while developmental work continued,

influenced by feedback from classroom trial. Greatly expanded work in the summer of 1958 permitted trial during the 1958–59 school year in nearly 300 schools, reflecting a variety of conditions but using especially trained teachers. Syllabus, text, laboratory apparatus, films, supplementary readings, teachers' guide, teacher training, examinations, and other components of the instructional systems underwent continuing development and modification. In the 1959–60 school year the course was being used in some 600 schools. The collaboration of hundreds of research physicists, college teachers, high school teachers, science writers, instrument makers, film experts, and other specialists finally made possible the preparation of a set of materials which was made available through commercial channels to all interested schools and teachers in time for the 1961–62 academic year.

The work of the Physical Science Study Committee (PSSC) quickly led physicists and teachers to see an ever-widening range of problems requiring the attention of the best minds. It became clear that work must continue on producing better films, an improved text and other basic materials, a growing library of supplemental readings, more information on effectiveness of the materials, new examinations; also continuing opportunities must be provided for physics teachers to meet and collaborate.

Some colleges began to use the PSSC course but found that they needed more material. Early in the PSSC activity, work had been done on certain areas (relativity, angular momentum, etc.) which had to be excluded from the published materials in order to keep within the one-year limit. The interest of the colleges in this approach led to a major effort in the development of text, laboratory, and film materials on "advanced topics" which it was believed could be used in a second high school course or a beginning college program. Physicists and schools throughout the world had by this time begun to be interested in the PSSC approach. In contrast to present American practice, secondary school physics in most countries is taught over a three- or four-year period. Physicists in other lands were therefore much interested in the advanced topics—and this work is now being carried out by a team drawn from Canada, New Zealand, Sweden, and the United States.

Since the beginning of this venture, the people involved in the PSSC have emphasized the view that their creation is only one of the intellectually and pedagogically valid approaches to secondary school physics.

The development of models and materials for alternative approaches will require dedicated work on the part of scientists and teachers of high competence. In recent months interest in one alternative approach has

grown, and there is even some possibility that the work can be done in part by an international team.

As students come from high school with improved preparation, colleges have the opportunity to offer them more sophisticated programs. This and other factors are leading many physics departments to examine their entire undergraduate curriculum. Work with initial emphasis on reformation of introductory courses, is under way at such centers as California Institute of Technology, Washington University, The University of California (Berkeley), Rensselaer Polytechnic Institute, Massachusetts Institute of Technology, and other institutions. Particular attention is being directed to providing laboratory experience that leads students to self-directed exploration of fundamental data and ideas, to presenting from the start a contemporary viewpoint, and to providing practice in physical modes of thought. Physicists in colleges and universities have also seen that motion pictures permit them to bring into the classroom a range of experimentation, demonstration, and discussion by outstanding thinkers not possible by other means; a number of project groups are exploring this avenue.

There is general agreement that diversity and variety of approach are essential in the national effort to improve courses, but this diversity creates problems in correlation of effort. Manpower and funds have limits. Concerted reflection and action are required to define problems, devise some guidelines, make sure that someone is giving attention to most of the promising approaches and important problems, and provide centralized information services so that each project group knows what others are doing and each college can avail itself of the products of all projects to whatever extent it chooses. This is the mission of the Commission on College Physics, an autonomous group of physicists formed to stimulate reform in college physics programs.

Somewhat to the surprise of physicists in the United States, course-content improvement efforts undertaken to meet American needs have turned out to be of great interest to many other countries. Because it has had a longer history of development, the PSSC course has attracted special attention.

Seminars, conferences, and other meetings on the course have been conducted, with the aid of U.S. personnel, in Great Britain (sponsored by the Organization for Economic Cooperation and Development), Austria, Scandinavia, Israel, Italy, Brazil, Japan, Pakistan, and India. Translations and adaptations are currently being prepared in several countries. Perhaps even more important is the fact that the PSSC illustrates the results of a method of reconstructing science curricula through collaborative work by research scholars and teaching scholars.

The work in physics has also had a horizontal impact in the United States itself. Its success has encouraged scientists and scholars in other fields to formulate comparable campaigns. The results of their work, in turn, feed back into the physics program: for example, new developments in mathematics curricula provide powerful tools for instruction in physics.

## Institute Programs

The Foundation's institute programs are designed to increase the effectiveness of the teaching of science, mathematics, and engineering in the Nation's schools by improving the subject-matter competence of teachers through the group training approach. They have as their goal helping teachers keep well informed concerning changes in their rapidly growing scientific fields and assisting those teachers whose basic training in science and mathematics has been inadquate. Institutes provide supplementary training for high school, college, and technical institute teachers, as well as for a limited number of elementary school teachers and supervisory personnel. At the college level these programs show increasing concern with "teachers of teachers."

Three major types of institutes conforming to the time patterns available to teachers for work and study, and allowing for variation within types as dictated by changing needs in the educational world, are supported: (1) Summer Institutes, which provide generally 4 to 12 weeks of full-time study during the summer period when schools usually are not in session; (2) Academic Year Institutes, which provide full-time study during the regular school sessions for a relatively small number of teachers who take leaves of absence for one year; (3) In-Service Institutes, which provide part-time study opportunities for teachers who are simultaneously holding full-time positions in the schools.

College Conferences serving special needs for extending knowledge in specialized fields are also operated for periods of up to four weeks during times of the year best suited to the schedules of college faculty members.

Because teachers at the several levels of the educational spectrum have somewhat different objectives—and frequently quite different academic backgrounds—from those of the usual professional students in scientific fields, institutes are commonly based on specially planned classes and group activities. A secondary objective of the program is, therefore, to encourage colleges and universities to establish "pre-service" courses or curricula that more effectively meet the subject-matter needs of teachers in science, mathematics, and engineering. Although this objective is

being achieved, to at least a limited degree, much more needs to be done to assure adequate competence in subject matter of teachers.

By offering a type of training which enables teachers to take courses of study expressly designed for the inservice teacher, the Foundation is providing motivation and support which help those who are presently teaching to upgrade their subject-matter competence, and is thereby directly affecting the quality of science teaching in the Nation's schools at all levels. It is also demonstrating to colleges and universities the need to review carefully science and mathematics courses now available to both pre-service and inservice teachers who seek to improve their competence in these areas. A review of this kind serves to reveal to institutions the need for revision in curricula and for the development of study opportunities which more effectively meet the subject-matter needs of teachers both during their initial years of training and in later years of professional work. On a long-range basis, this helps to upgrade generally the programs of study in science, mathematics, and engineering for all students.

Since the inception of institute programs in 1953, the Foundation has made grants for the support of more than 3,300 institutes, which have provided over 156,000 opportunities for study in science, mathematics, and engineering. During fiscal year 1962 the Foundation provided support for 911 institutes. Of this number, 35 percent were for part-time study during the regular school year, 7 percent were for full-time study during the regular school year, and 58 percent were for full-time study during the summer. These institutes made provision for some 40,800 opportunities for study.

During the summer of 1962 some 100 foreign teachers and students were provided places in various summer institutes. Travel funds for these persons, for the most part, are provided by the Asia Foundation, African-American Institute, Ford Foundation, American Friends of the Middle East, Department of State, etc.

In order to add strength to the staffs of the summer institutes and to add to the knowledge of the teachers attending these institutes, the Visiting Foreign Staff Project was again supported in 1962. In this project, the American Association for the Advancement of Science arranged for approximately 15 eminent foreign scientists and mathematicians to visit some of the summer institutes in this country. Each foreign scientist spent several days giving lectures, offering seminars, and taking part in informal discussions with the institute participants at each of the six to nine institutes he visited.

## CHARACTERISTICS OF INSTITUTE APPLICANT POPULATION

Research conducted during the past year indicates that, while there is a significant turnover in the institutes program's target population, approximately 35 percent of the teachers currently teaching secondary school science or mathematics have attended at least one NSF institute program. Another 13 percent applied but were not accepted and about 52 percent have not applied to any of the teacher-training programs supported by the Foundation. Having already conducted research in the area of the characteristics of the institute applicant population, the staff, aided by a contractual arrangement with the American Institute for Research, has initiated a study of that portion of the secondary school science and mathematics teacher population which has not applied to any NSF teacher-training program.

Studies show that there are some distinct differences between those teachers who apply and those who do not apply to the teacher-training programs. The applicant, particularly the successful applicant, tends to be a subject-matter oriented teacher who definitely finds satisfaction in intellectually stimulating situations. Such applicants are interested in furthering their intellectual self-improvement, whether through NSF institutes or local educational workshops. These individuals do not experience as much conflict between their professional and family obligations as do the non-applicant group and, compared with their non-applicant counterparts, they have a much higher level of drive or motivation.

This finding is important in that it appears from the study that the current non-applicant group, which is over half of the institute program's target population, is a low-drive, low-motivation group which seems content to accept the *status quo* rather than to make any significant move toward self-improvement or change of any sort. Thus it is likely that the non-applicant perceives himself as being less well prepared than his applicant counterpart and he tends to feel that the programs as they now exist, or at least as they have existed in the past, would be "beyond his depth" (despite the fact that there are institutes which would not be too advanced). Further, the non-applicant is generally less professionally oriented; he reads fewer journals concerning education, mathematics, or science; and he is less likely to join a mathematics or science organization or voluntarily attend meetings of this type of organization. Another problem is that a major sub-group of this non-applicant population is composed of those teachers who teach mathematics and science for only a small percentage of their workday and who may have a primary interest in a field other than science or mathematics. Such a

person is likely to say that he is an English teacher and then parenthetically state that he also teaches two classes of mathematics each day. However, this same teacher may be the only mathematics teacher in his school. The results of these studies have important implications for the future directions of the Foundation's institute programs.

## SUMMER INSTITUTES

Summer institutes offer instruction on a full-time basis during a part of the summer at various colleges and universities throughout the Nation. The sponsoring institutions receive Foundation support covering participant and operational costs.

**Table 2.—*Distribution of Summer Institutes, 1962, by Field of Study***

| Field | High School Teachers | High School and College Teachers | College Teachers |
|---|---|---|---|
| Anthropology | 2 | ..... | 2 |
| Astronomy | 2 | ..... | ..... |
| Biology | 48 | 2 | 6 |
| Chemistry | 29 | 3 | 6 |
| Earth Sciences | 24 | ..... | 1 |
| Engineering | ..... | ..... | 12 |
| History & Philosophy of Science | ..... | ..... | 1 |
| Isotope Technology | ..... | ..... | 5 |
| Mathematics | 106 | 2 | 10 |
| Physics | 23 | ..... | 3 |
| Psychology | 1 | ..... | 3 |
| Radiation Biology | 18 | 1 | 5 |
| Radiation in Physical Sciences | ..... | ..... | 3 |
| Regional Science | ..... | ..... | 1 |
| Science Curriculum | 2 | ..... | ..... |
| Multiple Fields & General Science | 157 | 1 | ..... |
| Total | 412 | 9 | 58 |

### *Summer Institutes for Secondary School Teachers*

For the summer of 1962 the Foundation awarded grants for 421 institutes to support 21,000 secondary school teachers of science and mathematics.

Disciplines encompassed by these summer institutes represent virtually all fields of the sciences (both natural and social), and include both traditional approaches to subject matter and the newer approaches developed through the Foundation's course content improvement programs.

Geographically, the 1962 summer institutes were distributed throughout the 50 States, the District of Columbia, and Puerto Rico. As in previous years, there was a wide variety of types of institutions represented among the host colleges and universities.

### Summer Institutes for College Teachers

For the summer of 1962, support was granted for 67 summer institutes for college teachers; 58 of these were for college teachers exclusively, and 9 combined secondary-school and college teacher participation. This permitted participation of an estimated 1,900 teachers.

Examination of the completed applications for places and the number of places available in summer institutes for college teachers indicates that there is a major task yet to be accomplished and many teachers yet to be provided with training. The average number of estimated applications per available place is slightly over four for the summer of 1962, and new programs in psychology, social science in general, and radiation in the physical sciences have been added to subject matter previously covered.

Several new aspects appeared in the program for the summer of 1962. One involved cooperation with the Atomic Energy Commission in three institutes in radiation in the physical sciences; for these institutes AEC pays the operational costs and NSF provides support funds for 75 participants. Also new to the program were three institutes in psychology and physchological statistics. These institutes represented very different approaches designed for quite different groups of participants, and emphasized quantitative social science rather than social studies. Another new program aspect involved support of an institute in regional science at the University of California, Berkeley. The training, endorsed by the Regional Science Association, took cognizance of the recent rapid changes in social science and emphasized the use of statistics in the study of regional and spatial structures. Geographers and economists have expressed great interest in this field.

### Summer Institutes for Elementary School Personnel

Twenty-one summer institutes for elementary school personnel were held in 1962. Grants for these institutes provided support for 712 participants.

The needs in this area of training are tremendous and the Division is actively pursuing studies of the best methods of attack on the problem. Work is progressing on course content and teacher source materials, particularly in mathematics, but also in physics and astronomy. Work

is also being done through AAAS on guidelines for elementary school teacher training.

It is a safe prediction that there will be a great expansion of the programs for the supplementary training of elementary school personnel. If the training is not done through programs of the Foundation, it certainly will be done through other programs. The merits of the Foundation's program lie in the relationships already established between the Foundation and the various departments of mathematics and science in the academic institutions. Very probably the greatest contribution that can be made by the summer institutes program of the Foundation is in the training of the "key" teachers and the supervisors of elementary science and mathematics.

### *Summer Institutes for Technical Institute Personnel*

Two grants made in fiscal year 1962 provided study opportunities for 80 participants. The program is presently designed to strengthen the subject-matter competence in mathematics and science of individuals who teach at technical schools and of junior college teachers who have teaching responsibilities in technical curricula.

### *Summer Conferences for College Teachers*

For the summer of 1962 a total of 35 conferences were supported. Grants for these conferences provided stipends for 985 participants.

A college conference may be essentially a short-term summer institute, but frequently the subject matter is more specific and more sophisticated, being especially designed for a clientele which consists of well-qualified specialists who need only to be brought up-to-date or made aware of some very recent development in their field or of some subdivisions thereof. This type of activity is a versatile tool for improving the quality of college teaching, for conferences may cover a specialized topic until the need of the participants is met, and then the conference may move quickly to other topics where an apparent need exists. Thus, college conferences can deal with an almost endless group of specialized topics which are constantly developing in all scientific fields. Further, many college teachers are available for training for short periods of time only. Proposals received in this program have reflected a significant increase in interest in programs designed specifically for college teachers of prospective elementary and secondary school teachers.

Since the college conference is most effective when conducted at a time when a large fraction of the target clientele can attend, and since this time varies with the nature of the subject field, proposals for projects to be held at any time during the year will be considered in the future.

## ACADEMIC YEAR INSTITUTES

The Academic Year Institute Program supports the efforts of universities and colleges in providing opportunities for secondary school and college teachers of science and mathematics to study intensively appropriate sequences of courses in the subject matter of their disciplines on a full-time basis for 9 to 12 months.

Since this program was introduced in 1956–57, with two institutes, the number of institutes supported has increased to 55 for academic year 1962–63. These institutes provide training opportunities for 1,725 secondary school teachers and 105 teachers in small colleges.

A trend which will be of increasing significance in the future is the marked growth in the portion of the program directed toward college teachers. The grant program for fiscal year 1962 is supporting 105 college teachers at 14 universities, as compared with 75 at 8 institutions during the previous fiscal year. Since the emphasis in this program is on training opportunities for "teachers of teachers" in liberal arts colleges, teacher training institutions, and junior colleges, the effects upon the future graduates of teacher training programs will considerably multiply the present direct efforts.

Pilot programs were underway during 1961–62 at the University of Wisconsin in advanced training for potential science and mathematics supervisors, and at Oklahoma State University in a fifth-year program providing strong pre-service training in science for recent college graduates who are certified as teachers. These experimental programs are being extended in 1962–63 to six institutes providing sixth-year training for potential supervisors and to six institutes providing fifth-year programs for pre-service teachers. Such developments as these are particularly significant since they may lead to noteworthy improvements in the general training of teachers.

## IN-SERVICE INSTITUTES

In-service institutes offer instruction on a part-time basis during the academic year at colleges or universities, or at off-campus centers, so that teachers may attend while still teaching full-time in their schools. Participating teachers receive no stipends, but receive modest travel and book allowances. The sponsoring institutions receive Foundation support to cover the participant and operational costs.

### *In-Service Institutes for Secondary School Teachers*

During the 1961–62 school year about 11,500 teachers received instruction in a total of 253 in-service institutes. A significant increase

was made in the program for 1962–63, with 284 grants awarded for the support of approximately 13,770 secondary school teachers, and including all but two States. In addition, a small number of college teachers were accommodated in this program. The principal expansion of the program has been in reaching many local areas not previously served by this program and in providing a greater number of programs in science for junior high school teachers.

Approximately half of the course work offered in these institutes is in the field of mathematics, with the remainder covering the range of the biological and physical sciences. The new course-content developments are increasingly offered in in-service programs, with approximately 33 percent of the institutes presenting programs related to one or more of the "new curricula" projects. These institutes will help to provide teachers with the background which will enable them to introduce into their classrooms those portions of the new materials which they deem desirable.

The increase in the total opportunities made available under this program appears to be the major accomplishment during fiscal year 1962. At the same time, a significant innovation has been the development of the combination of summer institutes with in-service institutes which will offer coordinated programs frequently leading to the master's degree.

This year, major attention was given to obtaining a maximum geographical coverage of the country consistent with scientific excellence; to consolidating institutes which are on one campus so as to promote efficiency and flexibility; and to visiting institutes—especially at the smaller colleges which do not have other NSF-supported programs.

It has been observed at a number of institutions that an in-service institute has been the opening wedge in awakening faculty interest in improvement of science education, especially in the training of future teachers. At the same time, the in-service institutes have provided opportunities for colleges and universities to work more closely with the secondary schools in their areas.

### *In-Service Institutes for Elementary School Personnel*

In-service institutes for elementary school personnel first received Foundation support in academic year 1959–60 on an experimental basis. For academic year 1962–63 a total of 35 grants providing support for 1,060 participants were made. This program is by its nature somewhat restricted in geographical distribution of the participants, and frequently it contains a more heterogeneous group of participants than that attending summer institutes for elementary school personnel. However, while it lacks the advantages gained by the participants' living together, the

in-service institute is probably the most effective mechanism for the training or retraining of a large number of elementary teachers at a low unit cost. It has the advantage of taking place at a time when the teacher is engaged in teaching and can, in many instances, put the training to immediate use.

## Fellowship Programs

The Foundation's fellowship programs are intended to strengthen the Nation's scientific potential by enabling persons of unusually high ability to increase their competence in science, mathematics, and engineering through the pursuit of advanced scientific study or scientific work. Since the inception of NSF fellowship programs in fiscal year 1952, approximately 21,000 fellows have been supported in seven fellowship programs. Fellowship recipients were selected solely on the basis of their ability from among nearly 80,000 applicants.

**Table 3.—*NSF Fellowship Programs, 1962***

| Programs | No. of Applicants | No. of Awards Offered |
|---|---|---|
| Graduate Fellowships | 5, 961 | 1, 761 |
| Cooperative Graduate Fellowships | 4, 118 | 1, 200 |
| Summer Fellowships for Graduate Teaching Assistants | 1, 818 | 868 |
| Postdoctoral Fellowships | 897 | 245 |
| Senior Postdoctoral Fellowships | 270 | 92 |
| Science Faculty Fellowships | 864 | 325 |
| Summer Fellowships for Secondary School Teachers | 1, 569 | 300 |
| Totals | 15, 497 | 4, 791 |

In the total NSF fellowship programs the number of applicants increased 19 percent over the number for fiscal year 1961. Marked increases were noted in the Postdoctoral (37 percent), Graduate Teaching Assistants (33 percent), Cooperative Graduate (27 percent), and Graduate (22 percent) Fellowship Programs. Applications in the Senior Postdoctoral Program remained essentially constant, but, for the second consecutive year, there was a decrease in the number of applicants for Summer Fellowships for Secondary School Teachers.

It is perhaps significant that applications in the Graduate and Cooperative Graduate Fellowship Programs combined exceed 10,000 whereas

the number of Graduate Program applicants in fiscal year 1958—just prior to the introduction of the Cooperative Graduate Program—was only 3,804.

In addition to the NSF fellowship programs, the Foundation continued to administer one extramural fellowship program—the North Atlantic Treaty Organization (NATO) Postdoctoral Fellowships in Science.

Applications for NATO Postdoctoral Fellowships in Science were received from 244 individuals, an increase of 93 over the previous year. A total of 48 awards were made.

## GRADUATE FELLOWSHIPS

Graduate Fellowships (the first fellowship activity established by the Foundation) provide support to unusually able students to permit them to complete their graduate studies with the least possible delay.

A record 5,961 individuals submitted applications in the fiscal year 1962 program, representing an increase of 1,086 over the number for the previous year. Although 1,761 awards were offered (224 more than in the past year), this number included 733 renewals, the result being that only one out of five of the new applicants was successful in obtaining an award.

## COOPERATIVE GRADUATE FELLOWSHIPS

These fellowships, similar to the Graduate Fellowships, differ from them only in financial provisions and in administrative aims and procedures. A greater degree of institutional participation is involved, especially with respect to the initial evaluation and the recommendation of applicants.

For fiscal year 1962 the "recommendation numbers" assigned to the participating institutions were substantially increased, with every school being permitted to recommend at least 20 applicants for fellowships. Although the number of applicants (4,118) and the number of awards offered (1,200) reached new highs, the "success ratio" was lower than in any previous year.

## SUMMER FELLOWSHIPS FOR GRADUATE TEACHING ASSISTANTS

These awards make it possible for Graduate Teaching Assistants in science, mathematics, and engineering to devote full summer periods to their own academic pursuits.

The sharp increase in the number of applicants this year (33 percent over the number for fiscal year 1961) was probably due mainly to the removal of "recommendation numbers" which had in earlier years limited the number of applicants in this program. Institutions were encouraged to recommend as many individuals as they considered qualified for these awards.

The 868 fellowships offered represented an increase of 243 over the number offered in the previous year.

## POSTDOCTORAL FELLOWSHIPS

During fiscal year 1962 this program continued to enable persons who had recently obtained their doctorates to undertake additional advanced training as investigators in their specialized fields. Applications rose from 656 in fiscal year 1961 to 897—the greatest number in the program's 11-year history. Available funds permitted the awarding of 245 fellowships—only 10 more than the number offered in the previous year.

## SENIOR POSTDOCTORAL FELLOWSHIPS

Senior Postdoctoral Fellowships are designed to offer well-established scientists, mathematicians, and engineers the opportunity to pursue additional study and/or research with a view toward increasing their competence in their specialized fields or toward broadening their knowledge in related fields of science, mathematics, and engineering.

Applications were received from 270 individuals and 92 awards were offered.

## SCIENCE FACULTY FELLOWSHIPS

These fellowships provide an opportunity for college and university teachers of science, mathematics, and engineering with at least three years of science teaching experience at the collegiate level to improve their competence as teachers by obtaining additional advanced training in their own or related fields.

In fiscal year 1962, for the first time, the program was open to applications in the social science areas supported by the Foundation. Of a total of 864 applicants, 39 were social scientists—10 of whom were offered awards. Awards offered totaled 325, including 118 in the various engineering fields.

### SUMMER FELLOWSHIPS FOR SECONDARY SCHOOL TEACHERS OF SCIENCE AND MATHEMATICS

This program emphasizes study by the fellows in the natural sciences and mathematics at a level acceptable to their fellowship institutions toward the traditional advanced degrees in science and mathemtics.

Both the number of applicants and the number of awards offered decreased for the second consecutive year, although the proportion of successful applicants was slightly higher than in fiscal year 1961. The present level of approximately 300 new awards per year appears to be optimum for this program.

### NORTH ATLANTIC TREATY ORGANIZATION (NATO) POSTDOCTORAL FELLOWSHIPS IN SCIENCE

For the fourth consecutive year the Foundation administered, in behalf of the Department of State, the program of NATO Postdoctoral Fellowships in Science. These awards enable United States citizens and nationals to study abroad, primarily in the NATO countries. Other NATO member nations select fellows from among their own nationals. Of the awards accepted this year, 35 were for study and research in the physical sciences (including 4 in mathematics), 11 in the life sciences, and 2 in economics.

## Surveys of Manpower Resources for Science and Technology

Long-range and continuing studies conducted by the Foundation are providing a variety of information and analyses on the education, professional qualifications, and employment of scientific and technical personnel. This information is made available for Foundation, other Federal agency, and public use as required for the management, operation, and evaluation of scientific manpower programs of all types. Activities include support and publication of studies and surveys, and the maintenance of the National Register of Scientific and Technical Personnel.

### NATIONAL REGISTER OF SCIENTIFIC AND TECHNICAL PERSONNEL

During 1962 analysis of National Register data collected during 1960 was completed, and preparation was made for the 1962 recirculariza tion of the register.

Analyses of the first 120,000 returns to the 1960 National Register were published in three preliminary reports: *Scientific Manpower Bulletin No. 14,* "Earnings of American Scientists, 1960;" *Scientific Manpower Bulletin No. 15,* "Geographic Distribution of Scientists in the National Register of Scientific and Technical Personnel, 1960;" and *Scientific Manpower Bulletin No. 16,* "Foreign-Language Proficiency of Scientists Reporting to the National Register of Scientific and Technical Personnel, 1960." The total number of individual scientists included in the final analyses of the 1960 data was 201,292.

These analyses culminated in a final report, *American Science Manpower, 1960.* (See table 4 and figure 2.) A special report, "Summary Characteristics of Scientists Reporting to the National Register of Scientific and Technical Personnel, 1960" was released as *Scientific Manpower Bulletin No. 17.* This Bulletin and the 1962 Questionnaire and Specialties List were mailed to American scientists during April 1962 by the cooperating national professional societies to initiate the 1962 registration. As of June 30, 1962, a total of 202,000 questionnaires had been received by the societies, with an anticipation that about 245,000 individual registrants would be included in the complete 1962 National Register.

Detailed information on scientific and technical personnel in the National Register was furnished in response to requests from the scientific community, Government agencies, industry, universities, etc. These requests may be categorized as:

1. Statistical information related to salaries, educational level, work activities, age distribution, types of employers of scientific and technical personnel, and other factors.
2. Numbers of registrants located in specific geographical areas, i.e., State, county, or metropolitan area.
3. Information on the techniques for establishing rosters for use by industrial establishments, educational institutions, and foreign countries.
4. Identification of individual scientists with specialized qualifications for foreign visit activities, international teaching assignments, and special studies to be conducted by Government agencies.

**Table 4.—*Highlights of General Characteristics of Registrants, 1960***

| Characteristics | Number | Percent |
|---|---|---|
| All registered scientists | 201, 292 | 100 |
| Men | 186, 553 | 93 |
| Women | 13, 551 | 7 |
| No report of sex | 1, 188 | ..... |
| Employment of status: | | |
| Full-time civilian employed | 172, 721 | 86 |
| Active military duty | 3, 945 | 2 |
| Students | 12, 905 | 6 |
| All others | 11, 721 | 6 |
| Type of Employer: | | |
| Educational institutions | 55, 663 | 28 |
| Government organizations | 32, 364 | 16 |
| Nonprofit institutions | 8, 855 | 4 |
| Industry, business, and self-employed | 90, 986 | 45 |
| All others. including military | 13, 424 | 7 |
| Professional experience: | | |
| 1 year or less | 6, 827 | 3 |
| 2–4 | 29, 556 | 15 |
| 5–9 | 46, 152 | 23 |
| 10–14 | 40. 615 | 20 |
| 15–19 | 22, 145 | 11 |
| 20 or more | 46, 761 | 23 |
| No report of experience | 9, 236 | 5 |
| Work activity: | | |
| Research, development, and design | 74, 949 | 37 |
| Teaching | 29, 539 | 15 |
| Management or administration | 48, 914 | 24 |
| All others | 47, 890 | 24 |
| Highest degree: | | |
| Bachelor's | 73, 555 | 37 |
| Master's | 50, 515 | 25 |
| Professional medical | 5, 432 | 3 |
| Ph. D | 62, 610 | 31 |
| No report of degree | 9, 180 | 4 |
| Age groups: | | |
| 20–29 | 36, 627 | 18 |
| 30–39 | 79, 981 | 40 |
| 40–49 | 49, 102 | 24 |
| 50–59 | 23, 643 | 12 |
| 60 and over | 9, 890 | 5 |
| No report of age | 2, 049 | 1 |
| Median age 38 years. | | |

Source: National Register of Scientific and Technical Personnel, 1960.

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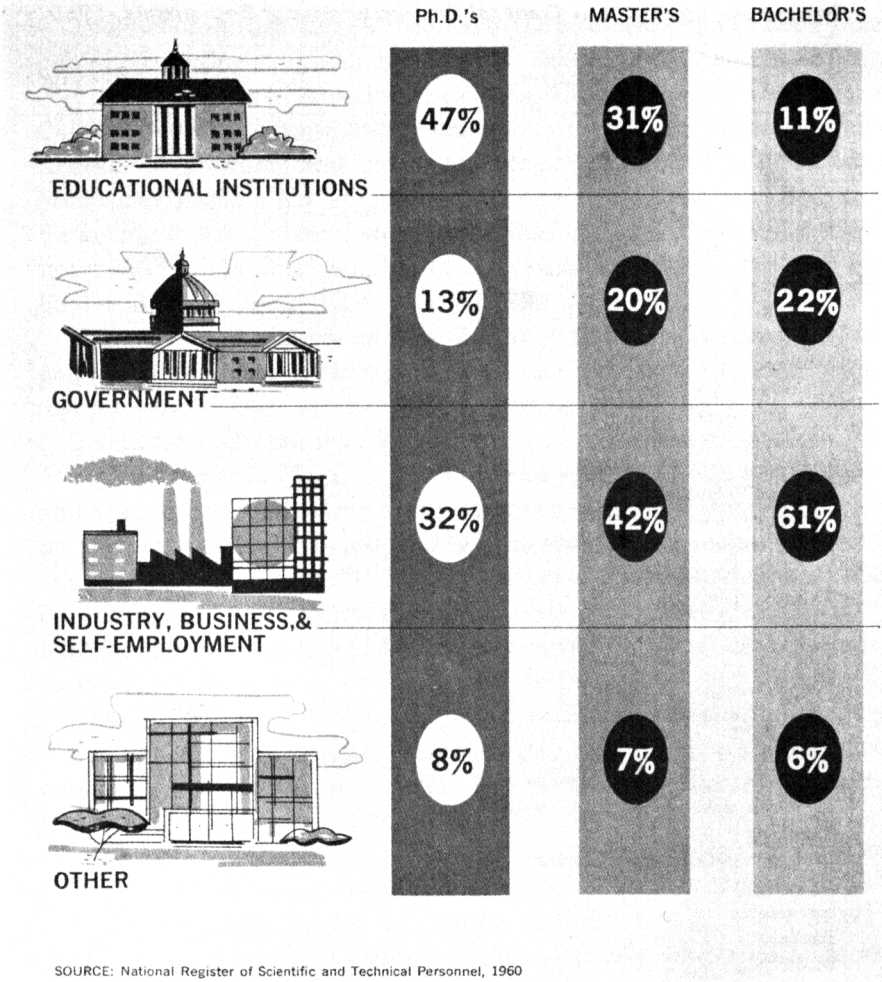



**Figure 2.** *Type of Employer of Scientist Holding Bachelor's, Master's, and Ph. D. Degrees*

## SCIENTIFIC MANPOWER STUDIES

Major studies of scientific and technical manpower undertaken by or on behalf of the Foundation are directed at providing information on critical manpower problems and aspects of scientific manpower potentials. Among the more important projects under way in fiscal year 1962 were studies of: Qualifications and Service Loads of Secondary School Teachers of Science and Mathematics; Evaluation of Sino-Soviet Bloc Countries in the Development of Scientific and Technical Manpower Resources of Other Countries; Offerings and Enrollments in Science and Mathematics in Non-public Secondary Schools; Sources and Extent of Financial Support of Graduate Students; Doctorate Production in United States Universities, 1920–61; Labor Market Behavior of Scientists and Engineers in Jet and Missile Production; and a Survey of Professional and Technical Manpower, based on a postcensorial survey.

During 1962, the Manpower Studies publications issued by the Foundation included:

*Education and Professional Manpower in the USSR*—The study was the result of a three-year research project and emphasized the development of Soviet education and specialized manpower resources in the entire context of total Communist ideology—political, economic, social, and cultural. The study covered topics such as the recent educational reform, the structure of the Soviet educational system (primary, secondary, specialized, and higher education), advanced degrees and Soviet research and academic personnel, and the employment of professional and specialized manpower in the Soviet Union. Some of the findings of this project were: (1) the Soviet Union is producing two to three times as many scientific and technical professional graduates yearly as the United States; (2) Soviet production of science and engineering professionals is seen as continuing at high levels throughout the 1960's; (3) professional instruction provided these graduates, though extensive in fundamentals of science and engineering, was found to be directed toward narrowly defined specialties.

*Employment in Professional Mathematical Work in Industry and Government*—Presents the findings of a survey of mathematical employment other than teaching. Data were collected on the age, education, experience and other characteristics of persons engaged in mathematical work, as well as on the nature of the current positions, functions performed, and income received (see table 5). Information on mathematics content required for work in this field will be useful to educators concerned with mathematics curriculum in the light of the changing re-

quirements of the Nation's technology. The chief employers of persons engaged in mathematical work were found to be aircraft and electrical equipment manufacturers and the U.S. Department of Defense. Approximately 94 percent of the survey respondents had at least a bachelor's degree, and one-third had advanced degrees (7 percent the doc-

**Table 5.—*Educational Level of Persons in Mathematical Employment,*[1] *By Employer, 1960***

| Employer | Number Reporting | Percent distribution by educational level | | | | |
|---|---|---|---|---|---|---|
| | | Total | Doctor's degree | Master's degree | Bachelor's degree | No degree |
| All employers | [2] 9,815 | 100 | 7.2 | 25.7 | 61.3 | 5.8 |
| Private industry | 7,098 | 100 | 7.4 | 26.5 | 61.4 | 4.7 |
| Aircraft & parts | 1,961 | 100 | 5.9 | 25.1 | 63.3 | 5.7 |
| Transportation equipment (except aircraft) | 208 | 100 | 6.7 | 28.4 | 62.5 | 2.4 |
| Electrical equipment | 1,226 | 100 | 8.7 | 27.5 | 58.9 | 4.9 |
| Machinery (except electrical) | 601 | 100 | 11.8 | 26.9 | 55.5 | 5.8 |
| Professional and scientific instruments | 186 | 100 | 10.8 | 29.6 | 58.0 | 1.6 |
| Other durable manufacturing | 521 | 100 | 4.8 | 31.0 | 58.6 | 5.6 |
| Petroleum products and extraction | 451 | 100 | 12.4 | 27.1 | 58.9 | 1.6 |
| Chemicals and allied products | 317 | 100 | 17.1 | 32.6 | 47.1 | 3.2 |
| Other nondurable manufacturing | 169 | 100 | 10.7 | 31.4 | 53.8 | 4.1 |
| Insurance | 909 | 100 | .8 | 20.7 | 73.3 | 5.2 |
| Other nonmanufacturing | 549 | 100 | 6.4 | 27.3 | 63.0 | 3.3 |
| Federal Government | 2,493 | 100 | 5.8 | 22.5 | 62.4 | 9.3 |
| Army | 929 | 100 | 3.1 | 19.4 | 60.2 | 17.3 |
| Navy | 577 | 100 | 7.1 | 22.5 | 66.9 | 3.5 |
| Air Force | 453 | 100 | 5.3 | 26.5 | 61.1 | 7.1 |
| National Aeronautics & Space Administration | 231 | 100 | 3.5 | 16.0 | 76.2 | 4.3 |
| Commerce | 104 | 100 | 20.2 | 21.1 | 57.7 | 1.0 |
| All other agencies | 199 | 100 | 10.0 | 35.7 | 50.8 | 3.5 |
| Nonprofit organizations | 224 | 100 | 20.5 | 35.3 | 43.3 | .9 |

[1] Other than teaching.

[2] Excludes 167 respondents who did not specify educational level.

Source: National Science Foundation.

torate). Three-fifths of the respondents were under 35 years of age and one respondent in seven was a woman.

*The Long-Range Demand for Scientific and Technical Personnel*—Provides results of a study undertaken to develop a systematic methodology for the long-range projection of demand for scientific and technical personnel through separate analyses and projections for each principal segment of the economy. The report describes a methodology and presents projections to 1970, illustrating the procedures and calling attention to the areas where more or better data and analytical techniques are needed. The report concludes that much additional data are needed in order to analyze accurately future supply-demand relationships. The continued development of comparable statistics on scientists, engineers, and technicians for all segments of the economy and more comprehensive data on the educational background and other characteristics of such personnel are prerequisites for such a study, according to the report.

*Women in Scientific Careers*—Contains information on the employment and education of women in relation to scientific careers, including data on occupational status, age, marital status, educational attainment, and employment status. The study analyzed the factors controlling women's selection of and participation in scientific careers—giving consideration to such items as the loss of interest attributed to the educational system and the influence of personal, cultural, social, academic and economic factors on women's choice of careers.

*Scientific and Technical Personnel in Industry, 1960*—Includes information on the number of scientists and engineers (by discipline) and technicians employed by industrial concerns and other functions.

*The Duration of Formal Education for High-Ability Youth*—Presents an analysis of available information on the flow of youth from high school to college and progress through college to the bachelor's degree. These subjects are analyzed for all students and for those in the top 10 percent and top 30 percent ability levels. (See figure 3.) The study indicates that about two-thirds, rather than the frequently stated one-half, of the abler high school graduates do not enter college. Among talented boys, three-quarters to four-fifths of the high school graduates continue their education. On the other hand, less than one-half of the men and less than one-third of the women with high ability complete an undergraduate college education.

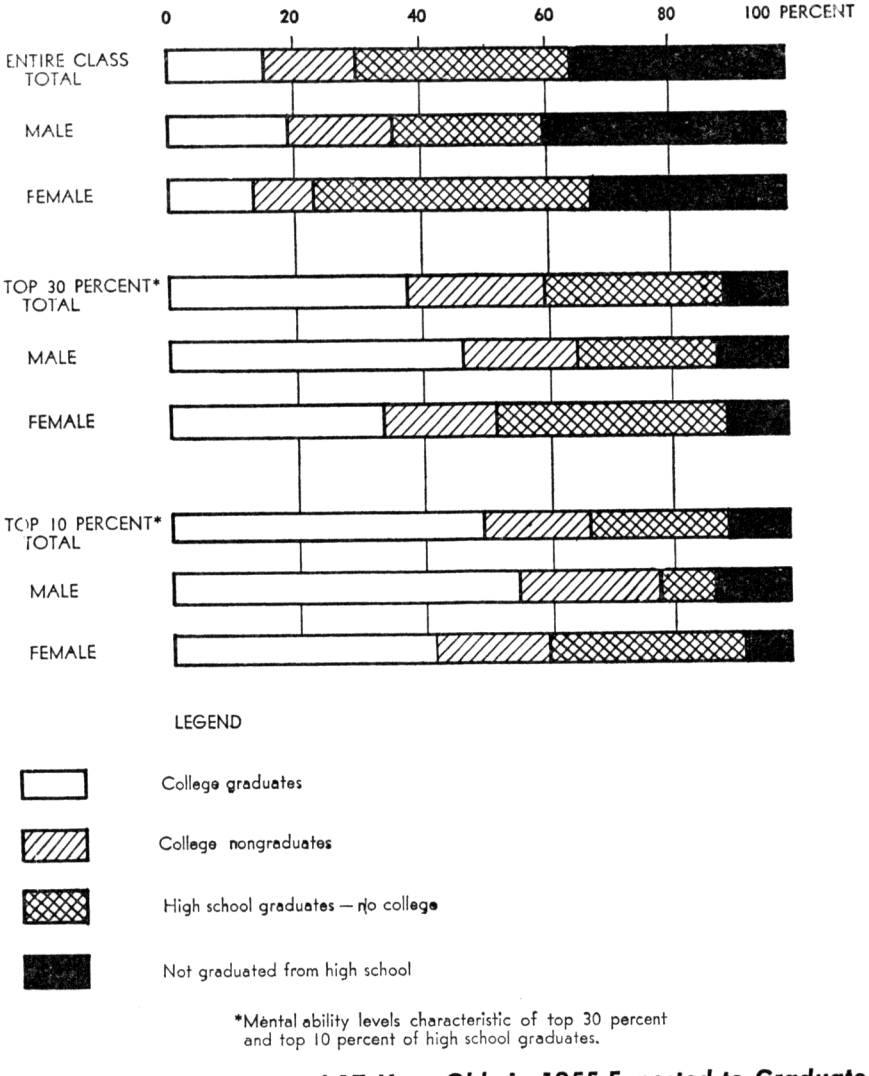



**Figure 3.** ***Percentages of 17-Year-Olds in 1955 Expected to Graduate From College (Through Full-Time Study)***

# DISSEMINATION OF SCIENTIFIC INFORMATION

All scientific research produces information. All scientific research uses information. Maximum scientific progress requires maximum effectiveness in the dissemination of research-produced knowledge. Improving the control and dissemination of scientific information for the benefit of U.S. scientists is the fundamental mission of the Foundation's Office of Science Information Service (OSIS). Fiscal year 1962 marks the third full year of operation under directives the Foundation received from the President and the Congress in 1958–59.*

An extensive and highly complex, but relatively uncoordinated, scientific information system has existed in the U.S. for many years. It being neither desirable nor possible to wipe this system out and start completely anew, the plans and programs of the Office of Science Information Service necessarily involve simultaneously two basic efforts:

1. Promoting the study and development of new and better techniques and systems for controlling and disseminating scientific information.
2. Maintaining and improving existing services in this field.

## Highlights

Three areas of scientific information can serve to illustrate and highlight the increased emergence in 1962 of an integrated pattern of OSIS activity that points toward a coordinated national scientific information system.

### GRANTS AS "MEANS" AND "ENDS"

In Fiscal Year 1962, OSIS made 232 grants (including contracts and purchase orders) totaling $7,575,000. During this same period, 311 formal proposals were received requesting over $16,000,000. Grants can be used merely to insure the achievement of immediate, more or less unrelated ends. But they also can be important *means* in a planned, coordinated program looking toward the accomplishment of

*Title IX, National Defense Education Act of 1958 and March 1959 Amendment to the Executive Order 10521.

major, long-term objectives. In the OSIS grant program, NSF places heavy emphasis upon the latter aspect.

Those grants solely or predominantly in the "means" category naturally are concerned largely with promoting the development of new and improved ways of handling, controlling, and disseminating scientific information, the ultimate goal being the achievement of a coordinated, effective national system. Such grants mostly can be grouped in terms of the following steps:

1. Obtaining a comprehensive picture of the existing situation.
2. Determining the information practices and needs of users of scientific information.
3. Carrying on studies and research on improved methods.
4. Supporting programs to test and evaluate new procedures and systems.

Among means-type projects illustrative of Foundation support along these lines in fiscal year 1962 are the extensive communications studies that the American Institute of Biological Sciences, the American Institute of Physics, and the American Psychological Association are conducting in their respective fields. An important aspect of these investigations is the description and analysis of present information activities and services. The same is true of the large-scale study of the abstracting-indexing problem recently launched by the National Federation of Science Abstracting and Indexing Services.

In the past, work directed specifically toward determining the information practices of scientists has been supported at Columbia University and the Case Institute of Technology. Obtaining such knowledge, which is basic to the analysis of needs, is another of the goals of the broad disciplinary and abstracting-indexing projects mentioned above. A Syracuse University analysis of how and to what extent scientists are using the translated USSR journals impinges on this objective.

Studies and research on improved methods of information handling have emphasized fundamental investigations related to the mechanization both of the storage and retrieval of information and of translation. Representative of such work funded during 1962 are projects in linguistic research at the Universities of Pennsylvania and Texas and a study of new mathematical techniques of subject classification by the Cambridge (England) Language Research Unit. Other work looking toward improved procedures, but not directly linked to mechanization, includes a project at Georgia Institute of Technology on the training of information specialists; one by John I. Thompson Company on the distribution of Government reports; and work by Arthur D. Little, Inc. on centralization of various aspects of information handling.

Experimental programs to test and evaluate new procedures and techniques are a logical follow-up of the preceding study and research activities. Among efforts of this kind is a project completed during 1962 by the British Association of Special Libraries and Information Bureaux (ASLIB). By making a comparative study of the retrieval efficiency of four indexing and classification schemes, ASLIB developed a test method that has been applied to several operating systems, among them the American Society for Metals-Western Reserve University metallurgical searching service. Work is continuing under a new grant on both testing methods and evaluation of various indexing techniques.

Experimental development and test programs looking toward new procedures or systems for use in operating situations are the *Mathematical Reviews*' experiments and test runs with the Photon (a photocomposition device) for mathematical composition, and *Chemical Abstracts*' work in mechanizing certain aspects of its chemical information handling.

NSF has also supported conferences closely related to various phases of developing improved information procedures. Among such meetings in 1962 were a mechanical translation conference on syntactic analysis in Princeton, N.J., a workshop on information system design organized by the University of California (Los Angeles) and the American Documentation Institute, and a storage and retrieval workshop held by the U.S. Patent Office.

On the other hand, many grants necessarily are directed *primarily* toward meeting immediate needs and emergency situations. Examples include temporary and emergency funding of primary and abstracting-indexing journals, support of monographic publications, subsidy of translation journals, assistance to sceintific societies for special projects, and the like. Even these can and do have important implications as means toward an ultimate, overall objective. Abstracting-indexing support, for example, is granted along lines that will aid in coordinating all such efforts. In brief, a very large fraction of the total grant effort in 1962 was either predominantly "means" in nature or had significant implications beyond any immediate ends that were met.

## A FEDERAL SCIENTIFIC INFORMATION PROGRAM

The Government, being itself a major producer and user of scientific information, possesses a large and complex internal program in this field. For the total U.S. system to be fully effective, intra-Government scientific information activities must be coordinated both with each other and with the extra-Government pattern. Effecting coordination within

the Federal establishment is complicated by the varying basic missions of different scientific information groups. Any over-all coordinating effort must try to combine maximum value to the national scientific effort with minimum jeopardy to the various programs' individual responsibilities.

The Foundation's plan for discharging its Federal coordinating responsibility has involved, as a minimum, the cooperative development of a Government system that could provide any U.S. scientist or scientific organization promptly and reliably with: (1) information on the nature and status of Federally supported research in progress; (2) announcements, abstracts, and indexes of reports issued on such research; (3) access to copies of these reports; and (4) a single source of information on where answers can be obtained to substantive scientific questions.

During 1962, significant additional progress was made toward this composite goal, through the joint efforts of OSIS and the several other agencies involved. Organizational mechanics were completed on the expansion of the former Bio-Sciences Information Exchange into the Science Information Exchange (SIE), which will cover the physical, and eventually the social, as well as the life sciences. The SIE maintains and provides information on who is performing what research where. To begin with, only research supported by Federal grants and contracts is being covered. Planning calls for further extension of the scope beyond Government-sponsored R&D.

In the field of technical report literature, the Office of Technical Services (OTS) of the Department of Commerce has for some years published the abstracting journal *U.S. Government Research Reports* (USGRR). As a result of the Foundation's work with OTS and the report-originating agencies, USGRR's coverage has increased steadily for the past three years. During 1962, it became essentially complete for unrestricted Atomic Energy Commission (AEC) reports, National Aeronautics and Space Agency (NASA) reports, and Department of Defense reports held by the Armed Services Technical Information Agency (ASTIA). To provide rapid subject-oriented announcement of technical reports, NSF promoted the establishment of a *Keywords Index* of documents, that later will be abstracted in USGRR. The first issue of this semimonthly journal appeared just at the close of the fiscal year.

USGRR always has carried information on how to obtain copies of all documents it abstracted. Thus, expansion of USGRR's coverage automatically has made many more technical reports easily available to the scientific and technical community. Also, a reference collection of all reports covered by USGRR has been maintained for some years in

the Library of Congress. Eleven more such regional report centers were established during fiscal year 1962 in selected universities and libraries scattered across the nation, increasing many-fold the number of scientists and engineers with ready-reference access to these documents.

As noted above, the Science Information Exchange is designed to meet the need for a single source of information on the nature and status of Federally supported research. A somewhat analogous need has been for a center that could dispense knowledge regarding the multitude of information services available within and outside of Government—that is, for a single source to which a scientist or an organization might go to find out where answers can best be obtained to specific questions. Toward the end of fiscal year 1962, plans were completed for the establishment of such a referral center in the Library of Congress during fiscal year 1963.

Supplementing these actions, which are tied specifically to the four minimum objectives stated previously, have been studies and surveys pertinent to a coordinated Federal information program as a whole.

But the Federal Government also has a scientific information responsibility beyond its own immediate operations. For example, various journals published by scientific societies are essential research tools for Government programs and find their principal (sometimes almost their total) market in the Federal establishment. NSF has played, and continues to play, a major coordinating role in these situations by calling together representatives of all parties concerned, private and Government, to work out fair and mutually beneficial patterns of support. A major 1962 advance in this problem area was the adoption by the Federal Council on Science and Technology, at NSF's recommendation, of a standardized Government policy favoring the honoring of journal page charges that increasingly are being levied by nonprofit scientific publishers. Enunciation of this policy was particularly significant in that it marked the recognition by the Council that dissemination of research results is an integral element in the R&D sequence and, therefore, properly should be supported from research funds.

## MECHANICAL TRANSLATION (MT) AND COORDINATION

One 1962 development in MT deserves special mention as a particularly significant coordinating advance. Encouraged by NSF's promotion of increased coordination in all Federal information programs, NSF, the Department of Defense, and the Central Intelligence Agency, developed, during 1962, plans for a joint research and development program for automatic language processing, with particular attention to MT.

## Documentation Research

The Documentation Research program concerns almost entirely the first of the two fundamental objectives of OSIS. It is directed principally toward stimulating and supporting studies, research, and experimentation along three general lines: (1) Identifying and assessing the information needs of scientists, (2) developing new and more effective systems—mechanized where advantageous—for handling and controlling scientific information, and (3) achieving mechanized translation of foreign language material into English.

### COMMUNICATION PROBLEMS AND INFORMATION NEEDS OF SCIENTISTS

Several major communications studies were mentioned previously. The one being conducted by the American Psychological Association includes the following topics: Communication and information practices of a sample of productive research psychologists; tools and techniques employed by psychologists who have prepared review papers; comparative coverage of *Psychological Abstracts* and the *Annual Review of Psychology;* the readership of psychological journals and the use of *Psychological Abstracts;* cross-citations among psychological journals and images of journals held by psychologists; the information exchange that takes place at meetings; the characteristics and patterns of communication within specialized societies or groupings in the field of psychology; and comparison of concepts expressed in titles of papers with those employed in indexing the papers. Another new study undertaken by the Advance Information Systems, Inc., is concerned with behavioral factors in information systems.

### INFORMATION ORGANIZATION AND SEARCHING

In the important University of Pennsylvania project on linguistic research, an exact, mechanizable procedure is being devised for converting a complex sentence into a much simpler form that will maintain the original meaning but be more amenable to machine processing for information retrieval. Much new knowledge about the English language is resulting from this work, and the development of computer programs to accomplish automatically the grammatical and transformational decomposition of English sentences is well along.

Other continuing projects showing significant progress this year include research by the National Bureau of Standards on the mechanical

processing of both pictorial and linguistic information*, development by the National Biomedical Research Foundation of a computer program for automatically producing a tabular form of coordinate index, and an Advanced Information Systems, Inc. study of large file organization with emphasis on self-organizing capabilities.

Among the new projects are a Lehigh University study of models of information retrieval systems, Western Reserve University research on automatic processing of abstracts for storage and retrieval, and an engineering terminology study by the Engineers Joint Council.

## MECHANICAL TRANSLATION (MT)

Probably the most significant 1962 development in MT was the three-agency agreement previously mentioned regarding future research and development. In U.S. basic research in this field, a major portion of which NSF supports, considerable progress was made in fundamental studies of language structure including the design of computer programs to aid in language analysis, the compilation of bilingual computer dictionary programs, and the development of computer programs for steps in the translation process. Also of considerable importance this year was the third in a series of working conferences of MT investigators. This one was devoted to certain phases of the syntactic analysis of languages.

## EVALUATION OF INFORMATION SYSTEMS AND PROCEDURES

The Association of Specialized Libraries and Information Bureaus project, already mentioned, is an example of significant NSF-supported work in this area, one which is increasingly being emphasized in the OSIS program. Because of a lack of rigorous standards on which to base quality judgments, two exploratory studies were launched to develop criteria for evaluating information systems and procedures. They were recommended by a National Academy of Sciences-National Research Council (NAS–NRC) committee set up to study this question and were conducted by Stanford Research Institute and Arthur Anderson and Company.

Other NSF-funded 1962 projects with significant evaluative aspects included: A test program of the ASM–WRU metallurgical searching service, the results of which are being evaluated by NAS–NRC; a survey by users of this service by the Bureau of Social Science Research; and an NAS–NRC study of chemical notation systems to determine the

*Jointly supported by NSF and the Patent Office.

uses currently being made of them and their strengths and weaknesses for organizing and searching information on chemical structures. Late in the year a grant was made to the Massachusetts Institute of Technology to design and establish in the Boston area, a test environment in which controlled tests can be made of information system components and new types of service.

### SURVEYS AND REPORTS

Two extensive state-of-the-art reports were issued with NSF support—on character recognition, by the National Bureau of Standards, and on coordinate indexing, by Documentation Incorporated. The Documentation Research program continued to compile and publish its semiannual report on *Current Research and Development in Scientific Documentation,* the May 1962 issue containing some 450 descriptions of R&D projects and studies in the U.S. and 20 other countries. During the year the program also surveyed operating systems that employ new techniques or devices and prepared for publication the third edition of its series *Nonconventional Technical Information Systems in Current Use.*

## Support of Scientific Publications

The activities of this program (SSP) are directed toward the goal of an optimum publication system for dissemination of research results. The program considers such a system to consist of two basic, related parts: primary publications for first reports of the results of research and secondary publications or services for reference purposes.

NSF concern with primary publication is largely a national problem, but the growth of world publication of scientific research results has broadened consideration of secondary reference services to the international level, especially in abstracting-indexing which is the keystone of scientific reference service. Projects supported are of two types, those that aid existing publications and services, and others that experiment with new techniques. Although the proposals received by SSP are many and varied, a major factor in their screening is their contribution toward providing prompt publication of the results of scientific research in a usable quantity and form.

Kinds of projects supported during 1962 included: modernizing and expanding coverage of abstracting-indexing services; publishing significant single items, including monographs, symposium proceedings, reviews, data compilations, and bibliographies; launching new primary

journals; eliminating manuscript backlogs of existing journals; and experimenting with new publication-oriented information techniques. Representative projects of particular significance follow.

## SUPPORT OF PRIMARY PUBLICATIONS

During 1962 this program supported the launching of three new journals: *Applied Optics, Applied Physics Letters,* and *Malacologia.* The first of these, which began publication in January 1962, is directed toward physical, electron, and space optics; lens design; optical engineering; and plasma and solid state physics. Although jointly sponsored by the American Institute of Physics and the Optical Society of America, *Applied Optics* is published independently by the latter. The new journal is devoted largely to original research and to reviews of major research topics; articles may be published in English, French, German, and Russian. *Applied Physics Letters,* a second rapid publication medium in physics, is aimed at providing a quick announcement service for short papers in a number of fields not covered by *Physical Review Letters,* the first such journal initiated with NSF support. *Malacologia* provides a medium for literature in the field of mollusks; at present such literature is scattered through many journals. Research in this field is moving at a rapid rate in many countries, and this new outlet will allow more prompt publication of good papers in systematic and experimental areas of malacology. All NSF funding of primary journals is done on a temporary basis.

More than half of the grants made for the support of publication of 31 monographs during 1962 were in biology, where outlets, particularly for taxonomic volumes, appear limited.

The Pacific Science Congress and the International Physiological Congress were two international meetings receiving publication support.

## STUDIES AND EXPERIMENTS IN SCIENTIFIC COMMUNICATION

The New York Botanical Garden pilot project on a machine coding system for plant taxonomy produced the first volume of the planned *International Index.* This volume contains all the plant families. Orders, genera, and species have also been coded. Subsequent volumes will contain this information.

Representative of the five catalogs and handbooks supported during 1962 is the "Checklist of Amphibians and Reptiles", an ambitious experimental project undertaken by the American Society of Ichthyol-

ogists and Herpetologists that will offer complete summaries of all North and South American species.

The American Institute of Physics Documentation Study mailed a questionnaire during 1962 to some 1500 physicists to determine how physicists describe their own fields of activity. Analysis of these descriptions will form a basis for compiling improved subject indexes, and designing a more adequate reference retrieval system for physics literature.

With NSF support, a group of Latin American editors attended the February 1962 meeting of the U.S. Conference of Biological Editors (CBE). At this meeting they organized a Latin American CBE to provide a forum to promote improved biological journal publication in their countries. As an initial project they are working on a Spanish style manual similar to CBE's "Style Manual for Biological Journals."

## SUPPORT OF SECONDARY SERVICES

Support was continued for improved operation and expansion of several major abstracting-indexing services including *Mathematical Reviews, International AeroSpace Abstracts, GeoScience Abstracts, Biological Abstracts,* and *Chemical Abstracts.*

The Operations Research Society of America (ORSA) initiated publication of the *International Abstracts in Operations Research* with NSF grant funds. In addition to the conventional author and subject indexes, each issue of IAOR contains a "Digest" that lists abstracts serially and describes the referenced publication by key words indicating principal topics and methodology and by letter codes representing bibliographic, computational, experimental, and other aspects of the contents.

Support of specialized bibliographies was limited, and only experimental indexing projects were considered. Six grants were made during 1962 for the publication of compilations in such diverse subjects as ethnography of South America, radio astronomy, and palynology.

NSF support during 1962 played a significant role in a number of activities relative to mechanization of abstracting-indexing procedures. For example, grant funds provided for the purchase of a Photon by the American Mathematical Society for use in developing complex mathematical photocomposition. Conversion to tape typewriters by *Engineering Index* will enable them to initiate monthly issues and to prepare these, as well as the annual issue, from a single typing. Permuted indexes were published by both *Chemical Abstracts* and *Biological Abstracts.* Large scale application of this indexing technique is relatively

recent, however, and funds were provided for further experiments. A grant was made for an experimental citation index in the field of statistical methodolgy. *Chemical Abstract's* mechanized file of chemical compounds, permitting computer searches for both molecular and structural correlations, approached productive level of coverage, and codes were developed to relate biological, physical, and physiological properties to the appropriate chemical entity.

## Foreign Science Information

The basic mission of the Foreign Science Information program is to promote the effective availability in the United States of scientific research results published in foreign countries and to foster interchange of scientific information between these countries and the United States. This mission is implemented by encouraging the broadest possible communication between U.S. scientists and their counterparts throughout the world. Program activities are designed:

1. To promote effective acquisition of foreign scientific publications through purchase and by exchange between U.S. and foreign organizations.
2. To provide data to the U.S. scientific community on sources and availability of foreign scientific information, which includes support for scientific and technical reference aids.
3. To increase the scope and quantity of translations of the most important foreign scientific publications.
4. To stimulate cooperation with international organizations in support of projects which will add to the U.S. store of information and materially improve scientific communication on an international scale.

### TRANSLATIONS

Emphasis was placed upon encouraging professional groups to obtain access to foreign scientific literature through programs of selective translation, principally from the Russian, and to inaugurate new programs for the translation of Japanese scientific journals in physics, chemistry, biology, and selected areas of engineering. By the end of the fiscal year, NSF was supporting, through grants to scientific societies and universities, the cover-to-cover translation of 42 Soviet scientific and technical journals and selected translations from 13 others.

An example of a highly selective translation journal is *International Chemical Engineering,* inaugurated by the American Institute of Chem-

ical Engineers, which concentrates on the literature of the Sino-Soviet bloc. Funds were granted to the American Mathematical Society for translation of the Communist Chinese journal, *Acta Mathematica Sinica.* Also, the American Institute of Physics was supported in a cooperative arrangement with the Japan Physical Society to encourage the dissemination in the U.S. of the English-language journal, *Japanese Bulletin of Applied Physics.*

Overseas translation activities carried out during fiscal year 1962 under Public Law 480 (Agricultural Trade Development and Assistance Act of 1954) constitute another important effort to utilize the results of foreign research and to stimulate international scientific cooperation. This program is being carried on in Israel, Poland, and Yugoslavia by Federal agencies using foreign currencies accruing through the sale of U.S. agricultural commodities overseas. A total of 25,800 pages of Russian, 13,000 pages of Polish, and 4,300 pages of Serbo-Croatian material was translated and disseminated in the U.S. in fiscal year 1962, under Foundation leadership. In addition, simultaneous English language editions of the leading Polish and Yugoslav primary journals are now under way.

## STUDIES AND REFERENCE AIDS

Considerable emphasis was placed on studies of scientific research and information activities in foreign countries. These included compilation of directories of foreign scientific research institutions and scientists, reviews of the state-of-the-art of sciences in foreign countries, science information activities in foreign countries and international organizations, and preparation of bibliographic guides to foreign scientific publications.

There was a similar concentrated effort to produce guides for the scientific community relating to foreign scientific literature available in the United States, both in the original languages and in translation.

## INTERNATIONAL ACTIVITIES

The FSI program has been instrumental in developing measures for closer coordination of science information activities among international scientific and information organizations, such as United Nations Educational, Scientific, and Cultural Organization, International Council of Scientific Unions, Federation of International Documentation, International Federation of Library Associations, International Organization for Standardization, and others. Assistance has also been rendered to

appropriate U.S. agencies and organizations in the development and strengthening of information activities within, or supported by, these and similar international organizations.

### RESOURCES AND EXCHANGES OF INFORMATION

Finally, emphasis was placed during the past year on fostering programs for the acquisition and exchange of foreign scientific publications. With NSF support, a large-scale exchange has been worked out by the American Mathematical Society and the Lenin State Library whereby multiple copies of some 700 Soviet scientific periodicals come directly to approximately 75 U.S. research libraries. The American Mathematical Society provides U.S. publications in return.

## Research Data and Information Services

The two general problem areas of primary concern to this program are: (1) the Government system for the control and dissemination of scientific information stemming from Federally supported research and development, and (2) specialized data and information centers. These categories obviously are not mutually exclusive since the Federal information complex includes a number of specialized services, and many privately sponsored centers handle certain Government-originated materials and include Federal agencies among their users.

Major 1962 emphasis continued to be on stimulating and, where appropriate, supporting the coordination of various Federal information activities, looking toward the development of a balanced, effective overall Government system.

### THE FEDERAL SCIENTIFIC INFORMATION SYSTEM

NSF's major role in these activities has been to encourage and work with the Federal agencies that are operationally involved. In some cases financial support also has been provided, usually for necessary experimentation or to speed up initiation of specific projects.

The Science Information Exchange, an expansion of a similar project of some years' standing in the life sciences, increasingly is providing information on Federally supported research in progress in the physical and biological sciences. Plans call for later extension to include the social sciences and to cover privately sponsored research. Abstracting coverage by *U.S. Government Research Reports* has become essentially complete for unrestricted AEC, NASA, and ASTIA-held Department of

Defense reports. OTS' new *Keywords Index* now can provide prompt, subject-oriented announcement of reports subsequently abstracted in U.S. Government Research Reports. Twelve regional report centers give scientists and engineers in major U.S. research and development centers ready reference access to the technical reports covered by USGRR. At the end of the fiscal year, the Library of Congress had just begun to establish a referral center that will provide a single source to which a scientist or engineer can go for information on where answers to substantive scientific questions can best be obtained.

Supplementary to these specific steps in the direction of a well-coordinated Federal information system have been studies on the initial distribution of technical reports, on the practicability and implications of various degrees of centralization of Federal information activities, and on problems of compatibility between existing information systems.

## DATA AND INFORMATION CENTERS

The continued growth in the number and use of scientific data, reference, and information centers has resulted in numerous requests to the Foundation for funds to establish and support such operations. NSF activities in this area are designed to develop basic information on the use and value of data centers and the services they perform.

Late in the year the Foundation initiated, as a part of a general continuing study, a comparative economic analysis of two different hypothetical information systems—one, a subject-oriented information service network and the other, a geographically-oriented network. The study, being carried out by a private firm, involves the construction of models characteristic of the two systems and the formulation of various mathematical expressions of the systems, through the use of which a comparative economic analysis is being made.

Under contract to the Foundation, the Battelle Memorial Institute carried out an extensive survey of specialized science information services in the physical and biological sciences. A directory based on the survey and listing more than 400 such groups was published during 1962. Entitled "Specialized Science Information Services in the United States," the directory is designed for use as a reference aid for working scientists and engineers.

A grant was made to the American Society of Mechanical Engineers for the establishment of a scientific film library service on flow visualization research data in fluid mechanics. Purpose of the project is to improve the dissemination of such data available on motion picture film

and, at the same time, to serve as an experiment in the use of scientific film as a medium for exchange of information among scientists.

## Education and Training

Although not established as a formal program, the OSIS education and training activity functioned during 1962 in much the same manner as the programs described above. The fundamental overall mission of this effort continues to be the improvement of the competence of: (1) science librarians and information specialists in organizing, controlling, and disseminating scientific information, and (2) scientists and engineers in the use and presentation of the results of scientific research. The Foundation's long-range objective is to encourage the development in U.S. colleges and universities of curricula, of various kinds and at a variety of levels, that will accomplish this two-phase mission. NSF's own role in stimulating and promoting such curriculum development requires it to study, on a continuing basis, the needs for trained manpower in these areas; to work with the universities and scientific groups in establishing program requirements for training the needed manpower; and to develop within the Foundation an effective, realistic plan of encouragement and support.

During the past year, activity in this program has concentrated on the initial aspects of the first of the mission areas. Studies were conducted in-house to obtain current information on educational programs, both academic and non-academic, for training information personnel. Library school curricula were surveyed to determine the extent to which course offerings prepare librarians for work with science collections or science information centers. Also, a survey was conducted of curricula in other departments of universities to determine the extent to which they are applicable to training students for work with science information. Finally, the content of various conferences, institutes, and short courses on science information activities was examined to determine its relevancy to training programs for librarians and information specialists.

In addition to the in-house activity, a grant was made to the Georgia Institute of Technology for a study of various factors that affect development of educational programs for information specialists. These include development of curricula, recruiting students, faculty requirements, and the relative values of short courses and degree programs. Preliminary conclusions developed from the study indicate that university programs for training specialized personnel for work in various aspects of science information can and should be developed.

Studies for support and encouragement of educational programs was also a major project in the 1962 education and training activity. The planning and development was coordinated with the NSF Division of Scientific Personnel and Education (SPE). Implementation by this division is expected to begin during the next fiscal year.

## SCIENCE RESOURCES PLANNING

Science today is a foremost national resource, a potent economic stimulus, and a key to national development and relations among nations. Because of his increasing reliance on scientific output, man must ensure that science will have the resources to meet present and future needs.

The primary resources of science are people—the scientists and engineers who teach, do research and development, and manage production; and the technicians and other specialists who assist them. Other resources of science are the equipment and facilities they use, and the institutions in which they work. Equally important are the funds that support science activities.

The increasingly rapid development of science and technology makes it necessary to be able to analyze trends, to study effects of Federal programs on the conduct of research and teaching in science, and to anticipate future demands on the Nation's science resources. To meet these needs, the Foundation established, in October 1961, the Science Resources Planning Office to serve as a focal point for studies relevant to the formulation of national policy for research and education in science and engineering.

SRPO responds to the needs of the Office of Science and Technology, the Federal Council for Science and Technology, the President's Science Advisory Committee, as well as other organizations concerned with policy for science and technology. The Science Resources Planning Office coordinates long-range planning within the Foundation. It is assisted in its activities by the Office of Economic and Statistical Studies and by the Manpower Studies Section of the Division of Scientific Personnel and Education Studies Section.

As a basis for science resources planning relevant to the formulation of national policy for research and education in science and engineering, the Foundation has conducted or participated in two general kinds of projects: (1) determination of present national resources, capabilities, and probable growth in scientific potential; and (2) exploration of scientific relations of colleges and universities with the Federal Government.

On such project is the Federal Agency Survey of Research and Development Levels Projected to 1970. The survey is being conducted for the Federal Council for Science and Technology and includes the eight agencies represented on the Council plus Agency for International Development (AID) and Federal Aviation Agency.

A second survey concerns the adequacy of physical facilities, including apparatus and equipment, used for teaching and for research, in all fields of science and engineering in educational institutions. In the past several years, requirements for such facilities have increased faster than their acquisition. Needs have arisen both from greater numbers of faculty and students and from unprecedented expansion of research activity under Federal support. Quantitative sampling of educational institutions should show anticipated facility requirements for the next ten years, as well as capabilities of institutions to meet the costs of expansion of facilities.

Another study considers instrumentation and its effects on research. Instrumentation often has an appreciable effect on both manpower and budgets. Manpower demands may, for example, be diminished by new instruments which reduce the number of assistants needed to record or analyze data. Other advances may open up new scientific opportunities and thus draw additional personnel into instrumented research efforts. The study is also aimed to yield quantitative data on the "inflation" of research costs owing to instrumentation, and on ratios of cost-per-person in highly instrumented fields of research. Such data constitute important inputs for long-range planning.

New dimensions in the involvement of colleges and universities with research and development have posed new problems in the organization and administration of colleges and universities. To investigate these problems, preliminary steps have been taken to initiate a survey of influences of R&D on such factors as academic organization, participation of faculty and graduate students in R&D, extramural consultant services, patent policy, and specially-financed research laboratories and institutes.

To stimulate and improve the practice of long-range planning in science, the Foundation has undertaken a series of basic analytical studies to provide better understanding of planning and policy-making. Typical is one concerned with the interdependence of scientific progress and the competition for scientists and engineers at the doctoral level. The study is analyzing the long-range effects of varying degrees of "feedback" of new doctoral scientists and engineers into educational institutions.

To provide general guidance for planning, conceptual frameworks are being developed for relating activities of the Foundation to the scien-

tific endeavor of the Federal Government and of the nation as a whole. In this connection the general philosophy and goals of the Foundation are being evaluated in relation to the fulfillment of its mission in the future. Questions include the support of critical areas of science; educational needs to meet expected growth in scientific manpower; and expansion of facilities for research and for education in science, at all academic levels. A parallel study bears on the future levels of NSF support programs such as those in research grants and in fellowships.

# ASSESSING THE NATIONAL RESEARCH AND DEVELOPMENT EFFORT

The Foundation conducts or sponsors detailed economic analyses and statistical surveys of the national research and development effort, measured by both funds and manpower. The studies, directed or conducted by the Foundation's Office of Economic and Statistical Studies, provide trend data for the past eight years. (See appendix H for a list of publications reporting the results of these activities.)

Comprehensive annual surveys are conducted of expenditures for research and development by both industry and the Federal Government, which comprise the two largest of the four survey sectors. Surveys of colleges and universities involve operating and capital expenditures for research and development, scientific manpower, and scientific equipment and facilities, the latter including projections as well as current data. In the fourth sector are the nonprofit research institutes and private foundations. (A study of scientific research supported by the private foundations in 1960 was reported in the Foundation's bulletin, *Reviews of Data on Research & Development,* Number 35.)

Related components of science and technology are also being measured. Projects are underway to survey scientific information activities of both industry and the Federal Government. During the past year data on these activities in the Federal sector were published.

## TREND IN R&D FUNDS, 1953–54—1960–61

During the fiscal year, the Foundation published a time series on the intersectoral transfer of funds for research and development as well as for basic research for 1953–54 through 1960–61.

Expenditures for the performance of research and development in the natural sciences in the United States were estimated at about $15 billion in 1961–62. This amount is nearly triple the $5.2 billion for 1953–54 reported in the first NSF survey. (See tables 6a, 6b, 7a, 7b.)

Most of the data in these tables are obtained from the Foundation's statistical surveys in which more than 90 percent of organizations queried have provided responses. Time series on R&D expenditures for years prior to those covered by the Foundation contain only fragmentary data and are based on limited studies.

The transfer tables provide a basis for further study and analysis. From them may be obtained a statistical framework of sixteen possible

## Table 6a. *Time Series on Transfers of Funds Used for Performance of Research and Development, by Sector, Distributed by Source, 1953–54—1960–61* [a]

[millions of dollars]

| Year | Total R&D | Federal Government | | Industry | | | Colleges and universities | | | | | Other nonprofit institutions | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | Total funds used | Source: Federal Government | Total funds used | Sources: Federal Government | Sources: Industry | Total funds used | Sources: Federal Government | Sources: Industry | Sources: Colleges and universities [b] | Sources: Other nonprofit institutions | Total funds used | Sources: Federal Government | Sources: Industry | Sources: Other nonprofit institutions [b] |
| | (1) | (2) | (3) | (4) | (5) | (6) | (7) | (8) | (9) | (10) | (11) | (12) | (13) | (14) | (15) |
| **Performance** | | 970 | | 3,630 | | | 450 | | | | | 100 | | | |
| **1953–54** | 5,150 | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
| *Source* | | | 970 | | 1,430 | 2,200 | | 280 | 20 | 130 | 20 | | 60 | 20 | 20 |
| **Performance** | | 950 | | • 4,070 | | | • 480 | | | | | • 120 | | | |
| **1954–55** | 5,620 | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
| *Source* | | | 950 | | 1,750 | 2,320 | | 300 | 20 | 140 | 20 | | 70 | 25 | 25 |
| **Performance** | | 1,090 | | • 4,640 | | | • 530 | | | | | • 130 | | | |
| **1955–56** | 6,390 | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
| *Source* | | | 1,090 | | 2,180 | 2,460 | | 330 | 20 | 155 | 25 | | 70 | 30 | 30 |
| **Performance** | | 1,280 | | 6,540 | | | • 650 | | | | | • 140 | | | |
| **1956–57** | 8,610 | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
| *Source* | | | 1,280 | | 3,330 | 3,210 | | 415 | 25 | 180 | 30 | | 70 | 30 | 40 |
| **Performance** | | 1,440 | | 7,660 | | | 780 | | | | | 150 | | | |
| **1957–58** | 10,030 | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
| *Source* | | | 1,440 | | 4,330 | 3,330 | | 530 | 30 | 190 | 30 | | 80 | 30 | 40 |
| **Performance** | | 1,730 | | 8,300 | | | • 840 | | | | | • 200 | | | |
| **1958–59** | 11,070 | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
| *Source* | | | 1,730 | | 4,760 | 3,540 | | 570 | 40 | 190 | 40 | | 110 | 40 | 50 |
| **Performance** | | 1,830 | | 9,550 | | | • 1,000 | | | | | • 240 | | | |
| **1959–60 (prelim.)** | 12,620 | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
| *Source* | | | 1,830 | | 5,610 | 3,940 | | 720 | 40 | 200 | 40 | | 130 | 50 | 60 |
| **Performance** | | 2,060 | | 10,500 | | | • 1,200 | | | | | • 280 | | | |
| **1960–61 (prelim.)** | 14,040 | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
| *Source* | | | 2,060 | | 6,130 | 4,370 | | 890 | 50 | 210 | 50 | | 140 | 70 | 70 |

[a] Data on sources of funds are based on reports by the *performers*.

[b] State and local government funds spent for research and development by the colleges and universities and other nonprofit institutions are included with the respective sector's own funds.

[c] Estimates derived from related available information. No sector survey took place in this year.

Note: Expenditures of Federal contract research centers administered by industry, colleges and universities, and other nonprofit institutions are included in the totals of the respective sectors.

Source: National Science Foundation, March 1962.

**Table 6b. *Sources of Funds Used for Research and Development, by Sector, 1953–54—1960–61*** [a]

[millions of dollars]

| Year | Total | Federal Government | Industry | Colleges and universities [b] | Other nonprofit institutions [b] |
|---|---|---|---|---|---|
| 1953–54 | $5,150 | $2,740 | $2,240 | $130 | $40 |
| 1954–55 | 5,620 | 3,070 | 2,365 | 140 | 45 |
| 1955–56 | 6,390 | 3,670 | 2,510 | 155 | 55 |
| 1956–57 | 8,610 | 5,095 | 3,265 | 180 | 70 |
| 1957–58 | 10,030 | 6,380 | 3,390 | 190 | 70 |
| 1958–59 | 11,070 | 7,170 | 3,620 | 190 | 90 |
| 1959–60 (prelim.) | 12,620 | 8,290 | 4,030 | 200 | 100 |
| 1960–61 (prelim.) | 14,040 | 9,220 | 4,490 | 210 | 120 |

[a] Data are based on reports by the performers.

[b] State and local government funds spent for research and development by the colleges and universities and other nonprofit institutions are included with the respective sector's own funds.

Note: With the exception of data for 1953–54 and 1957–58, the years in which surveys covered all sectors, data on sectors as sources of funds are estimates.

Source: National Science Foundation, March 1962.

source-performer relationships for the year covered. The presentation facilitates comparison of the R&D financing role of each of the sectors with respect to the others. The data for 1960–61 repeat the pattern shown for previous years. In 1960–61, the Federal Government was the primary source of R&D funds, with respondents reporting receipts from this sector of more than $9 billion, or 65 percent of the total outlay of $14 billion. Industry was again the largest performer, spending $10.5 billion in current operating costs of research and development.

In 1960–61 funds used in the performance of basic research in the natural sciences rose to an estimated $1.3 billion, nearly three times the $430 million spent for basic research in 1953–54.

Over the eight-year period, an increase occurred of more than 400 percent in the dollar volume of federally-performed basic research, largely owing to accelerated space research programs. During the same period, funds used by colleges and universities, traditionally the home of basic research, increased 175 percent. The average increase for all sectors was 200 percent.

As in previous years, in 1960–61 the colleges and universities expended more than other sectors in the performance of basic research—$575 million, or 44 percent of the total. The Federal Government provided the largest portion of total funds for basic research, more than one-half, or about $745 million. Of this amount $350 million went to colleges and universities.

## Table 7a. *Time Series on Transfers of Funds Used for Performance of Basic Research, by Sector, Distributed by Source, 1953–54—1960–61* [a]

[millions of dollars]

| Year | Total basic research | Federal Government | | Industry | | | Colleges and universities | | | | | Other nonprofit institutions | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | Total funds used | Source: Federal Government | Total funds used | Sources: Federal Government | Sources: Industry | Total funds used | Sources: Federal Government | Sources: Industry | Sources: Colleges and universities [b] | Sources: Other nonprofit institutions | Total funds used | Sources: Federal Government | Sources: Industry | Sources: Other nonprofit institutions [b] |
| | (1) | (2) | (3) | (4) | (5) | (6) | (7) | (8) | (9) | (10) | (11) | (12) | (13) | (14) | (15) |
| PERFORMANCE | | 47 | | 151 | | | 208 | | | | | 26 | | | |
| 1953–54 | 432 - | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
| *Source* | | | 47 | | 19 | 132 | | 119 | 11 | 62 | 16 | | 10 | 4 | 12 |
| PERFORMANCE | | 55 | | • 166 | | | • 230 | | | | | • 34 | | | |
| 1954–55 | 485 - | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
| *Source* | | | 55 | | n.a. | n.a. | | 129 | 11 | 70 | 20 | | 15 | 4 | 15 |
| PERFORMANCE | | 65 | | • 189 | | | • 250 | | | | | • 43 | | | |
| 1955–56 | 547 - | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
| *Source* | | | 65 | | n.a. | n.a. | | 144 | 11 | 75 | 20 | | 20 | 5 | 18 |
| PERFORMANCE | | 90 | | 253 | | | • 300 | | | | | • 51 | | | |
| 1956–57 | 694 - | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
| *Source* | | | 90 | | n.a. | n.a. | | 173 | 12 | 90 | 25 | | 25 | 5 | 21 |
| PERFORMANCE | | 111 | | 271 | | | 392 | | | | | 60 | | | |
| 1957–58 | 836 - | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
| *Source* | | | 111 | | 41 | 230 | | 240 | 14 | 111 | 27 | | 30 | 5 | 25 |
| PERFORMANCE | | 221 | | 305 | | | • 420 | | | | | • 70 | | | |
| 1958–59 | 1,016 - | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
| *Source* | | | 221 | | 55 | 250 | | 256 | 17 | 118 | 29 | | 35 | 6 | 29 |
| PERFORMANCE | | 220 | | 345 | | | • 500 | | | | | • 85 | | | |
| 1959–60 (prelim.) | 1,150 - | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
| *Source* | | | 220 | | 79 | 266 | | 305 | 20 | 140 | 35 | | 42 | 7 | 36 |
| PERFORMANCE | | 245 | | 382 | | | • 575 | | | | | • 100 | | | |
| 1960–61 (prelim.) | 1,382 - | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
| *Source* | | | 245 | | 100 | 282 | | 350 | 23 | 161 | 41 | | 50 | 8 | 42 |

[a] Data on sources of funds are based on reports by the performers.

[b] *State and local government funds spent for basic research by the colleges and universities and other nonprofit institutions are included with the respective sector's own funds.*

[c] *Estimates derived from related available information. No sector survey took place in this year.*

n.a.—*Not available.*

*Note:* Expenditures of Federal contract research centers administered by industry, colleges and universities, and other nonprofit institutions are included in the totals of the respective sectors.

Source: National Science Foundation, March 1962.

**Table 7b. *Sources of Funds Used for Basic Research, by Sector, 1953–54—1960–61*** [a]

[millions of dollars]

| Year | Total | Federal Government | Industry | Colleges and universities [b] | Other nonprofit institutions [b] |
|---|---|---|---|---|---|
| 1953–54 | $432 | $195 | $147 | $62 | $28 |
| 1954–55 | 485 | n.a. | n.a. | n.a. | n.a. |
| 1955–56 | 547 | n.a. | n.a. | n.a. | n.a. |
| 1956–57 | 694 | n.a. | n.a. | n.a. | n.a. |
| 1957–58 | 834 | 422 | 249 | 111 | 52 |
| 1958–59 | 1,016 | 565 | 275 | 118 | 58 |
| 1959–60 (prelim.) | 1,150 | 646 | 293 | 140 | 71 |
| 1960–61 (prelim.) | 1,302 | 745 | 313 | 161 | 83 |

[a] Data are based on reports by the performers.

[b] State and local government funds spent for basic research by the colleges and universities and other nonprofit institutions are included with the respective sector's own funds.

n.a.—Not available.

Note: With the exception of data for 1953–54 and 1957–58, the years in which surveys covered all sectors, data on sectors as sources of funds are estimates.

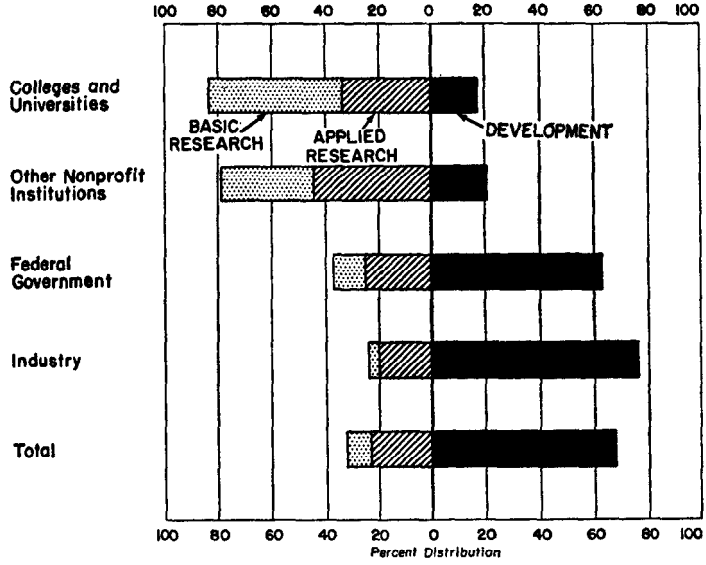
Source: National Science Foundation, March 1962.

## R&D FUNDS BY CHARACTER OF WORK

During the past year, for the first time national totals of R&D expenditures were separately classified by basic research, applied research, and development for each sector. Earlier estimates by the National Science Foundation of national totals have been limited to research and development and its basic research component, owing to the difficulty of separately identifying data on applied research and on development.

Available data for years preceding 1959–60 indicate the relatively constant distribution of funds among the three components of research and development. Basic research outlays have amounted to 8–9 percent of total R&D funds. Somewhat less than 75 percent of total R&D funds have been concentrated in the category of development. Applied research expenditures have accounted for the remainder. (See figure 4.)

At the sector level, industry and the Federal Government expended the greatest proportion of their R&D funds in the performance of development. This is consistent with the emphasis on development in defense and space projects conducted in these sectors. While basic research accounts for the largest proportion of R&D expenditures in colleges and universities, applied research receives more funds than either of the other two components of research and development in other nonprofit institutions.




**Note: Data on Federal estimates of applied research and development were not obtained directly by survey but were derived from available related information.**

***Figure 4. Basic Research, Applied Research, and Development—Percent Distribution of Funds Used in Performance, by Sector, 1959–60***

## SCIENTISTS AND ENGINEERS IN RESEARCH AND DEVELOPMENT

About 387,000 scientists and engineers were employed in research and development in the natural sciences in 1960 (including engineering) in all sectors of the economy (measured in terms of full-time equivalents, F.T.E.), compared with 327,000 in 1958, and 223,000 in 1954. (See table 8.)

The rate of growth in the number of R&D scientists and engineers appears to have declined from 1958 to 1960 as compared with growth from 1954 to 1958. In the later period, the number of scientists and engineers employed in research and development increased about nine percent per year. Between 1954 and 1958, the increase was about 12 percent per year.

## COMPARISON OF FUNDS AND PERSONNEL FOR RESEARCH AND DEVELOPMENT

Over the entire period for which data are available, 1954 through 1960, the increase in professional scientific personnel was almost 75 percent. During the same period, R&D funds increased more than 140 percent. Because total funds have risen more rapidly than total employment for research and development, the overall cost per R&D scientist or engineer (F.T.E.) increased. From about $23,000 in 1954, it rose to $31,000 in 1958, and $33,000 in 1960.

**Table 8. *Scientists and Engineers in Research and Development, by Sector, 1954, 1958, and 1960*** [a]

| Sector | 1954 | 1958 | 1960 (Prelim.) |
|---|---|---|---|
| | Full-time equivalents | | |
| Total | 223,200 | 327,100 | 387,000 |
| Federal Government [b] | 29,500 | 40,200 | 41,800 |
| Industry [c] | 164,100 | 239,500 | 286,200 |
| Colleges and universities [c] | 25,200 | 42,000 | 52,000 |
| Other nonprofit institutions [c] | 4,400 | 5,400 | 7,000 |

[a] Data consist of number of full-time employees plus the full-time equivalent of part-time employees.
[b] Limited to civilian personnel.
[c] Include professional research personnel employed at research centers administered by organizations under contract with Federal agencies.

Source: National Science Foundation, March 1962.

## RESEARCH AND DEVELOPMENT AND THE GROSS NATIONAL PRODUCT

R&D expenditures have grown considerably faster than total national expenditures for goods and services as measured by the gross national product. (See figure 5.)

In 1953–54, when the current dollar value of the gross national product was $365.4 billion, funds expended for research and development, also in current dollars, amounted to $5.2 billion, or 1.4 percent of the GNP. By 1960–61, the gross national product was $504.4 billion and R&D expenditures were $14.0 billion, or about 2.8 percent of the gross national product.

## R&D DATA ON FOREIGN COUNTRIES

The Foundation is expanding data collection activities on research and development to include information from other countries. A report on funds for science and technology in the Soviet Union is in preparation. Similar studies are planned of the Eastern European countries and Communist China. Totals are to be developed comparable with U.S. data.

Representatives of the Organization for Economic Co-operation and Development (OECD) have sought Foundation advice on the conduct of surveys of research and development in member countries.

## SPECIAL ECONOMIC STUDIES

Growing out of and supplementing the information provided by the statistical program are many special economic studies conducted concurrently with the fund surveys. Some key studies which have recently been completed or begun are described in this section.

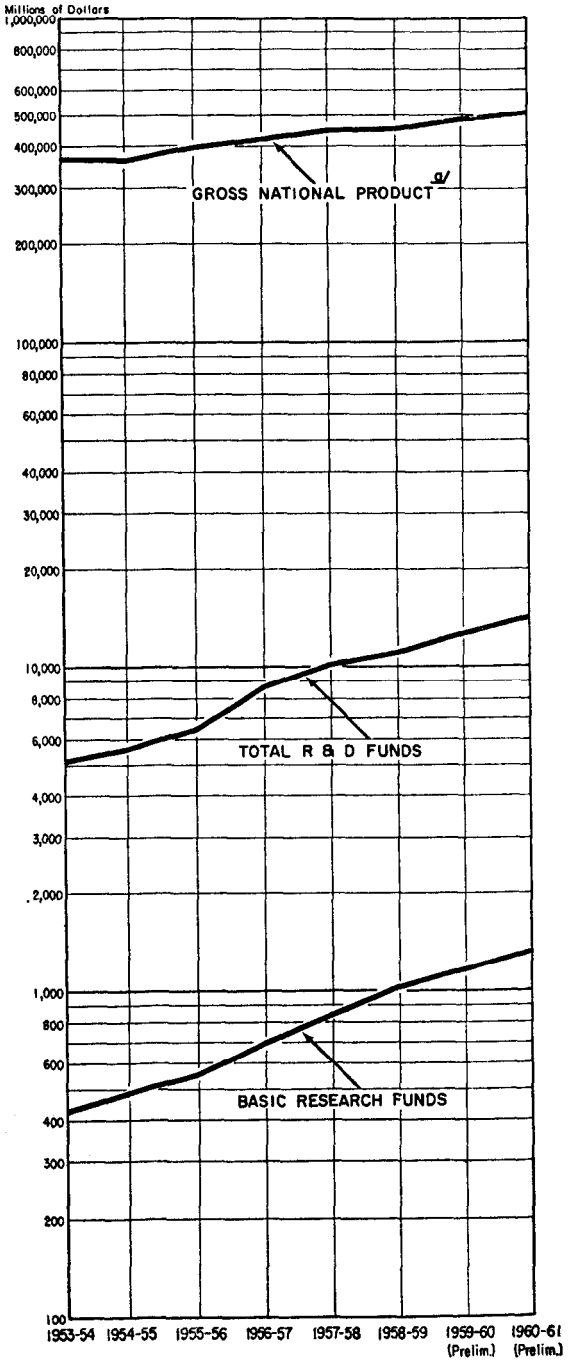



**Figure 5. *Trends in the Gross National Product, R&D Funds, and Basic Research Funds, 1953–54—1960–61***

[a] Gross national product data refer to calendar years, 1953, 1954, *et seq.*

Source: R&D data. National Science Foundation (March 1962). For GNP data, see U.S. Department of Commerce, Office of Business Economics, *Survey of Current Business*, July 1961.

*Cost Index*—Related to the statistical work is a project to construct a cost index that can be used to measure trends for research and development in terms of constant dollars. The measurement of the performance and financing of research and development discussed previously is expressed in current dollars.

*Scientific Output*—In connection with the Foundation's interest in developing measures of scientific activities in terms of data on scientific publication and patents, it has conducted a study of industry practices regarding the publication of basic research findings.

*Relation of Industrial R&D Data to Other Economic Data*—A study is under way to relate the data on industrial R&D funds to statistics collected by the Bureau of the Census and the Internal Revenue Service, such as value added, net profits, and capital expenditures, of such factors in an attempt to quantify the influence of such factors on company growth. Likewise, Internal Revenue data such as company sales will be correlated with funds for research and development.

*Indirect Costs*—To provide data on indirect costs of research grants and contracts, the Foundation surveyed present practices in colleges and universities with regard to reimbursement to them of indirect costs incurred in the performance of federally sponsored research. These findings, useful in government councils and congressional deliberations, answered questions on the amounts and sources of funds needed in addition to the funds for direct costs of Federal research grants or contracts.

*Inventory of Projects on Social Implications of Science and Technology*—The third annual inventory of current research projects dealing with economic and social implications of science and technology indicated that 262 projects are under way in this area in colleges and universities.

*Innovation in Industrial Firms*—Under contract with the Foundation, the Carnegie Institute of Technology has investigated innovations within a firm and within the economy. The Foundation published a report on diffusion of innovation within an industry and one on diffusion within individual firms. The Institute is turning its attention to the subject of decision-making with respect to R&D spending.

*Research Proposals*—Under contract with the Foundation, New York University and the University of Michigan conducted a study of the factors affecting the acceptance or rejection of research proposals in their institutions. A report is in preparation on the status of the proposals, the fields of science, ranks of the originators, and agencies to which they were submitted.