Program Activities of the National Science Foundation

SUPPORT OF SCIENTIFIC RESEARCH

A primary function of the National Science Foundation is the promotion of basic research by providing the scientist with the support necessary to carry out his creative work—the equipment, the assistance, and the time. Support is provided primarily through grants to colleges and universities for individual projects initiated by the scientist who would carry out the investigation. Also eligible for support are projects which are extremely broad in scope and which require an interdisciplinary approach.

Research grants are of significance not only for the scientific knowledge they produce, but also for the opportunities they provide for the next generation of scientists to receive research training and experience. Many more of these young people obtain their doctorate while participating as research assistants on grant-supported research than through the formal fellowship programs.

Support is provided for the purchase of research equipment (electron microscopes, ultracentrifuges, etc.) and for specialized facilities, such as Van de Graaff accelerators, oceanographic research vessels, and biological field stations. Funds have also been made available for the modernization and expansion of graduate-level research facilities—facilities which are now strained far beyond their design capacity.

Where the need was great and the facilities required were beyond the financial capability of any one university, the Foundation has established national research centers open to all qualified scientists. Four such centers have been created—National Radio Astronomy Observatory, at Green Bank, West Virginia; Kitt Peak National Observatory, near Tucson, Arizona; Cerro Tololo Inter-American Observatory, in Chile; and the National Center for Atmospheric Research, at Boulder, Colorado.

A number of national research programs are also supported and administered through the Foundation. These are programs which require a broad national effort because of the scope of the research involved; the financial requirements; and the need for coordination of scientific effort between Government agencies, colleges and universities, other private institutions, and even between nations are best handled in this fashion. Programs include: Weather Modification, U.S. Antarctic Research Program, International Years of the Quiet Sun, International Indian Ocean Expedition, and Project Mohole.

The Foundation also endeavors to keep abreast of those areas of science which become critical because of major breakthroughs or because of national needs. Increased support is then provided. A current example of such a field is oceanography, a field with great potential but one in which the research effort has been lagging.

This support is part of an overall 10-year national plan recommended by a Committee on Oceanography of the National Academy of Sciences-National Research Council and developed by the Interagency Committee on Oceanography of the Federal Council for Science and Technology. NSF, of course, is one of the Federal agencies most concerned with the basic research aspects of the plan. As envisaged in the plan, NSF would be responsible for approximately 22 percent of the recommended national oceanographic budget of $2.3 billion.

Support of oceanography is handled at the Foundation, not as a separate entity, but as an integral part of various existing programs. There are currently about 225 individual research projects being supported in biological oceanography and about 100 in physical oceanography. To date the Foundation has provided assistance for the construction or conversion of 11 research vessels and has made a number of grants to various institutions for the building and expansion of shore facilities, including research laboratory buildings.

In addition, oceanographic research is underway as part of two national research programs administered by the Foundation—the U.S. Antarctic Research Program and the U.S. portion of the International Indian Ocean Expedition.

Responsibility for the administration of research support programs is assigned among the following: 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 Division of Mathematical, Physical, and Engineering Sciences is concerned with the investigation of man's physical environment from the microcosm of the atomic nucleus to the macrocosm of outer space. The sectional organization of this division gives an indication of the broad scope of subject matter covered—Astronomy, Atmospheric Sciences, Chemistry, Earth Sciences, Engineering Sciences, Mathematical Sciences, and Physics.

Four national research centers, four university research facilities programs, and four national research programs are also administered through this division.

Astronomy

Research in astronomy is aimed at increasing man's knowledge of the physical universe—planets and their satellites, comets and meteors, sun, stars and clusters of stars, interstellar gas and dust, and the system of the Milky Way, and the other galaxies beyond the Milky Way. Observation of the radiations (light and radio waves) from the stars and other astronomical objects is the principal technique by which the astronomers and astrophysicists study the universe. During the 1963 fiscal year, probably the most significant research accomplished, through Foundation support, was the study of infrared radiation from Mars by use of the balloon-borne, 36-inch telescope STRATOSCOPE II. (See page 39 for a discussion of the results.)

The site of a third national astronomical research center has been selected—Cerro Tololo, Chile. It will make possible optical observations in the Southern Hemisphere. This observatory, along with the National Radio Astronomy Observatory, and the Kitt Peak National Observatory, will make vital facilities available to the Nation's astronomers. (See section on "National Research Centers" for details of activities at these centers.)

Though research in astronomy is going forward at a rapid pace—due largely to the development of new instruments and related equipment—the need for both radio and optical telescopes is increasing. Local university telescopes are needed for training for graduate work in modern astrophysics, and for faculty research use. Currently a study of these needs is being conducted by a scientific panel of the National Academy of Sciences. Meanwhile the Foundation is moving to partially correct this shortage by supporting such facilities. For example, a grant was awarded to Princeton University which will permit the construction of a modern 36-inch reflecting telescope, utilizing an already existing dome and mounting and replacing the present 23-inch old-fashioned, unused refracting telescope; a 36-inch quartz blank was already available as surplus to STRATOSCOPE II. This will result in a great saving of money when compared to the cost of a brand new telescope.

Atmospheric Sciences

Important trends in the field of atmospheric sciences have emerged more clearly in the past year. These include (a) the merging interests of atmospheric sciences and certain aspects of the new space science

activities, (b) increasing evidence of the global scope of interest and operations in the atmospheric sciences, and (c) the growing capability of the universities in the areas encompassed by this field. In response to these trends the Atmospheric Sciences program was reorganized as a section with programs in meteorology, aeronomy, solar-terrestrial research, and weather modification.

Meteorology includes investigations of the lower atmosphere. In this field the Foundation has supported basic research investigations of the physical and chemical structure of the atmosphere, heat budget, climatology as a possible method of clarifying the long-term behavior of the atmosphere, air-sea interactions, cloud physics, precipitation, and other phenomena. In addition, theoretical studies of the general circulation as well as basic investigations of atmospheric turbulence and diffusion have been conducted.

In aeronomy, the study of the higher altitude regions, scientists, under NSF support, are probing to learn more of their effect on the total atmosphere. The regions concerned extend from the lower areas where the circulation, winds, horizontal humidity and temperature gradients, and the pressure systems characteristic of meteorology are present, to the exospheric regions where individual particles and molecules are important. The layer studied by aeronomists is important as the transmission agency by means of which solar activity and interplanetary space are related to the atmospheric layers near the earth's surface.

Solar terrestrial research is concerned with direct influences on the earth of variations in solar activity and with the outer envelope of the sun in its interactions with the upper atmosphere and planetary atmospheres generally. In this regard the program supports research projects studying the transport of energy and material from the sun to the planets, the modulations of that transport by variations in solar emission, the electric and magnetic fields of interplanetary space and their effects on cosmic radiation, mechanisms of solar disturbances, interaction of the sun on planetary atmospheres, and the effect of the sun on the outer atmosphere and radiation belts of the earth and other planets. Much of this work has a direct bearing on national space programs.

In one study of "airglow," a weak light that originates in the upper atmosphere, a scientist has developed instrumentation which permits study of the light during daylight hours without resort to more expensive techniques involving rockets or balloons. The light or glow, thought to arise from chemical reactions, can now be studied when the atmosphere is receiving the great amount of energy poured into it by the sun.

The work of another researcher could well lead to more accurate high altitude aerial navigation and flight safety. His work has shown

that slowly moving gravity waves in the atmosphere are associated with strong wind shear such as frequently accompanies the jet stream. A technique developed around such observations may permit rapid determination of the presence of a jet stream or of turbulent clear air aloft.

Research in weather modification, a national research program, is administered as part of the Atmospheric Sciences program. (See page 53.) The National Center for Atmospheric Research, also administered through this program, is described on page 67.

Chemistry

The Foundation's chemistry program is concerned with fundamental research into the properties and characteristics of matter and of its transformations from one form into another. The discoveries and results of this research provide the basis for further investigation, both basic and applied, in biology, medicine, and the materials sciences.

Support is provided for research in the four classical subdisciplines of analytic, inorganic, organic, and physical chemistry. In analytical chemistry are included studies of electrochemistry, of transition metal ions (iron, cobalt, nickel), and separations and analyses by gas chromatography—a versatile, rapid, and extremely sensitive technique for the complete analysis of very complex mixtures of chemical compounds. A Foundation-supported scientist during the past year developed such a technique for the analysis of isotopic water samples which will make possible rapid and accurate analyses of heavy water samples.

Because the level of research activity in inorganic chemistry has been considered insufficient, special attention has been devoted to this area. During the past year grants were awarded for studies on coordination compounds; mechanisms of oxidation-reduction reactions; complexes, compounds and chemistry of transition metals; organometallic compounds; and boron hydrides and their derivatives.

The unusual and complex compounds of boron and hydrogen have been the object of increasing interest because of their potential for use as high-temperature resistant materials and as rocket fuels. Unfortunately, the difficult and expensive syntheses of some of the boron hydrides had hindered laboratory work and largely prevented consideration of these substances for practical use until the recent development of a new route to the formation of these compounds by a Foundation grantee. He discovered a simple synthesis of triborohydride salts from sodium borohydride. These salts can be converted to higher boron hydrides and their ionic derivatives, thus, making these compounds readily available for the first time.

Some typical areas in organic chemistry that have received Foundation support include syntheses of natural products, such as alkaloids and terpenes; syntheses of new types of organometallic compounds; syntheses of nonbenzenoid aromatic compounds; photochemistry studies; utilization of optical rotary dispersion for determination of absolute configuration of organic compounds; stereochemical and theoretical studies; and physical studies of the kinetics and mechanisms of organic reactions.

Two classical problems in the chemistry of aromatic molecules have been solved with the aid of a Foundation grant. The difficult and tedious synthesis of *trans*-15, 16-dimethyl-15, 16-dihydropyrene has been successfully completed. This compound, which has been shown to be aromatic, is unique in that it has functional groups within the cavity of an aromatic pi-electron cloud. This work paves the way to the synthesis of a variety of such molecules in order to test experimentally the exact nature of an aromatic pi-electron cloud with regard to various physical and chemical properties, such as steric hindrance, unusual bonding, and interactions with ions or radicals generated within the pi-electron cavity.

The hydrocarbons known as the caryophyllenes have occupied a unique position in the terpene field for more than a century because of the difficulty of synthesis. Isocaryophyllene, a naturally occurring sesquiterpenoid isolated from clove oil, possesses an unusual structure in that a 4-membered and a 9-membered ring are joined together. The structure had resisted synthesis due to the paucity of knowledge and methods available for the formation of its unusual ring system. A grantee has now solved this very difficult synthetic problem and has reported the total synthesis of isocaryophyllene by a brilliant and ingenious method.

In physical chemistry support was provided for studies on chemical and spectroscopic properties of compounds at low temperatures; determination of crystal structures by X-ray crystallography; electron spin resonance and nuclear magnetic resonance spectroscopy. A foundation-supported investigator has theoretically predicted and experimentally verified the existence of paramagnetic excitons in molecular crystals and solid free radicals. The lowest paramagnetic excited crystal states and the low-temperature paramagnetism of many aromatic free-radical solids is due to triplet exciton states. These crystal excitations can be thought of simply as running waves of molecular excitation. This work has significantly advanced our knowledge of the solid state by providing basic understanding at the molecular level and may result in useful applications in such diverse areas as electronics, materials of construction, and solid state chemistry and physics.

Earth Sciences

The Earth Sciences Section is responsible for research programs in geology, geochemistry, geophysics, seismology, oceanography, and in related fields such as hydrology and soil science. The scope ranges from the core of the earth to its surface, including both continents and oceans.

A major event in the past year has been the Foundation's support of university participation in the International Upper Mantle Project, a three-year international study of the earth's crust and upper mantle down to a depth of 1,000 kilometers (about 625 miles). Other parts of the U.S. effort are also being undertaken by the U.S. Geological Survey, the U.S. Coast and Geodetic Survey, and the Department of Defense through Project VELA Uniform. With NSF support, one scientist is studying tides in the solid earth, another is measuring the response of the earth's crust to surface loading (such as the shifts of water masses in tidal movements, or of low and high pressure centers in the atmosphere) and two others are studying free oscillations of the earth (such as overall earth motions set up by earthquakes) and the forces which operate to dampen them.

In attempting to achieve some of the goals of the Upper Mantle Project, American scientists for the first time are drilling holes specifically to obtain earth temperatures and establish the pattern of geothermal gradients. One grantee is conducting such a study between San Diego and the Rio Grande Valley. Another is working in several geologically critical areas in the United States in an attempt to establish regional heat flow patterns. A third investigator is probing thermally stable deep lakes in the United States and Canada.

Another powerful tool now in use in earth science research is the electron probe. This instrument permits the determination of the chemical composition of individual minerals within a rock. By scanning across minerals, an indication of the element distribution is obtained, and it becomes possible to elucidate some of the fundamental characteristics of minerals. Electron probe studies may thus provide truly basic information with respect to physico-chemical environment of formation of minerals and their host rocks. The resulting data in turn will be important in our understanding of genesis and evolution not only of individual minerals, but of ore deposits, rock groups, and indeed segments of the earth's crust itself.

In oceanography the Foundation has supported the operation of oceanographic vessels and has supplied special equipment for both ship- and shore-based laboratories. In addition, the Foundation's Pro-

gram Director for Oceanography serves as U.S. Coordinator for the International Indian Ocean Expedition, which includes geologic, geophysical, geochemical, biological, and physical oceanographic studies. One grantee, studying cores of ocean-bottom sediments, has found evidence of a sharp climatic boundary between the Pliocene and Pleistocene—the beginning of the last great Ice Age. Another, also using cores, is inferring past climatic conditions by measuring the relative abundance of oxygen isotopes in shells.

Engineering Sciences

Turbulent fluid flow, gaseous plasma, expansive cements, and laser communication are indicative of the diversity of subject matter supported by the Foundation under the broad heading of basic research in the engineering sciences. Such support results sometimes in the extension of fundamental knowledge, sometimes in the development of information or techniques for the synthesis of existing knowledge into a new process or device, such as a digital computer or a supersonic transport. The classical engineering departments of major universities are all engaged in basic engineering research, but there is an increasing trend toward interdisciplinary work, not only between engineering disciplines but between engineering and the physical, life, and social sciences.

As an example of such interdisciplinary research, the Engineering Section, in cooperation with the Divisions of Biological and Medical Sciences and of Social Sciences, is supporting a university research program in the general area of communication sciences. This work involves the combined efforts of electrical (communications) engineers, biologists, psychologists, linguists, and neurophysiologists. The broad problem being attacked is that of transmission of information, whether it be in machines, communication links, or biological systems.

The fluctuating aerodynamic force that occurs when a viscous fluid flows past certain objects creates problems which have stimulated engineering research. A phenomenon of this type was noted in Roman times in the form of a musical tone emitted from a string stretched in a windy location. These "Aeolian" tones were only the subject of mild curiosity until recent years when it was discovered that the forces creating the tones could actually reach destructive magnitudes on certain types of structures or impair effective operation of many fluid-operated or immersed devices. The spectacular destruction of such structures as large power plant smoke stacks and a suspension bridge indicated that lateral forces due to fluid flow do exist in the turbulent flow region and need to be considered extremely carefully in the design of such structures. Recent studies supported by NSF are directed toward gaining

a basic understanding of the forces that exist when there is turbulent flow around a circular cylinder. Such knowledge will provide the background for understanding more complicated situations such as exist around turbine blades or airfoils. Very important results have already been obtained from these studies. It has been found that the turbulent flow around a long circular cylinder is strongly three-dimensional, and that the unsteady aerodynamic forces can be expressed in terms of certain spatial correlation, stochastic (random function) analysis, and some characteristics of the surface. From the information already available it is possible to approach such problems as the analysis of the aerodynamic forces acting on a missile sitting on an open launching pad prior to and at the time of launch, as well as the types of problems previously mentioned.

Interest continues to grow in fundamental studies of plasma dynamics. This interest stems from the possible uses of plasmas for the propulsion of spacecraft, the generation of high-frequency electromagnetic energy, and the direct production of useful electrical energy by charged particle separation. Interest also comes from the fact that plasma in the upper atmosphere influences long range radio transmission. This phenomenon is apparent in the communication "blackout" which occurs during re-entry into the atmosphere of a space vehicle. Most current research on plasma is aimed at understanding its physical properties (electron density and energy) without disturbing the plasma by the insertion of a measurement probe. This was done by measuring the scatter of a laser beam passing through the plasma.

The laser itself continues to be the subject of much engineering research supported by NSF. This solid-state device, which emits an intense narrow beam of coherent light when properly excited, is receiving attention for such applications as high resolution radar, space communications, eye surgery, and determining properties of materials. Engineering research is directed primarily toward the areas of generation of coherent light at several different frequencies, modulation and demodulation of a coherent light beam for communication purposes, and investigation of methods of exciting laser action (aimed at the development of more efficient laser devices).

Engineers are conducting research to obtain very accurate and consistent measurements of the transport properties of gases. One group has concentrated on the viscosity of gases and has refined viscosity measuring techniques using both a capillary viscometer and an oscillating disk viscometer to a point where viscosity measurements are being performed at pressures from 1 to 50 atmospheres with an average error of only 1 part in 10,000. Accurate viscosity data are of immediate use

in design; but perhaps more importantly, the scientific value of checking the validity of new theories of the transport properties of gases transcends the limited aim of immediate use.

Another example of very promising basic research being supported by NSF is the recent work on expansive cements. These cements have a composition which causes an expansion of the concrete as it sets. If the concrete is restrained during the setting process, either by internal reinforcement or by external forms, it is placed under compression (i.e. a state of prestress) without any external energy source. As concrete is very strong in compression and weak in tension, the material is utilized in the most efficient manner. Prestressing eliminates problems of shrinkage and cracking and may greatly reduce creep (a gradual flow of the material over a long period of time) making possible a greater efficiency in the use of reinforcing material. Thus, in a highway or airport runway, for example, the use of expansive cement can provide a self-prestressed pavement of very greatly increased durability as well as a greater load-carrying capacity for a given thickness of pavement. Although laboratory samples have demonstrated the feasibility of using expansive cements, further work is required to provide an understanding of all of the characteristics of this new material.

Mathematical Sciences

Mathematics is the basic language of science, a feature common to all the disciplines of the physical sciences, and increasingly to the biological and social sciences. Many of the problems encountered in these disciplines are mathematical in nature and for their solution require some of the most modern techniques available to present day mathematics. In fact, abstract mathematical theories have found application in a variety of disciplines in a surprisingly short time from their development. The lag between theory and application is becoming ever shorter.

The Foundation's program in the mathematical sciences ranges broadly from applied mathematics to theoretical symbolic logic, and through computer sciences is involved in the study of artificial intelligence, pattern recognition, etc.

Among the highlights of the program in 1963 was a major contribution in the field of algebraic geometry. It has been shown that singularities of an algebraic variety can always be resolved in a higher dimension. The result for curves had been known for many years, the two- and three-dimensional cases for 20 years. But it remained for a grantee to simultaneously prove the possibility of resolving singularities

of algebraic varieties in the three previously known cases and in all higher dimensions.

In differential topology, two investigators have generalized the well-known case that one cannot tie knots in a string in four-dimensional space. They have shown that, in general, three extra dimensions suffice to unknot a manifold. Thus a two-dimensional surface can be unknotted in five-dimensional space, etc.

Physics

Physicists conducting research with NSF support are investigating problems in the areas of nuclear structure, elementary particles, solid state, and atomic and molecular physics In addition, the Foundation supports a program for nuclear research facilities. (See the "University Nuclear Research Facilities" section, page 71.)

Current studies of elementary particles largely involve learning more about their basic characteristics and interactions. The simplest and most direct experiment one can do to investigate new particles is to scatter them elastically. One group of physicists has found in its scattering measurements evidence in support of Regge pole behavior, a result which is extremely encouraging to those theorists who believe that the formalism of the theory is the doorway to our ultimately discovering the secret of the elementary-particle physics. Another important investigation concerns the behavior of high energy (and thus short wave length) particles in electromagnetic fields.

A Foundation-supported research group has presented a firmer figure for the recently discovered limit of applicability of electrodynamics to muon-proton interactions.

Another team of investigators has discovered a new particle, the positive anticascade particle, observed in a hydrogen bubble chamber exposed to antiprotons from the 33 billion electron volt (BeV) accelerator at Brookhaven. Its life span was found to be 3.5×10^{-11} seconds. The existence of this particle had been suspected from symmetry arguments but had not been confirmed by experiment. The event was found after 450,000 tracks were scanned on 34,000 photographs.

Cosmic radiation continues to be the only source of information on particle interactions in excess of 33 BeV. An experiment in which an array of scintillators was spread over a 4.5-square mile area at Volcano Ranch, New Mexico, has furnished definite information that particles with energies up to 10^{11} BeV are produced somewhere in the cosmos. Because the equipment used possessed directional discrimination, the investigation is expected to provide information on the source of these energetic particles.

While accomplishments were reported in many areas of atomic and molecular physics during the last year, most concerned the field of atomic and molecular spectroscopic techniques and instrumentation. Using new, high-sensitivity equipment, one investigator constructed a 45-meter multiple-pass absorption tube capable of simulating in the laboratory the optical thickness of the planetary atmospheres. Various gases are introduced into the tube and spectral data obtained. When these data coincide with those obtained from direct observation of the planet, the inference is that the same gas exists in the planetary atmosphere. By this means, strong evidence has been obtained for the existence of hydrogen on Jupiter, and it is now possible to estimate the total carbon dioxide content of Mars. Information such as this is extremely important to scientists in their theoretical analysis of the chemical, biological, thermal, and ecological characteristics of the planets.

The simultaneous observation and correlation of several parameters of an event adds new dimensions to nuclear structure research. This makes it possible, for example, to systematically study nuclear reactions involving three or more particles. An NSF grantee has been prominent in the recent development of "multiparameter analyzers," which not only perform this function but provide for the instantaneous display of intermediate results. One of these instruments is enabling him to study the "cluster" characteristics of the nucleus by means of reactions between complex nuclei.

Since World War II, solid state physics in the United States has enjoyed remarkable growth and scored brilliant successes. For the past several years fundamental understanding of the electronic behavior of semiconductors has been so satisfactory that semiconductor investigations have been conducted mainly as a branch of engineering. In consequence the interest of solid state physicists has turned increasingly toward other problems, such as the study of thermal vibration of metals, particularly superconductors. The problem of metals is more difficult than that of semiconductors. To account for the properties of metals it is necessary to consider the mutual strong interactions of a great many electrons. Moreover, at least in the case of superconducting metals, the interactions between electrons are greatly complicated by vibrations of the lattice, or "phonons."

During the past year NSF grantees have made substantial improvements in the theory of interactions between electrons and phonons. Investigators have shown that not simply the linking magnetic flux but rather a generalization of this parameter is the quantized property of superconducting circuits. This verifies a fundamental assumption

of the theory put forward a few years ago by an NSF-supported investigator. One consequence of that theory should be the existence of stable, non-history-dependent, superconducting states for which magnetic flux does not vanish everywhere within the metal. Grantees have developed strong experimental evidence tending to confirm this prediction. This kind of flux retention is fundamental and quite distinct from what was previously known.

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Current Research in the Biological and Medical Sciences

Basic research in the biological and medical sciences is directed toward understanding the life processes in plants and animals. These processes are studied at various organizational levels from that of the chemical constituents of cells and the complex activities taking place therein to the organization of cells into tissues, tissues into organs, organs into individual organisms, and the individual organisms into populations.

The explosive impact of recent developments in biology have resulted from the ability of scientists to conduct investigations at the subcellular and molecular levels and thus obtain greater knowledge of the physical and chemical aspects of the life processes. The elucidation of the molecular structure of DNA, the hereditary material, and the cracking of the genetic code are some of the fruits of these investigations, investigations which may well have an effect on the human species of more significance than the development of nuclear energy.

As the physical and chemical techniques and concepts necessary for an understanding of the subcellular and molecular bases of life develop and expand, they are applied to an ever wider range of problems affecting the whole spectrum of biological research.

The Division of Biological and Medical Sciences in carrying out the Foundation's task of supporting basic biological and medical research is organized on a functional basis rather than on the basis of the classical teaching disciplines. The Division covers the whole range of subject matter through the following eight programs: Molecular Biology, Genetic Biology, Developmental Biology, Metabolic Biology, Regulatory Biology, Environmental Biology, Psychobiology, and Systematic Biology. A ninth program deals with support for specialized biological research facilities.

Molecular Biology

The Molecular Biology program is concerned with providing the means for developing further knowledge of the molecular basis of life.

It borrows and adapts the methodology and latest findings in chemistry and physics for use in biological research. As molecular approaches and techniques become clearly identified as useful, they are applied to the solution of problems in various areas of biology—genetic, metabolic, developmental, etc.

The Molecular Biology program can be described in terms of four areas which deal with the general objective of understanding the molecular basis of biological systems.

The first deals with the molecules which make up biological systems, and the determination of their structure. This involves support for the isolation of suitably pure preparations, their chemical and physicochemical characterization, and eventually the application of any method which will lead to an exact description of molecular structure. This research may involve sequence studies of polymeric macromolecules such as proteins, nucleic acids, polysaccharides and lipids as well as investigation of secondary and tertiary structure by optical methods or X-ray diffraction; or it may involve details of electronic structure by such methods as electron spin resonance.

The second area involves physico-chemical interactions between molecules, particularly between macromolecules of various kinds or between macromolecules and smaller molecules. These studies are currently directed toward molecular descriptions of active sites of enzymes, combining sites in antigens and antibodies, and interactions of hormones and receptor sites. Another aspect in which substantial progress is being made involves the interactions of DNA, RNA, and protein.

A third level of complexity deals with the molecular basis for structures such as membranes, ribosomes, mitochondria, the golgi apparatus, and the various "particles" in which several kinds of functional molecules appear to be organized as a system for some biochemical process.

Finally, research in this program is concerned with the molecular basis for energy conversion. Included here are studies of the structural basis for contractility in muscles, biological luminescence, photosynthesis, and electron transport. Support is being given to studies of transport mechanisms at the molecular level in the function of permeases and the transport of ions across membranes, and toward the possibility that mechanisms of semiconduction may play a role in electron transport or other bioelectric phenomena.

The following examples are typical of the research currently supported in the program: (1) the mechanism whereby photochemical energy is stored in photosynthetic systems, and the mechanism(s) whereby it is transduced from an energy-poor into an energy-rich biochemical compound; (2) the structure of the systems which allow energy trans-

duction (what are the chemical component requirements of such systems?; Are there required genetic arrangements?); (3) the intimate structure of the enzymes which result in the catalysis of metabolic reactions under physiological conditions and the factors governing their specificity; (4) the organization of groups of enzymes into various subcellular units, and studies as to whether such organized groups operate in a different manner than the individual isolated enzymes; (5) the structure of the chromosomes, especially those polymers, the nucleic acids, in which the hereditary and enzyme-directing properties reside and the detailed chemistry of the method of self-reproduction of these hereditary units; and (6) the relation between such structures and their utilization, usurpation, or destruction by the nucleic acids of viruses.

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, evolutionary studies, and research in quantitative and mathematical genetics.

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. NSF-supported research on mutant forms of the enzyme tryptophan synthetase has pioneered in the analysis of mutant protein structure and the correlation of protein changes with specific changes in the hereditary material. This type of analysis is revealing additional features of the genetic code for amino acids (protein building blocks), and is being extended in other laboratories to a variety of enzymes and other proteins in bacteria and higher organisms. Other NSF-supported projects are concerned with the mechanisms of information transfer involved in genetic coding unit determination of the amino acid sequence of proteins. The physical-chemical properties of isolated genetic material are also being intensively examined. Incorporation of isolated genetic material into the genetic structure of bacteria (transformation) is being employed by a grantee to determine the effect of physical-chemical alterations in the isolated material on its ability to transmit genetic information. Recent studies indicate that the process of transformation may also occur in human cells in tissue culture. Thus, it appears that major breakthroughs may be imminent in the genetics of mammalian and human cells in tissue culture, and the NSF is supporting several promising programs in this area.

An important synthesis is being generated in genetic biology by current emphasis on the genetic regulation of gene and chromosomal activity. This development was sparked by investigations in bacteria on the way in which certain elements within the genetic material function as regulators of the activity of "structural genes." Studies on the extent and role of "regulatory" genetic elements are being conducted in such organisms as bacteria, *Neurospora* (a lower fungus) and corn. These studies are being integrated in many cases with studies of mutant enzyme structure and with studies of the genetic control of the enzymes associated in particular metabolic pathways. There is also great interest in certain seemingly diverse genetic phenomena in higher plants, insects, and mammals which have controlled changes in gene or chromosome activity in common. In addition, detailed morphological and biochemical studies of development in different genetic types are continuing. These diverse approaches are rapidly converging on one of the most important problems in modern biology—differentiation.

Projects on the genetic basis of evolutionary phenomena are an important part of the program and are frequently integrated with investigations of gene structure, transmission, and function. These evolutionary studies are concerned with genetic differences between species and natural populations and include investigations of chromosome and gene variation, inter-specific hybridization, and gene frequency changes in natural and laboratory populations under various environmental conditions. The Foundation is, for instance, supporting a coordinated attack on the evolutionary problems involved in the extraordinary proliferation of *Drosophila* (fruitfly) species which has occurred on the Hawaiian Islands. The rather short geological time involved in this evolution raises the hope that many species still are closely enough related that induced hybrids can be obtained, and that analysis of the genetic relations will be possible.

Many of the traits which appear to be most significant in evolutionary phenomena are determined by numerous genes acting in concert and must be studied by the complex techniques of quantitative genetics. The development of mathematical and statistical theory in conjunction with new experimental design is being sponsored. The use of electronic computers is contributing heavily in this area to experimental design development and the analysis of data.

Developmental Biology

Developmental biology is concerned with problems of growth and differentiation in all living organisms. These problems are analyzed at different levels of organization ranging from the whole organism

through organs, cells, and subcellular systems, down to the molecular level. This multilevel analysis of development is essential since development begins at the primary site of gene action and involves a transition from the molecular to the multicellular condition characterized by the "translation" of intracellular genetic and macromolecular events into higher levels of organization.

At the molecular level of organization, research projects are being supported for research on the biochemistry of developing systems, the metabolic patterns of enzyme systems involved, and the role of precursors, small molecules, and growth-stimulating substances in developmental processes. The role of genes in development and the factors responsible for their activation and inhibition represent a new major effort in the program. *In vitro* protein-synthesizing systems are being studied in an effort to understand the factors responsible for the appearance of new proteins in cell and cell-free situations. Modern immunological, enzymological, and physicochemical techniques are being applied in an attempt to understand the fundamental molecular and macromolecular control systems participating in the phenomena of cell division, cell interaction, and cell differentiation.

At the subcellular level, new electron microscope techniques combined with cell fractionation procedures are used to correlate biochemical activity with fine structural analysis. A major research effort underway in many laboratories is an analysis of the mechanism of cell organelle differentiation (plant cell walls, flagella, mitochondria, pigment granules, spindles, etc.) in a variety of cells and tissues.

At the cellular level, significant advances have been made in the *in vitro* analysis of cell population interactions and the dynamics of the elaboration of tissue fabrics and patterns in plants and animals. Support has been given to studies of individual cell surface phenomena, such as motility, adhesiveness, aggregation, and surface contact interactions in order to understand the mechanism of form and pattern building. In numerous cell and tissue culture systems, morphologic and biochemical differentiation are being studied in an attempt to better understand causal interrelationship. These studies are reinforced by cytological, cytochemical, and histological analyses.

Cell-virus interactions are of current interest, since it appears that viruses may be employed as useful tools to modify the developmental and differentiation capacity of cell populations. Studies of transplantation immunity, compensatory growth, and regenerative growth are of considerable developmental interest and are supported by this program. Problems of neoplastic growth and of aging are extensions of funda-

mental aspects of cell growth, development, and differentiation, and represent a minor portion of the program's activities.

Finally, on the organism level, research programs in descriptive anatomy of plants and animals, descriptive embryology and descriptive plant morphogenesis are areas which continue to attract considerable interest. The new techniques of enzymology, electron microscopy, and immunology are being applied in descriptive studies of developmental systems, providing new insights into classic problems.

Metabolic Biology

Studies supported by the Foundation in metabolic biology are directed toward understanding the biochemical reactions involved in the building up and breaking down of the substances of cells and organisms. The range of these investigations include work in the biosynthesis of metabolites (the products of metabolism); energy metabolism; purification and characterization of enzymes (the catalysts of biochemical reactions); energy coupling systems; mechanism of enzyme action; isolation and identification of metabolites; enzyme, antibody, and other protein and nucleic acid synthesis; metabolic control by metabolite interaction (the "feedback" mechanism); photosynthesis; isolation and identification of vitamins, cofactors, and growth factors; metabolic role of trace elements; biochemistry of subcellular particles; microbiology; comparative biochemistry; overall metabolism of organisms; and nitrogen fixation.

Involved in these projects are the gamut of organisms from higher animals through plants, fungi, bacteria, and viruses. Many of the studies reveal patterns of similarity between diverse organisms, that is, provide a basis for a unity of biochemistry. However, as greater details of the steps and interrelationships in metabolism become known, fine differences in metabolic pattern appear and the possible significance of these differences becomes important. A sampling of research projects in metabolic biology supported by the Foundation follows.

A group of researchers is attempting to establish the metabolic reactions for which vitamin A is required. The scientists hope the results will demonstrate the general mechanisms of action of vitamin A as it functions in all tissues in the body.

Increased knowledge of antibiotics and the organisms that produce them is expected from an investigation of the biogenesis of the streptomycin group of antibiotics.

In an investigation of the synthesis of proteins in chloroplasts, scientists have developed a cell-free system in which isolated whole chloroplasts synthesize proteins from free amino acids as precursors. They are seeking evidence pointing to the source of messenger RNA for chloro-

plast protein synthesis—whether from the nucleus or the chloroplast itself. Ultimate goal of the work is clarification of the mechanism for light activation of chloroplast synthesis. Another investigator, studying the metabolism of the opening and closing of the stomates in leaves of plants has found classes of compounds which apparently are capable of greatly reducing water loss by their effect on the size of the pores through which water is lost by transpiration.

Regulatory Biology

Regulatory Biology supports research on the whole organism and its organ systems and includes most of what may be termed classical plant and animal physiology, also considerable research in pathology, nutrition, and transport of material. For convenience, current Foundation support can be categorized under five general headings: parasitism, neurophysiology, endocrinology, metabolism, and growth.

Some examples in the first category are host-parasite and symbiotic relations, including such areas as entomology, nitrogen fixation, plant disease, mechanisms in immunity, and epizootiology in insects. Examples of those under the heading of neurophysiology are subjects ranging from behavior to locomotion wherein investigators are concerned about the electrical and chemical phenomena of individual neurons and their membranes, as well as about mechanisms governing the function of special senses.

Grants for projects classified as endocrinology have been given for studies of insects as well as man; included are a considerable number centered around the pituitary-gonad axis. In the metabolism group the Foundation has supported studies in such areas as photosynthesis, transport and translocation, mineral metabolisms, and, in a general manner, certain aspects of metabolic regulation in the whole animal. The last category, growth, includes among other items problems of break in dormancy, indole auxins, certain aspects of the gibberellins, geotropism in roots and shoots, photoperiodism, and the effects of environment.

Remarkable advances in our knowledge of the basic processes of life have occurred over the past two decades and are presently occurring at an even more rapid rate. In the fields of neurophysiology and neurochemistry, further developments are expected from research into the manner in which the brain codes, retrieves, and acts on information it receives through the sense organs (vision, olfactory, taste, sound, touch, and pain). Basic to an understanding of the mechanisms involved is a fuller understanding of the nature and origin of rhythmic impulses and the significance of the different frequencies characteristic of many nerve elements.

It is now well established that the most profitable approach is through "comparative" experiments. Information obtained on the most simple or primitive nerve nets found in invertebrates has led to some startling discoveries that have advanced our knowledge on the functioning of the central nervous system of man. Following is a small, though representative, sampling of the profitable use of this comparative approach. A scientist working under NSF support is studying the crayfish and the Hawaiian crab; the latter has an unusually long external optic tract. His findings on the nature of the transmission, coding, and responses to visual stimuli are among the outstanding discoveries of the past decade. Another researcher is concerned principally in understanding the mechanism through which the excitation by light changes the visual pigment, rhodopsin, so that it causes the rods of the eye to respond in such a manner as to lead to the stimulation of the optic nerve. For his studies he uses rhodopsin prepared from the eyes of cattle. He has in the course of his investigation discovered the existence of a possible transient intermediate substance acting in the chain of events between rhodopsin and the stimulation of the optic nerve.

Yet another investigator has been employing squid as his source of nerve material. This marine invertebrate has a nerve with an axon unusually wide in diameter. The scientist is investigating the possibility that the operational properties of different nerve types are determined by the characteristics of the "ionic" current components.

To many experts in this field, it is becoming increasingly apparent that a mechanism may be involved in the symbiotic relationships between animals and plants and their parasites. Some have suggested that such an explanation can also extend to a variety of immunological phenomena, disease states, and even to the relationship between a cancer cell and its host tissue. It is quite likely that through the investigations of these biologists a unified theory may soon be forthcoming to explain their relationships. Here, as in most biological disciplines, the comparative approach—using many different species of plants, microorganisms, and animals—is proving to be the most fruitful.

Environmental Biology

The environmental biology program deals with support of investigation into the interactions between organisms and the physical, chemical, sociological, and other biological features of their environment. This program encompasses the broad spectrum of plant and animal ecology, including those areas sometimes identified more specifically as environmental physiology, paleoecology, palynology, limnology, biological oceanography, orientation and migration, macro- and micro-

bioclimatology, phytosociology, animal community and population dynamics, bioenergetics, life history studies, environment-controlled distribution of organisms, biological productivity, and certain features of mycology and parasitology.

The substantial breadth of research supported through this program is best illustrated by the following sampling of grants activated in the past year.

One investigator is studying the effects of varying temperatures, light periods, and humidity levels upon infection time, incubation period, severity of host reaction, etc., of a fungus parasitic on potato plants to obtain a better understanding of the very complex phenomenon of parasitism as it involves the effects of various environmental factors on the host, the parasite, and on their interaction. Another grantee is investigating the conditions which control the numbers of individuals and species of organisms in a given habitat. Based on his previous studies of bird species in a few major habitat areas of the United States, it would appear that, if enough time has elapsed and the species are sufficiently plastic, habitats should have acquired those numbers of species that make all habitats equally difficult for a randomly chosen new species to colonize. If his conclusion is correct, this would mean the increased numbers of species present in the tropics reduces the opportunity for colonization by precisely as much as does the more severe and unpredictable climate of temperate regions.

A pilot study has been initiated to test the hypothesis that the blue hazes so commonly observed in the atmosphere are derived from organic substances, such as the terpenes, which emanate from plants. The grantee has suggested that this material condenses under the influence of light to produce the blue haze, and that it can be precipitated and become a source material for petroleum.

An investigation is being conducted to determine the degree of plant water stress which limits plant processes and modifies the quantity, quality, and mechanism of growth. A grant has been made for research on animal cycling and population regulation through a study of the ptarmigan population in Iceland.

Another area of interest is reflected by a grant in which the investigator hopes to interpret the distribution of certain amphibians in Puerto Rico on the basis of the relation of their water economy to the ecological conditions under which they live. If moisture is the restrictive factor between the distribution of restricted and widespread species, it would be expected that the widespread species will have broadly adaptive physiological traits which are lacking in the species restricted to moist forests.

In a study of energy transfer phenomena at various trophic levels of an ecosystem, a group of scientists has been engaged in concerted studies of the productivity and nutrient cycles of Arctic tundra ecosystems. The most recent NSF grant provides for the continuation of these investigations in the Point Barrow area in Alaska with greatest effort being directed to analyses of decomposition rates and chemical cycling in the tundra vegetation.

Another potentially significant research effort initiated during the past year is on heat transfer between plants and the environment. Many physiological processes within plant tissue depend upon the temperature of the plant which, in a given environment, is dependent in turn upon the heat load imposed by that environment. The investigator has demonstrated the manner in which transpiration rate and certain other fundamental physiological plant processes can be evaluated if the solar and thermal energy incident upon the leaf and the leaf temperature can be measured at the leaf surface. He has devised means of accurately determining heat transfer to and from plants and has proposed an equation to reflect this energy relation. The present effort will yield precise measurements of the actual thermal conditions of the environment which influence the physiological behavior of plants.

A final example of NSF-supported research in environmental biology is a continuing study of large marine turtles which inhabited the Caribbean at an earlier time and which have been disappearing at an alarming rate. The investigator, an outstanding authority on these marine reptiles, has been active for a number of years in conducting with NSF grants an exhaustive study of their life histories, reproductive ecology, migratory patterns, behavior and evolutionary history. Continuing studies concern the behavioral ecology and ecological geography of additional marine turtle genera.

Psychobiology

The Psychobiology program supports research on human and animal behavior. The work on human behavior falls for the most part within the traditional areas of experimental psychology, and encompasses such fields as psychophysics, perception, vision, hearing, other sensory systems, learning and memory, psychomotor behavior, motivation and emotion, problem solving and thinking, and physiological and neurological correlates of behavior. Certain types of studies in statistics and mathematical models also are supported when these are especially relevant to the research areas of the program. Studies of animal behavior may be conducted either in the laboratory or in the field. Laboratory research deals with such topics as sensory processes, learning, and motivation. Field

studies tend to be centered around those forms of behavior which are best observed in a natural environment, such as social behavior and communication. Frequently, field observation is supplemented by laboratory experimentation.

There has been a growing interest in research dealing with sensory and perceptual functions in animals. Examples drawn from NSF-supported investigations include a study of how white pine weevils react to odorous compounds in white pines in order to determine how changes in these essential oils, resulting from hybridization of the pine, will alter their attractant and repellent effects on the weevil. The scientist expects the study to contribute to a better understanding of host specificity as it relates to the natural resistance of trees to the white pine weevil. This problem is a good example of how interdisciplinary techniques are used in animal behavior research. It involves methods and techniques used in plant genetics, gas chromatography, infrared spectrophotometry, and psychophysics of olfaction. In another study, an investigator has developed a procedure which allows him to determine auditory frequency thresholds of sharks and other bony fishes. Basic information about the quantitative aspects of hearing in fishes and the physiological mechanisms of their hearing will be correlated with behavioral studies to show how these animals utilize acoustic energy for the detection and location of moving objects, and for orientation and communication.

Bony fishes are being used by another team of researchers in studies of spectral sensitivities and capacities for hue and brightness discrimination. They are comparing, in specific instances, the behavioral data and electrophysiological data on the retinas and optic tracts of the same species. This is a comparative study directed toward determining the similarities and differences between the visual discriminative capacities of the bony fishes and those of humans and other mammals.

Another trend, reflected in grants awarded this year, is the growth of research in the general area of neurophysiological correlates of behavior. Projects in this field frequently use a multidisciplinary team approach. An example of research being supported is a study of the manner in which such behavioral variables as fatigue, effort, motivation level, emotional excitement, and the general activation level of the human subject simultaneously affect overt verbal and motor activity, and such somatic events as the electroencephalogram, tension level, skin conductance, heart rate, blood pressure, and eye movements. Another study deals with brain processes related to learning in monkeys. This study considers the behavioral and neuronal aspects of the occurrence of bursts of electrical current of a particular frequency recorded from the temporal cortex during the acquisition of visually guided tasks, and the

facilitation of learning by low-voltage stimulation of the prefrontal cortex.

Several grants deal with more or less traditional psychophysical studies of the human senses. Among these are investigations of cutaneous communication, visual motions, and sound localization. The topics of learning and conditioning still account for about one-half of all the grants made in the Psychobiology program. Laboratory studies include verbal learning operant conditioning, classical conditioning, problem solving, and decision making.

The role of simple associative processes in the perception, learning, recall, and mediated generalization of children is being investigated. In one study an effort is being made to determine the extent to which the relationships established with adults may be used to account for children's behavior, and to examine some of the factors that may lead to differences in performance between adults and children. Other projects are being conducted on instrumental behavior of animals and relaxation-response as an important class of behavior in avoidance learning.

Systematic Biology

The scope of systematic biology is broad, calling for the survey and subsequent naming, description, and orderly arrangement by natural relationships of all forms of life, both past and present. Foundation support continues to encompass the entire taxonomic range of organisms—living and fossil—from the classical descriptive or evolutionary studies to investigations utilizing modern methods and recently developed and promising techniques. This work is of vital importance since, to some extent, all other biological disciplines are dependent upon it. Research projects in systematic biology are not limited by geographical or national boundaries, but must encompass the entire region or environment occupied by a particular organism.

One classical approach to systematic problems is the biotic survey. Among current projects supported by NSF are floral surveys of Panama, of the Iranian Highlands, of Indonesia, and of the United States. Studies are also being made of vascular plants of aquatic and marsh habitats and of marine algae of the Atlantic coast. In the sea—the western Atlantic—zoologists are conducting comparable faunistic surveys on stomatopod crustaceans, amphiurid brittlestars, and offshore Ectoprocta. Other marine studies are centered on intertidal amphipods, and on microorganisms of the deep sea; while, on the land, studies are progressing on the mammals of highland Ethiopia and of Panama.

Attention is being given to the Permo-Triassic reptiles of South Africa, Triassic tetrapods, and the phylogeny of Paleozoic reptiles.

Although work resulting in revision, clarification, and addition to classification arrangements may be initiated with the broad survey, grants are often made for projects devoted to a single specific genus. A case in point is an intensive study of the wheatgrasses (Agropyron). Cytology of somatic cells and pollen, paper chromatographic analysis, serodiagnostic methods, anatomy of stem and leaf, study of flowering periods, and interspecific hybridization are all utilized in this biosystematic research.

Monographic studies that produce revisions of taxa, the classification of which was once restricted largely to structural characters of diagnostic value, now draw freely on experimental techniques. This approach is essential for the clarification and understanding of the many perplexing problems awaiting systematists' serious attention. Work on chromosome numbers of orchids, modifications of morphological characters in lacustrine fungi resulting from culture techniques, and recent discovery of reproductive structures of trichomycete fungi living within insect larvae and nymphs—are representative of current investigations with systematic importance. Monographic treatments of Diptera (flies and mosquitoes) of Hawaii, of Orthotera (locusts and grasshoppers) in North America, and North American fossil cycads continue.

Studies of the fossil record are essential to the clarification of the status and relationship between extinct and living forms. Projects on mammals, amphibians, reptiles, birds, invertebrate groups (corals, bryozoans, crustaceans) are being conducted in the field and in study collections in the United States and in many other parts of the world, e.g., Mexico, Australia, New Zealand, Europe, and South Africa.

The Foundation, through the Systematic Biology program, also is lending support to the newer developments such as biochemical systematics and numerical taxonomy which employ the most recent advances in molecular biology and computer technology to resolve systematic problems. Sophisticated biochemical investigations directed toward clarifying questionable relationships are gaining favor. Examples include blood protein studies in amphibians, reptiles, birds, primates, fishes, insects, and biochemical constituent studies of plants (legumes, grasses, hops). The systematist's use of computers for statistical treatment, analysis, and interpretation of data is increasing. Research on methods and principles of numerical taxonomy continues. Comparative studies underway on both plant and animal groups should eventually clarify the feasibility, significance, and effectiveness of this computer

approach. Both biochemistry and computer techniques are being used to achieve a more practical and useful classification of bacteria.

Behavioral aspects of speciation are being investigated in amphibians and birds, and the evolution of adaptation or functional morphology is also being studied in fishes, snakes, and lizards.

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Current Research in the Social Sciences

The primary justification for support of basic research in the social sciences is the same as that for the life or physical sciences—to enrich our understanding of the world we live in. In the case of the social sciences, this means investigation into man's behavior, in relation to other men as individuals, groups, and nations. A special challenge in pursuing such research comes from the difficulties of carrying on objective investigations in an area where unscientific ideas, misconceptions, and prejudices are often of ancient origin, deep-rooted, and of highly emotional content. Other sciences, of course, even geographical exploration, have encountered similar resistance, but it is probably true that the obstacles are unusually refractory in relation to the study of social behavior. However, this very challenge can inspire highly creative and productive research.

A second major reason for NSF support of the social sciences is their ultimate practical importance to the Federal Government itself. There is enormous potential in the practical usefulness of increases in knowledge of social behavior, even advances that do no more than allow crude analysis to be replaced by slightly less crude methods of understanding. Somewhat better economic analysis than we now have that would enable us to prevent, or mitigate, even a small depression would repay its cost of development by a tremendous margin. To learn how to reduce even slightly the socially produced psychological tensions of industrial and urban life would add exponentially to human happiness. So, too, would any improvements, however small, in our ability to understand differences in human behavior in different cultures—an understanding that would facilitate communication between peoples.

The program activities of the Foundation's Division of Social Sciences do not cover the entire range of interests of the sciences of man and society. Rather, these activities have been concerned with basic research, not with studies of public policy, social issues, or other applied problems. Research support has been focused on problems and topics which can be studied by objective methods, which will yield independently verifiable results, and above all, which are general in nature

rather than specific to a particular time, place, or event. This orientation fits very well some of the major trends in all of the social sciences over the last two or three decades, in particular, the improvement of methods for the collection and analysis of data, and increasing sophistication and formalization of theoretical ideas and systems.

The Division of Social Sciences is organized into four programs: Anthropological Sciences—including archaeology, social and cultural anthropology, physical anthropology, and linguistics; Economic Sciences—including econometrics, mathematical economics, economics of science and technology, economic and social geography, and research in other areas of general economics which lend themselves to scientific treatment; Sociological Sciences—including sociology, social psychology, demography, and psycholinguistics; and the History and Philosophy of Science.

Anthropological Sciences

Through an analysis of past and present cultural events, the anthropological sciences seek to understand how man behaves in patterned ways and the processes involved in changing this behavior. They also study human biological phenomena in an effort to clarify how early man and modern types have evolved and the processes responsible for their development. The anthropology program supports research in these areas. Attention is also given to the testing and developing of new research techniques.

Archaeologists with Foundation support are investigating both primitive and complex societies of the recent prehistoric period as well as very early manifestations of culture. For example, one group of grants supports research on the prehistoric phases of the highly developed indigenous civilizations of Mexico, Central America, and Peru. This work has particular significance for anthropological theory because the great cultures of the Aztec, Maya, and Inca represent one of very few (perhaps only two) instances of the independent development of culture to the level of literacy and true urban social organization. Archaeological investigations at the opposite end of the cultural and time scales are concerned with the very old and relatively simple cultures of Europe, Africa, and North America. The age of these societies is measured in terms of tens and even hundreds of thousands of years. Another group of grants, the largest in number, supports the traditional central interest of American archaeologists, the construction of a detailed culture history of North America. The research covers every region in the United States and also adjoining areas in Canada and Mexico.

Physical anthropology is represented by several grants. One supports an investigation of the evolution of the primate pelvis by means of surgical modifications of monkeys. A second is a study of a unique blood component in South America that sheds light on the aboriginal peopling of that continent.

The third grant category, linguistics, supports research which describes and classifies the languages of the world, traces their historical interrelationships, and studies the dynamics of linguistic change and the relationship of language to other aspects of culture. One project involves the application of electronic computer methods to the deciphering of inscriptions in the Etruscan language. Another is the investigation of paralinguistic behavior at a New Mexican Indian pueblo. Paralinguistics is the study of phenomena closely related to and surrounding articulate language—grunts, groans, gestures, and the like—and the findings of this research will add new depth to the study of communication behavior.

Research projects in social anthropology and ethnology, the fourth support area, are directed mainly toward the cultures of Africa, Oceania, southern Asia, and Latin America. Several of these projects use the technique of cross-cultural comparison, in which two or more formerly similar communities are chosen for study because one has been subjected to some recent disturbing influence, frequently increased exposure to European-American culture. A variant of this technique is the restudy of a community after an interval of 20 or more years. These studies are designed to investigate the interrelationships of social organization, technology, and natural environment and to describe the dynamics of cultural change. Current research is also underway in comparing peasant communities within the complex societies of India, Latin America, and the Balkans.

Trends in ethnology and social anthropology are reflected by the character of Foundation grants. The natural history period of anthropological research is obviously drawing to a close; the simple expedition having the purpose of describing the culture of a hitherto unknown society in terms of certain standard categories is now a rarity. Ethnologists and social anthropologists now have a body of basic data about a large number of existing societies with which to test theories. At the same time, new formulations of social theories indicate a tendency for anthropology to develop stronger bonds of common interest with other fields. It has become apparent, for example, that social systems are not closed but are devices for operating other kinds of systems. Consequently, modern anthropologists no longer anticipate finding full

explanations of present social behavior without considering many related variables, such as technology, ecology, and historical data.

Economic Sciences

This recently formed program makes support available for fundamental economic research not directed specifically toward an immediate solution to business, governmental, or local community problems. NSF offers the prospect of support for investigations using more sophisticated methods than those typical in economics today, and economists are challenged to develop new techniques. Often, but not always, these involve computer programming.

The economic research projects now underway vary greatly in subject and method. For example, one NSF-supported study is investigating relative prices and price changes and their influence on the composition and direction of world trade in manufactured goods. Although data are abundant about the prices of agricultural and other raw materials, little is known about manufactured goods. Another related study is reclassifying imports of leading countries by end-use categories and examining the United States shares and changes in them from this previously untried point of view.

Economic fluctuations, or business cycles, are another focus of public interest. One of the key problems is to explain business decisions to purchase new capital equipment, for variations in this component seem to be responsible for much fluctuation in Gross National Product, and consequently in employment and prices. On the individual level, studies are being carried out to investigate the decision-making behavior of persons with high incomes and wealth, since this factor is also very important to our economy.

Still more specific is the examination being made by a grantee of the determinants of expenditures on automobiles. The study also hopes to develop new methods of survey analysis.

Sociological Sciences

In addition to improving methods of research, this program seeks to encourage the development and verification of formal theories about social and psychological processes and to build a broad base of data for testing these theories, without being limited to a single culture or a narrow sample.

A number of grantees use computer simulation of social or cognitive processes to determine the implications of theoretical ideas. The outcomes of these simulations may then be compared to observations and data to test the adequacy of the theoretical ideas.

One such grant involves a model of community controversy. The model ties together various strands developed in previous psychological and sociological research and in a sense synthesizes the microphenomena of social psychology and the macrophenomena of mass sociology. Under the grant, a field study will be conducted to test the empirical adequacy of the initial model, and after appropriate revision, a further field study will be conducted in several communities. The specific setting used for the test will be community referenda on the issue of the fluoridation of water.

The implications of some simpler theoretical ideas about social and psychological processes are worked out in mathematical models that are soluble without computers. Under a grant dealing with the learning and use of language, an information-theoretic model of language learning has been developed and is being coordinated with a mathematical model of vocabulary structure. Both types of models are being developed in close interplay with experimental data on such matters as rote learning and concept formation.

Some grants involve formal theories of social and psychological processes expressed without the use of computer language or mathematics. For example, research was conducted during the American Mount Everest Expedition to test a theory about the feedback of information among members of a group under stress.

In an effort to establish a broader, more representative data base in sociology and social psychology, many cross-cultural or cross-national studies have been supported. Current projects include a study of child-rearing practices in the USA, Switzerland, and the USSR; a study of the social structure of isolated institutions in four Scandinavian countries; and one on occupational attitudes in Brazil, Mexico, and the United States. An example of a cross-national study recently begun is the investigation of social ramifications of modernization of Chile, Nigeria, and Pakistan, concentrating upon the changes in popular attitude and values that are associated with the process of industrialization in developing countries. This study is expected to make an important contribution to our understanding of the effects of work environment upon fundamental attitudes and values, and consequently may indirectly affect the technical assistance programs.

The objective of improving scientific methods of research is being pursued under several grants. One example is a program of research on the conceptualization and measurement of attitudes. The research includes refinement of older techniques and development of some very novel ones. For example, the investigator proposes to look into the potential value of pupillary contraction or dilation in the eye in response

to various stimuli as an attitude measure. Preliminary research has suggested that dilation occurs when stimuli are regarded favorably, and contraction occurs in the case of disliked stimuli. Another example is a project to develop an automated system of analyzing the content of documents or conversations by computer.

A secondary aim of the program is to encourage new unconventional work that may challenge contemporary theories and widen research horizons. One project of this kind is devoted to the replication and elaboration of a field study of behavior settings in an American town and an English town. This work employs a novel conceptual framework and deals with problems of behavior in relation to broad features of the environment that have been largely ignored by other researchers. Hence, it is new both in the problem it attacks and in the perspective that brings to bear upon the problem.

The History and Philosophy of Science

This program is concerned with analyzing what scientists are actually doing when they say they are doing science, also with tracing the historical development of science.

During this fiscal year historians of science have been given support for projects ranging in time from Zeno (300 B.C.) through the 19th century, in subject matter from astronomy to zoology, and in purpose from the translation of Babylonian texts to the collecting and editing of basic documentation for the history of science. By far the majority of grants awarded this year supported research in the history of the life sciences. One investigator is concerned with the development of the germ theory of disease, another with the American patriot Benjamin Rush, who, among his many achievements, laid the foundations for modern psychiatry, and a third with the influence of chemistry and physics on modern biological theory. A study of the career of A. R. Wallace will not only be of intrinsic interest but will also illuminate the development of evolutionary thinking in the 19th century.

In the philosophy of science, grants were made for investigations into the philosophical bases of scientific thought as well as into the philosophical problems of specific scientific disciplines. One of the investigations of more general philosophical problems is an attempt to explain the probability concepts utilized by empirical sciences. This research is focused on the inductive methods for inferring or estimating relative frequencies of events (such as the collisions of molecules in a given solution), the grounds for selection of these methods, and the bearing

of the selection of such methods on the problem of interpretation of probability concepts. Projects directed toward specific disciplines concern themselves with, among others, mathematics, psychology, and quantum mechanics. Although sharply focused, these researches will have broad relevance. For example, one study of logic has applications relating to the foundations of mathematics and behavioral science. It sheds light on the nature of the classical requirement of relevance between antecedent and consequent, a requirement which has been lacking in the modern tradition of mathematical logic. Experimental evidence indicates that for effective problem solving, the first clause of an "if . . . then . . ." statement must be relevant to the second. In another study, the analyses of cognitive behavior associated with recognition that have been contributed by three philosophic traditions—Aristotelianism, Empiricism, and Phenomenology—are being applied to the problems of mechanical pattern recognition encountered by computer technologists. Specific pattern-recognition techniques arising in the course of the project will be programmed and tested by computer and, if successful, will enable psychologists to conceptualize the structure of mental behavior and to devise new approaches to recognition and pattern.

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Significant Research Developments

SEQUENCE OF AMINO ACIDS ON PRIMARY CHAIN DETERMINES THREE-DIMENSIONAL CONFIGURATION OF A PROTEIN—Enzymes are biological compounds which make possible most of the chemical processes in the living cell, such as the conversion of food into energy or the transmission of nerve impulses. They serve as catalysts that speed up the biochemical reactions continuously taking place in the cell and are usually unaffected by the reactions they produce. Without enzymes these reactions would either not occur at all or would occur at an extremely slow rate. All known enzymes are proteins, which, in turn, are polymers of one or more amino acid chains. Many enzymes are "simple" proteins and do not contain other such compounds as liquids, carbohydrates, and pigments which are associated with many proteins. Nevertheless, even these simple proteins have a truly remarkable specificity for the nature and conditions of the reactions which they catalyze.

Although the specificity of an enzyme is known to be dependent, at least in part, on its three-dimensional configuration (tertiary structure), biochemists had long believed that the theoretically almost infinite variety of possible configurations of such a polymer would make it practically impossible to create the specific tertiary structure necessary for

catalysis with the relatively crude techniques of modern biochemistry. It was therefore a discovery of great significance by an NSF grantee (Schachman, University of California, Berkeley) that the tertiary structure of some proteins was self-determined by the primary structure.

By the primary structure is meant the sequence of amino acids making up the chain. If the amino acids were given names corresponding to the alphabet: a, b, c, . . . etc., up to . . . r (only 20 of these amino acids are believed to be involved in protein formation), the primary sequence might be: a-c-c-p-r-m-n-g-g-g-i-b-c. This would be different from a sequence in which any one of the letters were changed, e.g., one in which the sequence read: a-b-c-p- . . . i-b-c, where the second amino acid "b" has replaced a "c".

By virtue of certain structural and chemical features common to all these amino acids, the primary chain tends to arrange itself into a helix or coil. That is, under the usual conditions, this secondary structure, the coil, is more stable (requires less energy for maintenance) than the random snake-like structure of the primary sequence.

What has now been shown is that the spatial arrangement of the secondary structure itself and the unique positions thereby accorded particular amino acids of the primary sequence, results in a further folding of the helix into the truly unique three-dimensional configuration (the tertiary structure) of any particular protein. Consequently, the primary structure predetermines a unique tertiary structure under physiologic conditions, even though, in theory, an almost astronomic number of tertiary configurations is possible.

It is, therefore, apparent that the accidental changing of even a single amino acid in a chain of hundreds, can result in a different tertiary structure. This change may be so profound that it will not allow the protein to function. Such is the case in "sickle cell disease," where the hemoglobin has been altered by a mutation in which a single amino acid has been replaced by a different amino acid (Ingram, Massachusetts Institute of Technology). The resulting hemoglobin can no longer combine effectively with oxygen and the whole red blood cell which, in normal human beings, lasts about 4 months, now has a lifetime of only a relatively few days.

Nevertheless, it is well known that the same enzyme (i.e., the enzyme which performs the same catalytic function) may have different compositions in different organisms. The most reasonable explanations of the allowance of such species differences is that certain positions in the primary structure must be relatively insensitive, exerting little effect upon the secondary and tertiary structure. An alternative possibility is that these substituted amino acids do have a profound effect on the tertiary structure

but not in that portion of the enzyme where the catalysis itself occurs (the active site).

The primary amino acid sequence of a particular protein is determined by a corresponding sequence in another polymer, that of DNA, the deoxyribonucleic acid of the chromosomes in the cellular nuclei. A commonly studied system is the synthesis of the protein coat surrounding the nucleic acid (NA) of a virus. This viral nucleic acid thus has, as two of its major functions, the synthesis of enzymes whose function it is to produce more viral nucleic acid and, secondly, the synthesis of protein to coat the naked viral NA. Recently it has been shown (Fraenkel-Conrat, University of California, Berkeley) that certain sites on the viral NA are more susceptible to mutation than others. He observed that although the nucleic acids are composed of only six types of compounds (a sugar, phosphoric acid, and two each of two classes of common cyclic, nitrogenous compounds—purines and pyrimidines), a chemical reaction specific to one of the pyrimidines—of which there are from 1,000 to 10,000 per NA—does not result in many subsequent amino acid changes, but in relatively few. This implies that very few pyrimidines react—those in specific, exposed positions. Thus, certain positions are more mutagenic than others—a fact which has been known to geneticists for some time, but which did not have a firm basis until these molecular biological studies.

* * *

CONFIRMATION OF OPERON THEORY THAT A SINGLE ELEMENT COORDINATES THE ACTIVITIES OF ADJACENT STRUCTURAL GENES—The study of regulatory systems in bacteria has led to the hypothesis that chromosomes may be organized into units of transcription and regulation called operons. An operon contains one or several adjacent structural genes whose activities are coordinated by a single element or operator. The operator is considered the receiver of the regulatory signal for the whole group of genes belonging to the operon. A major prediction of the operon model is that chromosomal rearrangements which result in a disconnection of a structural gene from its normal operator should result in some alterations in regulation.

This prediction has recently been substantiated by research supported by the National Science Foundation (Jacob *et al.*, Institute Pasteur). The eight genes involved in the pathway of histidine biosynthesis have been shown to constitute an operon controlled by a single operator. The activity of these eight genes is regulated by the end product of the biosynthetic pathway, histidine. Deletions of the operator result in a non-functioning of the whole operon. However, certain

chromosomal rearrangements can restore the activity of the structural genes, but these genes are then no longer subject to regulation by histidine.

These experiments make it clear that the operator element controls the activity of the whole group of structural genes and is the exclusive receiver of the regulating signals. This striking confirmation of the operator's role is a major contribution of our understanding of the mechanisms by which the activities of genes are regulated.

* * *

STRUCTURE OF ANTIBODY RELATED TO ITS FUNCTION OF IMMOBILIZING ANTIGENS—An antibody is a protein synthesized by specialized cells, created in response to the invasion of an organism by antigens—any of a variety of foreign substances (certain polymers found in bacteria entering the blood stream through a wound, in pollen, in specks of flour or fur dust impinging on the delicate mucous membrane, etc.) To all these, the response of the tissues is the synthesis of a specific antibody, so tailored that its shape or three-dimensional configuration allows it to combine with and immobilize the antigen. The blood protein fraction associated with disease resistance—gamma-globulin—is also the source of antibody formation. The gamma-globulins are simple proteins composed only of chains of amino acids.

Despite the uniqueness of the antigen-antibody interactions, there are certain structural features which the gamma-globulin (protein) antibodies have in common. One type of antibody, for example, can be treated in such a way as to suggest that it is derived not from a single chain of amino acids but from a combination of three different ones (called I, II, and III). NSF-supported investigators (Porter, St. Mary's Hospital Medical School, London and Haurowitz, University of Indiana) have shown that I and II are similar in size (400 amino acids long) and composition and contain the antigenic sites, whereas III (650 amino acids long) is apparently simply structural, i.e., for maintenance of the spatial configuration of chains I and II.

Recently, it has been demonstrated (Nisonoff, University of Illinois) that chains I and II are derived from different gamma-globulins, both of which contain what appear to be identical III chains. It is therefore suggested from this observation and from other more quantitative aspects that gamma-globulins are made of two, possibly identical, subunits. Each pair of subunits contains either chains I and III or chains II and III.

The particular grouping(s) of amino acids involved in the binding of antigens to antibodies is only beginning to be clarified. Two general

methodologies are used. In one case, the antigen and antibody are allowed to combine and, while in combination, amino acids of the antibody are made to undergo unique reactions. These reactions presumably occur with all the amino acids except those at the antigenic site where the reactive atoms are being used in binding. Following reaction, the antibody is removed and broken down into its constituent individual amino acids to ascertain which did not react. In this way, it has been established that the amino acid tyrosine is at the reactive site of this antibody. An alternative, more direct procedure (Singer, University of California, LaJolla), is to attach a small reactive group on the antigen so that, following combination of antigen and antibody, a reaction occurs at the reactive site in which one of the antibody amino acids is modified. Then, following separation of antibody and breakdown into its individual amino acids, it can be ascertained which amino acids did react. By this procedure, tyrosine has again been identified as occurring at the active site in this type of antibody.

Much work remains to be done. There is no assurance that different kinds of antibodies will not contain different amino acids. Absolutely nothing is known about the three-dimensional relationships or requirements of the binding site. And, finally, there is as yet little knowledge of the mechanism whereby the peptide strands of gamma-globulin can be folded into unique configurations to fit each antigen of diverse shape and composition or of the reason why some substances are antigenic and others not.

This last query is slowly being answered. For example, if a synthetic polypeptide chain consisting of the amino acids tyrosine, glutamic acid, and alanine serves as an antibody, the polypeptide chain must be at least 350 amino acid units long before it will induce antigenicity. Thus, size itself is a factor in the question as to when something is an antigen.

* * *

CHINESE HAMSTER EMBRYONAL CELLS PROVE SUITABLE MEDIUM FOR INVESTIGATION OF MECHANISM BY WHICH TUMOR-INDUCING VIRUSES TRANSFORM NORMAL INTO MALIGNANT CELLS—An understanding of the mechanisms by which cell populations become altered so that they exhibit uncontrolled proliferation (malignancy) is of the greatest importance in cancer research. However, studies of cells in the process of becoming malignant have been hampered by the usually rapid accumulation in tissue cultures of cells containing abnormal chromosome numbers.

It has been known for some time that Chinese hamster cells are much more stable in their chromosome numbers than those of other widely studied species. Recently NSF-supported research (Yerganian,

Children's Cancer Research Foundation) has shown that embryonal cells from the Chinese hamster can be transformed by the tumor-inducing Polyoma and SV 40 viruses without increasing the low percentage of cells with abnormal chromosome numbers. Moreover, no increase in spontaneous chromosome breakage has taken place during the first twenty transfer generations after viral transformation. However, the transformed cells do feature distinct morphological and physiological relationships.

Future experiments under this program are designed to determine the exact nature of cell transformation by tumor-inducing viruses in the absence of the complicating factor of large numbers of cells with abnormal chromosome numbers.

* * *

PROCESS DISCOVERED BY WHICH BARK BEETLES IDENTIFY AND ATTACK SUSCEPTIBLE TREES—Bark beetles, native to large areas of the Western States, attack trees which have been uprooted by storms or chronically deprived of adequate moisture. Although all of the reasons for the relative inability of beetle populations to become established in healthy trees have not been positively identified, investigators have determined that the organisms are able to select trees which are receptive to attack.

After several years of NSF-supported effort, an investigator (Vité, Boyce Thompson Institute for Plant Research) has discovered the process by which the beetles identify and swarm to susceptible trees. Advance scouts attack trees at random but are successful in colonizing only those trees whose oleoresin exudation pressure is less than 4 atmospheres. Within 48 hours after this probing attack by the males of the species, a mass attack by both males and females is launched on the susceptible trees. The mass attack appears to be in response to a volatile attractant produced by the scouts' hindguts and released from the tunnels created by the probing males as they fed on phloem tissue. The grantee is now analyzing the attractant materials chemically to learn more about its production and influence on the behavior of other insect species.

* * *

STRATOSCOPE II MAKES FIRST SCIENTIFIC FLIGHTS—On the night of March 1–2, 1963, the 3½-ton balloon-borne telescope STRATOSCOPE II made its first scientific flight, from the NCAR Scientific Balloon Flight Station, at Palestine, Texas. A second flight was made November 26–27. STRATOSCOPE II is a Princeton University project under the overall direction of Dr. Martin Schwarzschild. Its initial flight, an infrared study of Mars, was a joint effort of Princeton and the

University of California, with Dr. Harold Weaver of California as faculty investigator. Dr. Robert Danielson of Princeton was on-site supervisor of the telescope during both preflight and flight operations. The second flight made an infrared study of Jupiter and certain red giant stars.

Results of the first flight, reported to the American Astronomical Society meeting in Tucson on April 20, showed that the atmosphere of Mars is almost completely lacking in water vapor. Earlier calculations and theoretical treatments had indicated that the water content of the Martian atmosphere might be between $\frac{1}{1000}$ and $\frac{1}{50}$ of the content in the earth's atmosphere. But examination of the Martian spectrum in the region of the three strongest bands of water vapor, a feat not possible from the surface of the earth, revealed the amount of water vapor to be definitely less than $\frac{1}{1000}$ and probably less than $\frac{1}{1000}$ of that in the earth's atmosphere.

Observations from the telescope, floating about 80,000 feet above the earth, clearly revealed a sizable measure of carbon dioxide on Mars, adding strong confirmation to earlier studies made from the earth's surface.

While scientific results of the second flight are not yet available, the operation was termed an unqualified success by Dr. Schwarzschild. Technical difficulties that arose during the first flight were fully overcome, resulting in unexpectedly fine scientific data that is now being analyzed. In addition to Jupiter, the instrument made infrared scans of Betelgeuse, Mira, Aldebaran, R. Leonis, Rho Persei, Mu Geminorum, and Mu Cephei, as well as the moon and Sirius for comparison purposes. Strong absorption bands were observed; in the case of the giant red stars, the bands appear to be very strong in the coolest stars.

Of great significance is the fact that a 6,800-pound telescope has been successfully lofted and flown through the night, while pointing and focusing operations were carried on by remote control from the ground. On both landings damage to the $2.5 million instrument was relatively small. It was the heaviest payload ever carried by a balloon system.

The flights prove the feasibility of large unmanned balloon flight systems for certain scientific purposes. A tandem balloon system was used, with a small "launch" balloon to hoist the main balloon and flight train into the air. During the ascent, as the helium in the top balloon expanded, it passed through a collar into the main balloon so that at altitude both balloons were fully inflated.

The first flight was also the first scientific operation from the Palestine balloon station, a facility of the National Center for Atmospheric Research sponsored and funded by the National Science Foundation.

STRATOSCOPE II is Princeton's continuing program of high altitude balloon-borne astronomical observations, jointly sponsored by NSF, the Office of Naval Research, and the National Aeronautics and Space Administration.

* * *

NEW THEORY EXPLAINS ORIGIN OF STRANGE RADIO EMISSIONS FROM JUPITER—For years scientists have been puzzled by sporadic, low frequency radio emissions from Jupiter. These narrow band, sharply beamed signals occur in bursts of great intensity and exhibit a fairly consistent polarization; that is, the waves nearly always travel away from Jupiter with a corkscrew motion. Furthermore, they can be detected only when certain areas of Jupiter are facing the earth. The frequency of emissions from these regions varies as Jupiter rotates.

As a result of more than three years of observation, a grantee has proposed a new theory to explain the origin of these unusual radio emissions (Warwick, National Center for Atmospheric Research). The theory states that the magnetic field and subsequently the radiation belts of Jupiter are mysteriously off-center, virtually touching the skin-like atmosphere of the planet on one side of the Northern Hemisphere. Because high speed electrons moving along lines of magnetic force emit waves in a narrow frequency band (the frequency of the waves depending on the strength of the field) and because of the lopsided magnetic field of Jupiter, the variations are related to longitude. The investigator believes the earth's upper atmosphere rather than Jupiter's may cause the emissions to be received in bursts of great intensity.

Many questions about Jupiter's radio emissions remain unanswered. Further research in this area will contribute much to an understanding of planetary processes in general and may prove quite useful to manned space flight.

* * *

NEW DEVICE PERMITS DAYTIME OBSERVATION OF LIGHT RADIATING FROM HIGH ATMOSPHERE—Airglow, a type of weak light originating in the high atmosphere, is thought to arise from chemical reactions involving nitrogen, oxygen, and, to a lesser extent, hydrogen. There is a definite relation between the color of the light radiated and the chemical reaction producing it, and study of the light can therefore reveal much about the reactions taking place in the high atmosphere. Until recently observation of the radiation was confined to nighttime except for the expensive and limited observations from rockets and balloons which had the capability of lifting experiments above the region of the atmosphere in which the scattering of sunlight is appreciable.

Under an NSF grant a new device has been developed which permits ground observation during the daytime (Goody, Harvard University), when the state of the atmosphere and the reactions occurring differ greatly from nighttime conditions because of the great amount of energy poured into the atmosphere by the shining sun. The new development takes advantage of the fact that light originating from reactions in the high atmosphere is not polarized and the unwanted scattered light is polarized. The device responds to light polarized only in a particular way.

* * *

NATIONAL RESEARCH PROGRAMS

Among the widely varied research programs for which the Foundation is responsible are those which, owing to geographical location, the need for international cooperation, and the necessity for coordinated planning, are best planned, administered, and funded as national programs. The Foundation's role in each of these varies with the nature of the program, but in each case stems from the Foundation's position as a leading Federal sponsor of basic research and from its close relationship with the scientific and academic community.

United States Antarctic Research Program

The Foundation, through its Office of Antarctic Programs, plans, coordinates, manages, and funds the United States Antarctic Research Program, known popularly as USARP. This program enables scientists of the Nation's colleges, universities, Government laboratories, and other research centers to carry out a wide variety of basic scientific investigations in Antarctica.

The Foundation is advised on polar research matters by 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). Logistic support for USARP is provided by the Department of Defense with the Navy having primary responsibility and, in special cooperative arrangements, by the expeditions of other nations.

During the past year, a new scientific station, Eights, was established on the plateau of West Antarctica; the Antarctic research vessel USNS *Eltanin* (equipped to permit research in a variety of scientific fields) completed her first year of operation in Antarctic waters; preliminary steps were taken for the establishment of a biological station on Palmer

Peninsula; grants were made in support of Arctic research projects with a direct bearing on overall Antarctic studies; and preparations were made for an increased emphasis on upper atmospheric research to coincide with the International Years of the Quiet Sun 1964–65.

At the completion of the austral summer field season, running roughly from October 1 to March 1, about 13 tons of scientific data and specimens were documented and shipped to the United States. Approximately 250 scientific personnel passed through McMurdo Station, the main U. S. Antarctic staging base, during that time.

International Activities

Antarctic Treaty—This treaty, which entered into force in June 1961, provides for international cooperation in the scientific exploration of Antarctica with exchange of data and personnel. The Second Antarctic Treaty Consultative Meeting took place in July 1962 in Buenos Aires and was attended by the Head of the Foundation's Office of Antarctic Programs.

Scientist Exchange—The exchange of scientists with the Soviet Antarctic Expedition, carried out since 1957, continued during the past year. An entomologist from Ohio State University spent the austral winter of 1962 at the Soviet Mirnyy Station investigating the microhabitats of coastal land invertebrates. During the Antarctic summer of 1962–63, a meteorologist from Texas A&M College spent 3 months aboard the Soviet research ship *Ob* studying surface radiation temperatures.

An investigator from the Soviet Arctic and Antarctic Research Institute was aboard the *Eltanin* during two cruises (February to June) and a meteorologist with the Hydrometeorology Institute in Leningrad studied atmospheric circulation at McMurdo Station during the winter of 1963.

The *Eltanin* was also host to a hydrographer of the Chilean Navy, as well as to two marine biologists of the University of Chile. At the same time, several University of Wisconsin geologists working in Tierra del Fuego and on Palmer Peninsula received logistic support, technical assistance, and scientific advice from Chilean authorities.

Cooperative and Joint Programs—The cooperative scientific program with Australia at Wilkes Station continued throughout the year with notable success. A similar arrangement with Argentina at Ellsworth Station, effective since 1959, was terminated in December 1962 when the Argentines decided to close the station because of the difficult logistics problems.

The joint New Zealand-United States program at Hallett Station continues very satisfactorily. Other arrangements with New Zealand

during the past year included participation by a U.S. geologist with the Victoria University of Wellington field party in the ice-free valleys of the McMurdo Sound area, and the inclusion of a New Zealand geologist in a USARP field party in Victoria Land.

Cooperation continued between Canadian and U.S. institutions in conjugate-point investigation of radio-wave phenomena. For the second year, Canadian scientists went to Byrd Station to work, while Stanford University physicists took an active part in the operation of the Canadian end of the link. Two mobile stations were set up in Canada to aid in defining the conjugate area to Eights Station.

Antarctic Information

The Foundation serves as the clearinghouse and source of information for Antarctic records and documents. Furthermore, the United States bears responsibility under the Antarctic Treaty for exchange of information with other treaty signatories. Preliminary actions by NSF in this field include the organization of a library of Antarctic reference materials and the collection of a representative file of color slides. Also, a grant was awarded during the year to the Library of Congress for the preparation of a comprehensive bibliography of current Antarctic literature. This bibliography will be in the form of cards containing abstracts and indexes, to be followed later by annual or semiannual cumulative volumes.

In response to a report of the President's Science Advisory Committee concerning the responsibilities of the Government in the transfer of information, the Foundation is utilizing the facilities of the Department of Commerce's Office of Technical Services to announce and to distribute reports of NSF-sponsored Antarctic research.

Plans for an Antarctic Map Folio Series (Atlas) were formalized, and a contract for its preparation let to the American Geographical Society. In addition, papers were invited for an Antarctic Research Series to be published under a grant to the American Geophysical Union.

In cooperation with the Foundation's Office of Science Information Service, support was provided for continuation of the American Geophysical Union's *IG Bulletin*. Under a similar arrangement, the University of Wisconsin translated for publication the *Information Bulletin* of the Soviet Antarctic Expedition.

Science Programs

The scientific investigations of USARP are carried out at seven stations and a number of in-field regions throughout West Antarctica. The mainland U.S. stations are McMurdo, Pole, Byrd, and Eights.

Hallett Station is run jointly with New Zealand, and Australia's Wilkes Station has a cooperative scientific program with the United States. The *Eltanin*, a 266-foot ice-strengthened research vessel operated for NSF by the Military Sea Transportation Service, can be considered a floating scientific station since it is able to accommodate as many as 40 scientists in such a variety of disciplines as meteorology, upper atmosphere physics, gravity and magnetism, marine biology, entomology, oceanography, and submarine geology.

The *Eltanin*'s scientific and technical complement during the year numbered 101, representing 15 U.S. institutions as well as institutions in Brazil, Chile, and the U.S.S.R. The first American women scientists to work in the Antarctic regions, two marine biologists from De Paul University, participated in two cruises and were joined in one by two women biologists from the University of Chile. During the last year, the *Eltanin* spent 309 days at sea and traveled 44,575 nautical miles in 5 separate cruises in the area around the Drake Passage between Antarctic's Palmer Peninsula and the southern tip of South America.

During the 1963 fiscal year, the Foundation supported 71 active field projects involving 193 people. The accompanying table shows the distribution of effort by discipline.

Field Projects of U.S. Antarctic Research Program—1963

Discipline	Field project	Personnel
Biology	20	36
Geology	10	30
Glaciology	8	31
Gravity and Magnetics	3	3
Seismology	2	5
Oceanography	6	16
Upper Atmosphere Physics	15	32
Meteorology	6	32
Cartography	1	8
Total	71	193

BIOLOGY

During the past year there were 16 biological field programs and 1 caretaking project for the support of the biological laboratory at McMurdo. An additional two programs carried out Antarctic research at home institutions.

As in previous years, almost all field biological programs were based at McMurdo Station. This situation results partly from the excellent air transportation availability which greatly expands the area for investigations, and partly from the station's most extensive scientific complex, the biology laboratory which recently underwent a 50 percent enlargement. Stanford University marine investigations at McMurdo Station were conducted throughout the winter. Fish required in the metabolic studies were obtained by means of nets and traps through holes kept open in the sea ice throughout the period of investigation. A cooperative program between Stanford University and an investigator from the University of Sydney, Australia, to measure growth and development of phytoplankton utilized the aqualung for obtaining evidence of plankton bloom on the underside of the sea ice. Carbon-14 techniques were applied in a study by the University of California, Davis, to measure primary productivity in fresh water lakes at Cape Evans on Ross Island and in the ice-free valleys of Victoria Land. From experiments carried out to determine why algal growth was less evident in certain lakes, it appears that too much light inhibits optimum photosynthesis.

Ornithological programs were carried out by Johns Hopkins University and the University of Wisconsin. Field activities of the former centered around Cape Crozier, Bird Island in South Georgia, and West Point Island in the Falkland Islands. Birds banded by the South Georgia and Falkland Islands teams were 3,000 black-browed albatrosses and 800 giant petrels. So far, 14,800 birds have been banded and their recoveries may serve to reveal patterns of migration.

The homing and orientation program of the University of Wisconsin, hampered by adverse or marginal weather conditions, began in mid-October at Cape Crozier. In early November three sets of homing experiments were carried out with male Adelie penguins released in the center of the Ross Ice Shelf, on the Victoria Land plateau, and on the Marie Byrd Land plateau.

Surveys along the Victoria Land coast north and south from McMurdo Station extended the known locations of springtails and mites about 150 miles in both directions. The Bishop Museum party making this survey also recorded ecological data from various habitats.

Biological studies at Hallett Station by members of both the New Zealand and the U.S. programs were aided during the past season by the availability of a small laboratory and adequate equipment and supplies. The two U.S. biological programs at Cape Hallett were developed by Ohio State University. Lichen ecology studies included recordings of microclimate, rephotographing of lichen quadrants for growth

rate measurements, and weekly moisture content determinations. An OSU microbiological program was begun in early November by fertilizing 1-yard plots in lichen-populated areas with minerals and various sources of carbon and nitrogen. A similar series was also laid out in lichen-free areas.

Primary productivity studies in Drake Passage were continued by Texas A&M College aboard two Argentine vessels. The concentration of chlorophyll *a* and carbon–14 uptake were found to be higher along the Patagonian coast than in the Drake Passage.

Five *Eltanin* cruises (4 through 8) represented the first year of work in Antarctic waters, largely in the Drake Passage and Scotia Sea area between 30° and 75° west longitude south to the limits of ice.

The Bishop Museum continued its overall Antarctic air sampling program by means of nets flown continuously from the *Eltanin's* main mast. The Lamont Geological Observatory of Columbia University carried on sea water analysis during all cruises for primary productivity studies, bacterial density profiles, phyto- and nano-plankton counts, and routine phosphate, nitrate, and silicate analyses. Abyssal, midwater, and surface gear was used to obtain biological specimens for the University of Southern California study. Generally, trawls in less than 300 fathoms gave very large collections, whereas deep-sea dredging or trawling was less productive of specimens. Faunal breaks appear to occur at the Antarctic and sub-Antarctic Convergences and definite vertical zonation of species was observed. During Cruise 4, 2,100 lantern fishes were taken.

Areas worked during Cruise 6 included the shallow waters of the Patagonian continental shelf, Burdwood Bank, and Bransfield Strait. This selection of locales gave good coverage of a wide variety of habitats in sub-Antarctic and Antarctic regions, and the marine collections from this program have made available a very good representative collection of the Antarctic fishes and other specimens currently so poorly represented in U.S. museums.

The Virginia Institute of Marine Science collected some 35 specimens of fish for ectoparasite materials during Cruise 5. A study of the metabolism and molt cycle of crustaceans in relation to temperature and temperature acclimation was conducted by De Paul University during Cruises 6 and 7.

EARTH SCIENCES

Geology—The most ambitious U.S. field geology program yet attempted in Antarctica took place in the summer of 1962–63, involving 10 agencies and 30 field personnel with operations that ranged from the

southern tip of Chile to McMurdo Sound. As in previous years most of the work was concerned with reconnaissance geology.

The U.S. Geological Survey initiated geological studies in the Patuxent Mountains, the southernmost part of the Pensacola Mountains. In general, these mountains are mildly metamorphosed and much faulted, with rocks that are unlike any previously known in this part of Antarctica, though there may be some similarity with rocks from the Ellsworth Mountains. Geologists from the University of Minnesota continued work started in the 1961–62 season in the Ellsworth Mountains.

An Ohio State University party concentrated its studies in the Trans-antarctic Mountain range in the vicinities of Mount Weaver and Mount Wilbur. Coal beds found there attain thicknesses of 20 feet and are of better quality than those previously encountered in the Antarctic. Almost directly south of Mount Weaver is a half-eroded extinct volcano.

A party from Texas Technical College started geological work in the vicinity of the Shackleton Glacier, south of the Ross Ice Shelf, with a detailed study of the basement complex. A University of Wisconsin party, working from Punta Arenas, Chile, made a detailed sedimentological study of the Upper Cretaceous outcrop belt between the Straits of Magellan and the Ultima Esperanza Ranges some 200 miles north for comparison with similar cretaceous sequences of South Georgia and the Palmer Peninsula.

A study of the occurrence and distribution of inclusions in the volcanics of Ross Island was undertaken by a party from the University of Alaska. A Bowling Green State University geologist was included with the expedition from the Victoria University of Wellington, New Zealand, in ice-free ranges between the Darwin and Carlyon Glaciers of Victoria Land. Under a grant made to the Australian National University at Canberra, a special study was started of the chemical and mineralogical variations in the Ferrar dolerite sills, which are known to extend along most of the Trans-antarctic Mountains, intruded mainly in the Beacon sandstone group.

Studies of patterned ground by investigators from the University of Wisconsin continued for the third consecutive year. Pedological studies by investigators from Rutgers University continued programs started during the previous summer. Using trimetrogon photography obtained for mapping purposes, a photo-geology program was initiated at the University of Massachusetts. Studies are also underway to determine the feasibility of geologic mapping from this and from special color photography of the ice-free rock formations. Compilation of morphological data from the McMurdo Sound area is continuing under a program at Tufts University.

Glaciology—A traverse from the South Pole, operated by the University of Wisconsin and including scientists from Ohio State University and the U.S. Coast and Geodetic Survey, covered over 800 miles in two triangular routes between the South Pole and the Transantarctic Mountains in the vicinity of the Horlick Mountains. Snow elevation, ice thickness, near-surface snow and ice character, gravity and magnetic observations were obtained.

A photogrammetric ice movement study was initiated by Ohio State University geodesists with the placing of 178 markers along the 200-mile line between the Whitmore Mountains, which will serve as a fixed site, and Byrd Station. Aerial photographs of these markers were obtained at the end of the season and will be repeated after a few years to determine the ice movement along the line. Under a University of Michigan grant, a similar line of stakes was set out along the northern edge of the Ross Ice Shelf between a fixed site on Ross Island and the eastern part of the Ross Ice Shelf north of Roosevelt Island. Markers will be resurveyed after three years to determine the Shelf movements.

University of Wisconsin glaciologists concluded the initial phase of studies on Roosevelt Island, an ice-covered dome on the eastern side of the Ross Ice Shelf. Detailed ice thickness surveys showed the minimum value to be about 1,900 feet.

Ice deformation studies in the deep pit at the South Pole and at Byrd Station were continued by the Cold Regions Research and Engineering Laboratory. Research on the stable isotopes of oxygen and hydrogen and on microparticulates in the Antarctic snow layers was started by investigators from the University of Brussels. Results of these studies will provide clues to the recent climatic history of the ice cap and the worldwide accumulation of cosmic dust. Testing of the thermal drill designed to penetrate the complete ice sections in inland Greenland and Antarctica is again under way by engineers from CRREL at Camp Century, Greenland, after major delays from mechanical design problems.

Geophysics—Information on the crust below the Antarctic ice cap is obtained from gravity, seismic, and magnetic observations. Regional values of gravity and magnetic fields continued to be compiled in various areas of Antarctica during the past year. On the oversnow traverse, gravity and magnetic measurements were conducted by the University of Wisconsin and the U.S. Coast and Geodetic Survey. In the McMurdo Sound area, a University of Wisconsin investigator conducted local aerial magnetic surveys and obtained surface gravity values at various sites in the Trans-Antarctic Mountains. A proton magnetometer also was trailed behind the *Eltanin* throughout the

operations in the Scotia Sea and Drake Passage, and to and from the scene of operations and the staging port of Valparaiso.

As part of a U.S. Coast and Geodetic Survey program of modernization and standardization of station seismograph equipment at more than 100 stations throughout the world, new equipment was installed in the summer of 1962–63 at the Hallett and South Pole Stations. Seismograph station operations continue also at Byrd Station, and at Wilkes Station, where California Institute of Technology instruments are run by Australian scientists.

Oceanography—Under grants to the Lamont Geological Observatory of Columbia University, a concentrated effort was made with closely spaced hydrographic stations and bathythermograph lowerings to detail the significant Antarctic water mass characteristics, particularly in the region of the Antarctic Convergence. *Eltanin* cruises in the Drake Passage and Scotia Sea were designed specifically for maximum information in the Convergence area. This area, present at all longitudes around the continent, is a region of transition where northward and southward surface movements meet.

Aboard the *Eltanin* another oceanographic program was carried out by Texas A&M College investigators studying carbon dioxide in the air and shallow waters, as well as carbonate saturation amounts. A further major program on the *Eltanin* was the routine collection of long cores of up to 50 feet in length by the heavy piston corer. Collection programs were carried out by Florida State University, Lamont Geological Observatory of Columbia University, and the University of Southern California. Standard bottom camera pictures for use by both biological and physical oceanographers were made at all stations occupied by the *Eltanin*.

On a Navy icebreaker used earlier in the summer season for assisting the passage of cargo ships to Antarctic bases, the U.S. Naval Oceanographic Office carried out a very successful survey in the western Ross Sea, accumulating data from over 120 closely-spaced hydrographic stations. Through a grant to the Texas A&M College, and with the cooperation of the Argentine Navy, investigators aboard an Argentine vessel in the Scotia Sea studied the structure of currents at different levels.

ATMOSPHERIC SCIENCES

Upper-Atmosphere Physics—Antarctic aurora and airglow observatories continued to be operated by the Arctic Institute of North America. A new development of the year was the initiation of work at an auroral substation some 40 miles northeast of Byrd Station. Auroral heights

are now measured by coordinated photography from both Byrd Station and the substation. A program of the University of Colorado to obtain diurnal curves of the hydrogen alpha auroral emission in an area where total darkness prevails throughout the 24 hours is also continuing at Byrd Station. New and improved airglow photometers from the National Bureau of Standards are in operation at all stations, including the vessel *Eltanin*.

Geomagnetic observatories continue in operation at all U.S. Antarctic stations, including the new Eights Station, under the cognizance of the U.S. Coast and Geodetic Survey. Portable micropulsation equipment was installed at Byrd and Eights Stations by the National Bureau of Standards. Radio-noise monitoring on eight different frequencies continues at Byrd Station and has also been initiated aboard the *Eltanin*. Under an NSF contract, the AVCO Corporation is in its second year of a study of IGY data from all stations south of 30° S., while NBS investigators are analyzing *E* and F_1 region characteristics for variations in the composition of the upper atmosphere.

During the past year, prompted mainly by the coming IQSY program, riometers (relative-ionospheric-opacity meters) were installed at Byrd, Eights, and Pole Stations and on the *Eltanin*. These riometers monitor the absorption of cosmic radio noise caused by *D*-region ionization.

With the increased scope of upper-atmosphere physics operations on the Antarctic Continent, parallel programs are being initiated in eastern Canada. For polar areas, eastern Canada and western Antarctica are the only two large land masses magnetically conjugate to each other. Presently in operation or being installed are observatories in Canada at Great Whale (Byrd conjugate), Quebec City (Eights conjugate), Frobisher Bay (Pole conjugate), and Shepherd Bay (McMurdo conjugate). The work in the North is done in cooperation with various Canadian agencies.

Meteorology—The meteorological program of the U.S. Weather Bureau continues to be one of the largest maintained in the Antarctic. With a large volume of synoptic data now available for study, emphasis is being gradually shifted from the routine surface and upper-air studies on the continent to more special research programs and to observations in the waters north of the continent. Standard surface and upper-air programs were a regular part of operations on the *Eltanin*.

Texas Western College of the University of Texas continued its 2-year program of meteorological rocket soundings at McMurdo Station on a schedule of about one per week. Although mechanical difficulties with the rockets reduced the total number of firings, much new data on winds and temperatures to maximum heights of 38 miles were obtained.

Through the U.S. Weather Bureau, continued support went to the International Antarctic Analysis Centre at Melbourne, Australia, where synoptic charts prepared daily for the Antarctic and sub-Antarctic areas are used both for research requirements and in forecasting Antarctic flight conditions. The U.S. Weather Bureau continues its Polar Analysis Center in Washington, D.C., with emphasis on the description and explanation of the physical processes occurring in the atmosphere, ocean, and ice of Antarctica and the surrounding region, and on the establishment of the heat, mass, and water budgets.

CARTOGRAPHY

Although not a basic research field, Antarctic cartography is an essential requirement for the pursuit of studies in all other disciplines. Three phases are involved in the production of Antarctic maps, all of which were actively pursued during the past year—aerial photography, the establishment of geodetic control, and map compilation.

The U.S. Navy performed aerial mapping flights in the McMurdo Sound area and in the remote previously unphotographed parts of the Ellsworth and Pensacola Mountain areas.

In the 1962–63 austral summer, topographic engineers from the U.S. Geological Survey established control reference points in various parts of West Antarctica. One team transported by U.S. Army helicopters completed the program called "Topo East and West" in Victoria Land and in the mountain range southeast from Beardmore Glacier through the Queen Maud Range and Horlick Mountains. In 1,600 miles of traverse, 75 stations were occupied with electronic distance-measuring devices used for base-line measurements, these averaging about 20 miles in length. Field engineers also accompanied the geologists in the ice-free areas of the Ellsworth and Pensacola Mountains, obtaining mountain-peak locations from measured base lines referenced to astronomical positions. Considerable increase in accuracy was achieved by daylight stellar observations.

Production of maps and charts from aerial photographs and the adjustment of control data continued at the U.S. Geological Survey. Shaded-relief maps at the scale of 1: 250,000 were published for the Executive Committee Range, the Thiel Mountains and the Horlick Mountains. Special uncontrolled maps were compiled for local biological and geological work, and a two-layer plastic relief map of the continent, showing surface and subice topography, was completed during the year. The American Geographical Society continued to compile

data for a small-scale map of the continent and published an up-to-date 1: 3,000,000 scale map in four colors.

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Weather Modification

One of the great challenges to modern science is developing the means for altering the weather in a controlled fashion, so that rain falls where there are droughts, rain clouds are dissipated where there are storms, hail and lightning damage are prevented, etc. For the past 5 years, the National Science Foundation, in response to congressional directive, has been supporting a program of research and evaluation in the field of weather modification, as part of its broader program of basic research in the atmospheric sciences. The Foundation also serves as coordinator of the Federal effort in weather modification and has participated in several joint research projects with various Government agencies concerned with activities in this field.

The research program supported by the Foundation includes laboratory, field, and theoretical studies, and statistical evaluations, as well as support of research facilities and instrumentation.

Studies range in scope from examination of microscopic meteorological events to hemispheric or global phenomena, in subject from the nucleation of ice crystals to the physics of major storms, and in purpose from a better understanding of natural events to their artificial creation or dissipation. Included, too, are investigations of the possible effects of weather modification. One grantee, for instance, is studying the changes in heat and water budgets that weather modification might produce in the southwest United States—specifically the effects of 1, 5, 10, 20, and 50 percent increases in the mean annual precipitation. Aside from the obvious increase in water supply and the benefits accruing from it, such changes would alter maximum and minimum temperatures and would bring about departures from the present heat balance.

Much of the field research in weather modification is conducted in the Western States largely because they provide a natural laboratory where it is possible to study weather conditions ranging from the periods of relatively heavy precipitation in the Northwest to the arid Southwest; also to observe the strong influences of terrain (mountains and deserts) on local cloud conditions. In the studies scientists are using new methods and new instrumentation. For example, one group is using doppler radar in its investigation of cloud physics. This radar shows speed and direction of such phenomena as raindrops within a cloud. Computers are used in the formation of mathematical models of weather phenomena. In one such project an investigator is study-

ing the feasibility of artificial modification of tropical storms. Other studies involve examination of lightning processes, hailstorms in the high plains, the physics of convective clouds, and other subjects.

Thirty-six NSF-supported research projects are now underway at university, government agency, and other nonprofitmaking institutions and laboratories. Details of the NSF weather modification program for 1963 will be presented in the fifth annual weather modification report, now being prepared.

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International Indian Ocean Expedition

The International Indian Ocean Expedition (IIOE) is a multinational effort to explore scientifically the world's least known ocean. The Indian Ocean, a fertile and productive sea, is surrounded by countries containing about a quarter of the world's total population. Merely learning more about this ocean's potentially rich and unharvested food resources might make it possible for nations rimming the Indian Ocean to better feed their people and promote their economic development.

The international character of the expedition continues the pattern of cooperative oceanographic studies that began during the International Geophysical Year. Overall coordination of this effort is in the hands of the International Oceanographic Commission for which the National Academy of Sciences is the U.S. representative; the U.S. program is coordinated by the National Science Foundation. Funding for the U.S. program is provided principally through the Foundation and the U.S. Navy, with smaller amounts provided by the Weather Bureau and the Bureau of Commercial Fisheries.

The U.S. program for the IIOE, in accordance with the stated aims of the expedition, is devoted to the scientific examination of four great areas of interest. The first is the tectonic framework—why is there an ocean basin in the first place; what are the forces that have shaped and are continuing to shape the basin; and what are the similarities and differences between this piece of the earth's crust and any other. The techniques used in attempting to answer these questions are primarily geophysical and geological, and they have been or will be employed on expeditions sent out by Scripps Institution of Oceanography, Lamont Geological Observatory, Stanford University, and Woods Hole Oceanographic Institution.

The second broad area of investigation involves the chemical and physical description of the waters and the study of their motions. The techniques used involve sampling of the waters in predetermined pat-

terns, both horizontal and vertical; concurrent precise measurements of water temperatures; chemical and isotopic analyses; and the measuring of currents at various depths. All U.S. ships participating in the IIOE will be equipped for water sampling. The direct measurement of current flow is the particular object of a scientific party from the University of Rhode Island aboard the Scripps Institution's vessel *Argo*.

The third major field is the living populations of the Indian Ocean, plant and animal. All U.S. ships will be equipped to sample plankton and to observe surface biological phenomena, and some will measure primary productivity. The research vessel *Anton Bruun* will have biological oceanography as her primary mission, and the Stanford University vessel *Te Vega* will concentrate on biological and physiological studies of island groups and other shallow water areas.

The fourth main area of research is concerned with the interaction between the ocean and the atmosphere. Several of the U.S. research vessels will be equipped to make upper-air meteorological observations, but the greater part of the U.S. meteorological effort will be based ashore. Observations will be made from aircraft of the U.S. Weather Bureau and of Woods Hole Oceanographic Institution, working in connection with the International Meteorological Center that has been established with the assistance of the Government of India and the United Nations Special Fund; from meteorological satellites; and from meteorological buoys (to be planted in the Bay of Bengal and Arabian Sea with the help of the Indian Navy).

All U.S. vessels participating in the IIOE will contribute to at least two of the four fundamental areas of interest; some will contribute to three; and some to all four. In addition to the vessels already named, the *Spencer F. Baird,* the *Vema,* the *Conrad,* and the *Atlantis II* are or will be participating.

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International Years of the Quiet Sun

As part of the International Geophysical Year (1957–58), the earth was subjected to the most comprehensive examination it had ever received. Scientists of 66 nations participated in this effort. The sun during this period was especially active.

Scientists realized that the scientific knowledge gained during IGY, especially the synoptic data, would be greatly enhanced if complementary data obtained when the sun was quiet (a period of minimum activity) were also available. It was, therefore, decided at a metting of the International Council of Scientific Unions (ICSU) in September 1961 that an international geophysical program be conducted in 1964 and

1965, a period during which the sun would be in that part of its 11-year cycle when its activity would be at its low point. ICSU then recommended participation in this program, to be known as the International Years of the Quiet Sun (IQSY), to all scientific unions and nations.

In September 1962, President Kennedy authorized U.S. participation in the IQSY and designated the National Science Foundation as the responsible agency to correlate the Federal Government's regular activities which contribute to the program and to coordinate and make necessary budgetary arrangements for these additional activities which may be required.

The U.S. program for the IQSY divides naturally into two categories: (1) the continuation and intensification of synoptic geophysical observations, and (2) observations devoted to special research opportunities which are available at the time of least solar activity.

In the synoptic portion of the program there will be an intensified solar patrol: work in geomagnetism, aurora and airglow, ionosphere observations including a vertical incidence network, a radio noise network, a riometer network, several whistler networks covering both very low and extremely low frequencies, and cosmic ray neutron monitors and meson telescopes.

Special research activities during solar minimum will include solar optical and radio observations, as well as active radar, to study the electron density and "temperature" in the disturbed and quiet corona, X-ray and ultraviolet radiation measurements from space probes, examination of the interplanetary medium with plasma and particle detectors as well as magnetometers and instruments for measuring the galactic flux as a function of solar distance, rocket and balloon observations of particle streams entering the upper atmosphere at geomagnetically related points in Alaska, Canada, and the northern United States, conjugate to locations in Australia, New Zealand, and the Antarctic. In the Pacific regions, daily solar variation of the magnetic field will be measured, with special studies of the equatorial electrojet.

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Deep Crustal Studies of the Earth (Project Mohole)

Development of deep-drilling techniques is making possible an attempt to realize an old dream of scientific exploration of the earth's interior. Project Mohole is a national research program, funded and directed by the National Science Foundation. The purpose of the project is to drill through the earth's crust into the mantle. Sample cores and

direct measurements obtained from such drilling will perhaps provide more information about critical geophysical problems than would any other project within current technological capabilities. From this project scientists hope to learn more about the structure and composition of our planet, its age and origin, the origin and evolution of life through studies of the fossils found in the sedimentary layers, and the age and structure of the ocean basins.

The crust, the earth's outer or surface layer of rock is between 15 and 45 miles thick beneath the continents, being thicker under the mountains, and between 3 and 6 miles thick beneath the oceans. Below the crust is the mantle, which extends about halfway to the earth's center (or to a depth of about 1,800 miles) and comprises about 80 percent of the planet's volume. The mantle envelops a core which has a radius of 2,175 miles.

The boundary between the crust and mantle is known as the Mohorovicic Seismic Discontinuity, named for the Yugoslav seismologist who discovered it through the study of the varying of velocity of earthquake waves. He concluded that the faster waves must be traveling through the denser underlying rocks; the slower, through the surface layer of rocks. The zone where these waves changed in velocity, the Moho, was established as the boundary between the mantle and the crust. Hence, the Mohole—a hole through the Moho. And because the crust is so much thinner in oceanic areas than under continents, the Mohole is to be drilled in a deep ocean basin.

Phase I of the project (a small-scale experiment) was completed in the spring of 1961 with the first successful drilling in deep water from an unanchored vessel. A number of holes were drilled, the deepest being 601 feet into the bottom in water more than 2 miles deep. The tests demonstrated that it was possible to hold an unmoored drilling vessel on station under its own power in deep water using steering motors.

With the feasibility of drilling in deep water thus demonstrated, Phase II began. For this effort, drillers will have to pierce 15,000 feet of sediment and rock at a point where the ocean is more than 3 miles deep. Phase II includes deep ocean surveys, the design and construction of deep drilling equipment, and the drilling of a series of holes in the deep ocean floor, one of which is to completely penetrate the earth's crust.

Scientific studies at the drill site, as well as the final disposition and distribution of samples and data, are responsibilities of the National Science Foundation. In carrying out these scientific activities, NSF has the advice and aid of the AMSOC Committee of the National Academy of Sciences-National Research Council. The Committee structure includes various specialized scientific and technical panels. In

1962, Brown & Root, Inc., of Houston, Texas, was selected by the Foundation as the prime contractor of Phase II of Project Mohole. This company has assembled a Mohole Project staff of 70 to 80 people—engineers specializing in drilling, mechanical, and stress analysis techniques and in instrumentation and electronics; naval architects; marine engineers; geologists; geophysicists; oceanographers; and meteorologists.

In general, the program developed by the prime contractor consists of several systems. Some use items readily available, or ones that require but slight modification; others involve new, unusual, and time-consuming developments.

The drilling vessel concept proposed by the contractor is a platform with six columns rising from twin submerged hulls of cylindrical shape. It is self-propelled with twin main propellers on the lower hulls. Positioning is accomplished by right-angle drive propellers located in the columns. The platform could be drydocked in some locations. From the standpoint of working area and stability the platform shows great promise. Power would be supplied by a 20,000 h.p. diesel-electric system. Design studies are continuing, including structural analysis of the platform design by computer methods. This will be followed by testing a model under various conditions of stress (wind, current, etc.).

A dynamic positioning system for the drilling vessel is being designed. A fully automatic system is required for determining and keeping position within a 500-foot radius in 18,000 feet of water. The proposed system will consist of an outer array of radar targets mounted on surface floats and an inner array of sonar targets mounted on taut-line bottom-moor subsurface buoys placed around the drill site. A third array of sea-floor mounted sonar targets will serve as a back-up system. Preliminary designs on propellers and positioning power units have been completed.

A drilling system has been laid out by Brown & Root that utilizes proven equipment design principles and materials and standard engineering practices to the fullest extent. Two methods of drilling are being considered: (1) the conventional method of rotating the drill string from the surface by use of either a rotary table or a power swivel; and (2) a turbo-coring tool, now under development, in which torque is applied directly at the drill bit by means of a fluid-driven turbine.

One of the most critical problems to be solved is that of developing a drill string that can withstand the loads to be encountered. The required string would be about 40 percent longer than any previously used in drilling on land. To solve this problem, the prime contractor has initiated a carefully coordinated laboratory and field testing pro-

gram of steels of higher strength than that currently used in drill pipe. Successful performance of the drill pipe depends on increasing the mechanical strength of the pipe, reducing the effects of corrosion (by mud inhibitors, coatings, or both), and minimizing the fatigue damage imposed on the drill string by vessel motion in the open sea.

Concurrently with the drawing up of the engineering plan and the preliminary design work accomplished on many of the components, surveys were undertaken to determine possible sites for drilling the hole to the mantle. Seismic surveys of sites north of Puerto Rico and along the Barracuda Fault Zone off Antigua were completed in fiscal year 1963. Similar work in the Hawaiian arch area is to begin in the late summer of 1963.

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The United States-Japan Cooperative Science Program

The United States-Japan Committee on Scientific Cooperation was established as a result of agreements between President Kennedy and Prime Minister Ikeda in June 1961. A joint committee of distinguished scientists was formed by the U.S. Department of State and the Japanese Foreign Office to explore ways in which scientific cooperation between the two countries could be improved. The task of the joint committee was not difficult because there are many areas in which mutual scientific interests and highly developed competence in both countries provide a broad and firm base for cooperative activities.

At the first meeting of the joint committee, held in Tokyo in December 1961, it was recommended that cooperative projects should be initiated in the following categories: (1) Exchange of Scholars in the Sciences, (2) Exchange of Scientific and Technical Information and Materials, (3) Research on Earth Sciences of the Pacific Area, (4) Research on Animal and Plant Geography and Ecology of the Pacific Area, and (5) Cancer Research. Subsequently, the Cancer Research Category has been redesignated as Medical Sciences, and two new categories have been added: Education in the Sciences, and Research on Hurricanes and Typhoons.

The National Science Foundation has been given the responsibility for the coordination, administration, and financial support of U.S. participation in this joint scientific venture.

In October 1962, an administrative meeting was held in Tokyo at which administrative ground-rules for the joint program were agreed upon. During the remainder of that fiscal year 9 research projects were funded, and 15 scientific meetings were convened which were attended by 80 American scientists and 80 Japanese scientists.

Cooperative scientific activities which are now under way cover a wide range; included are studies such as joint analysis of TIROS weather data, the study of volcanoes in the United States and Japan, aeromagnetic surveys of calderas, completion and analyses of collections of Pacific Area insects, the study of rice blast fungus and special studies of the natural enemies of insect pests. Plans in various stages of implementation provide for activities such as exchanges of senior scientists to identify areas for future cooperation in research and study; small, intensive seminars on scientific topics; studies of deep ocean trenches, coral reefs, and migrations across the Pacific Ocean; improvement of exchanges of scientific information and materials; and cooperation on projects directed toward the improvement of education in the sciences.

A significant feature of the program is that it is fully cooperative both financially and scientifically. Japanese funds are used for Japanese participation, and U.S. funds support the participation of American scientists. In addition, Japanese and American scientists contribute equitably to each project in terms of special knowledge, facilities, equipment, or experience. Projects are supported in which the scientific achievements from a cooperative effort promise to be greater than if each group worked separately without the special knowledge of the other. For example, in a comparison of United States and Japanese magnetometers and gravity meters, different instruments developed in the two countries have for the first time been compared over the same oceanographic equipment range and under the same conditions. This has permitted evaluation of the advantages and disadvantages of each type of instrument, and more importantly, will permit meaningful exchanges of data collected in either country with either type of instrument. Another example is in the preparation of monographs on specific flora and fauna with the Japanese contributing their collections and knowledge of western Pacific species and Americans contributing their collections and knowledge of eastern Pacific species. The final product of collaboration is scientifically of much greater value and is achieved at much lower cost to each country than if each group had worked separately.

The confidence of President Kennedy and Prime Minister Ikeda that increased scientific cooperation between scientists of the two countries would be of mutual benefit has been borne out. The broad and intense interest in scientific cooperation between U.S. and Japanese scientists has needed only a mechanism for implementation. This has now been provided, and, even in this brief period, there are many evidences of beneficial scientific results. From the point of view of U.S. science,

the program is demonstrating that significant gains can be achieved through the cooperative mechanism.

NATIONAL RESEARCH CENTERS

The national research centers maintained by the Foundation are capital research facilities that are deemed essential to the Nation's basic research effort. They have been established because the cost and other requirements of the programs render them unsuitable for operation by any single academic institution. They are available, or will be when completed, to all qualified U.S. scientists and visiting foreign scientists, subject to priorities based on scientific merit and feasibility of the proposed research. These facilities are also used by staff scientists as well as by a limited number of graduate students.

The centers are Government installations which are managed by independent nonprofit corporations composed of confederations of universities. They are four in number—National Radio Astronomy Observatory (Green Bank, West Virginia), Kitt Peak National Observatory (Tucson, Arizona), Cerro Tololo Inter-American Observatory (Chile), and the National Center for Atmospheric Research (Boulder, Colorado).

National Radio Astronomy Observatory

This observatory was the first national research center established by the Foundation in response to an urgent need for facilities, both complex and costly, to study the heavens by means of the radio waves emitted from sources in outer space. The wide spectrum of observable radio wavelengths as contrasted to the narrow range of visible light greatly extends the possible observation of the heavens, in character and in range. Radio wavelengths are more than 10,000 times longer than optical wavelengths.

To receive and analyze the weak radio signals from space requires a variety of techniques and equipment—huge radio antennas with directional capabilities similar to optical telescopes and very large apertures to intercept as much radiation as possible and to achieve high resolution for wavelengths which may range from one centimeter (about 0.4 inch) to 10 meters (about 11 yards), together with appropriate amplification and recording systems.

In September 1962, construction was completed on a 300-foot transit radio telescope, the largest movable parabolic antenna in the world. Research projects using this instrument have been under way for some time. The Observatory also operates an 85-foot fully steerable radio

telescope, and several smaller instruments including a 40-foot automated dish, a 20-foot telescope, a 120-foot calibration horn antenna, and a 30-foot instrument used for continuing interference measurements. Construction is going forward on a fully steerable 140-foot telescope, expected to be the most accurate in existence when completed in the middle of 1965.

Staff investigations, during fiscal year 1963, included studies of terrestrial magnetism, supernova remnants, normal galaxies, discrete sources, and planets. The staff also initiated a survey of all radio sources on one celestial latitude, in this case +40° declination. With the 300-foot telescope locked in this position, rotation of the earth allows the entire celestial latitude to be scanned every 24 hours.

Green Bank is located in a sheltered valley in the secluded hills of West Virginia, but some noise from nearby towns still interferes with telescope reception. One member of the staff has been studying noise levels in the 200–400 mc/sec. range in order to select optimum frequencies for observations with the 85-foot telescope.

Radio astronomers investigate not only the intensity and frequency of radio sources emanating from space, but also their polarization. The major research program during the past fiscal year was a polarization study by radio astronomers from the U.S. Naval Research Laboratory. These astronomers have observed more than 100 radio sources for possible polarization of radio waves. The 300-foot telescope is also being used for observing the distribution of hydrogen in the Andromeda galaxy and in our own galaxy.

Another 85-foot radio telescope is presently being built to be used in conjunction with the existing 85-foot telescope as a two-element interferometer. By taking advantage of wave interference phenomena, it is possible to increase the resolving power of the telescope combination above that of either telescope alone. The new telescope will be mounted on wheels so that it can be moved down a track for distances of up to 9,000 feet from its twin.

Kitt Peak National Observatory

Located 53 miles from Tucson, Arizona, the Kitt Peak National Observatory was established to provide optical astronomers with high quality telescopes and modern techniques at an ideal viewing location. Research is organized into three categories—stellar, solar, and space.

For stellar research, there is in operation of a 16-inch and a 36-inch reflecting telescope. An 84-inch reflecting telescope is essentially com-

pleted and astronomical research with this powerful new instrument has already been started. Plans have been made for the addition of another 36-inch telescope and a giant 150-inch reflecting telescope to the instruments now available to optical astronomers.

On November 2, 1962, the new McMath Solar Telescope was officially dedicated. This instrument, with an image-forming concave mirror 60 inches in aperture and a focal length of 300 feet, is the largest solar telescope in the world. It produces an image of the sun 34 inches in diameter. Already it is being used part-time for research and soon will be in full-time operation. Its great light-gathering power and variety of possible spectographic dispersions may make it the first optical telescope to be used around the clock. It is excellent for observing bright night-sky objects, such as first-magnitude stars, planets, and the moon.

Work on a 50-inch remotely controlled space telescope is continuing. Designed to develop techniques for operating orbiting telescopes in space and for testing them, this new telescope will be controlled by wire or radio from Tucson.

Most of the research carried on in fiscal year 1963 involved studies of spectra and light intensities of astronomical sources. The vacuum spectrograph attached to the solar telescope was used to make experimental photographs of solar spectra and of sunspot velocity fields. The solar telescope was used to photograph stars, planets, the moon, and the sun.

The 36-inch telescope was especially in demand by visitors for photoelectric photometry studies of the intensity of various light sources. In addition, it was used to make infrared scans of the planets and brighter stars and to obtain spectra of galaxies in the visual red region.

During the past year, substantial progress was made in the space program to obtain astronomical information from above the earth's atmosphere. Included was the firing of an Aerobee rocket equipped with a spectrometer to measure dayglow in the upper atmosphere. The rocket was launched from the White Sands Missile Range in April 1963, with the cooperation of the Naval Research Laboratory. In the future, it is hoped to be able to use space vehicles in conjuction with ground-based techniques in the study of zodiacal light and the atmosphere of the planets.

Other programs of current research include studies of airglow, the eerie glow in the night sky that limits the observation of faint stars. Astronomers are interested in finding out what causes this glow in the atmosphere and in measuring its brightness and variation with respect to sun spot activity and time of day. Another study is investigating the

various disturbances in seeing with the telescopes on Kitt Peak, such as the microthermal fluctuations in the atmosphere and air currents close to the ground. One goal of this program is to determine the optimum design and location of the proposed 150-inch stellar telescope.

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Cerro Tololo Inter-American Observatory

A Foundation-supported search for a suitable location for an astronomical observing station in the Southern Hemisphere culminated early this year in the selection of a 7,400-foot mountain in northern Chile. Named Cerro Tololo, the mountain is located in the La Serena-Vicuna area about 300 miles north of Santiago. The site offers exceptionally fine observing conditions because of its altitude and extremely dry climate. The observatory to be constructed there will be accessible to U.S. astronomers on the same basis as the facilities on Kitt Peak.

Although the major portion of the observing time will be allotted to U.S. astronomers, Latin Americans will be encouraged to use the facilities of the Observatory. When completed, a 60-inch reflecting telescope of the most modern design and a 36-inch reflector identical to an existing telescope at Kitt Peak will enable astronomers to study such objects as the southern part of the Milky Way and the two nearest external galaxies (the Magellanic Clouds). These and other important astronomical objects cannot be observed from the Northern Hemisphere.

The major effort during the past year was the construction of a 14-mile road linking the observatory site with the nearest existing road. Construction is 30 percent complete, and the road should be finished this winter. Other funds were used for the development of an adequate water supply and other utility systems and for the purchase of basic equipment for a diesel generating system.

Following site survey work completed early in the year, actual astronomical research began on Tololo using one of Kitt Peak's two 16-inch reflecting telescopes. A program of photoelectric photometry designed to measure the intensity of various celestial light sources has been carried out. Excellent viewing conditions were reported with clear skies on 90 percent of the nights and with seeing very good most of the time.

Dr. Jurgen Stock, who conducted the site survey, has been appointed Director of the Cerro Tololo Observatory.

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National Center for Atmospheric Research

Established in 1960 at Boulder, Colorado, the National Center for Atmospheric Research seeks to advance basic knowledge in the atmospheric sciences through fundamental research programs and through major facilities developments designed to assist and extend the research and educational programs of universities and other research organizations. It makes possible an interdisciplinary effort on a scale beyond the means of any single university department.

NCAR operates two laboratories—the Laboratory of Atmospheric Sciences and the High Altitude Observatory—and a Facilities Division.

The Laboratory of Atmospheric Sciences is primarily concerned with studies of the terrestrial atmosphere below the levels of the ionosphere. These studies all relate to the development of a fundamental and quantitative theory of the general circulation and long-term climatic change. The problems range across atmospheric dynamics, chemistry, radiation physics, cloud physics, and the theory of turbulent exchange of heat, momentum, and energy.

By carefully observing the many phsyical processes that combine to make up the total behavior of the atmosphere, the center hopes to gain enough basic atmospheric knowledge to devise a mathematical model which simulates climate and weather phenomena. Such a model when perfected might make it possible to improve weather prediction all over the world. Also, using a simulated atmosphere, the total effect of various weather modification experiments could be tested to determine both their effectiveness for the region intended and possible harmful repercussions elsewhere. Currently, scientists at the Laboratory of Atmospheric Sciences are studying the physico-chemical reactions involved in silver iodide cloud-seeding experiments to produce rain, and are conducting theoretical studies of such matters, as propagation of seeding effects, fall rate of concentrated layers of meteoric dusts, development of a qualitative picture of the vertical and radial circulation of intense vortices, and stability and propagation of internal gravity waves.

In contrast, the High Altitude Observatory is dedicated to solar physics, planetary studies, and investigations of solar-terrestrial relationships. One current research program is designed to obtain improved photographic observations of the corona of the sun. Because dust in the atmosphere scatters light from the sun and smears fine details otherwise attainable by telescope, a group of scientists at the High Altitude Observatory send balloon-borne coronographs into the relatively "clean" upper atmosphere. Balloon flights in 1960 revealed that the earth is

accompanied by a dust halo as it revolves about the sun. Knowledge gained about balloon observation techniques and capabilities was applied to an improved series of flights during the summer of 1963. A network of 10 simple eclipse telescopes for solar atmospheric motion studies was in operation during the total solar eclipse of July 1963.

Another atmospheric scientist of the High Altitude Observatory recently proposed a new theory to explain the origin of unusual radio emissions from Jupiter. For a full description of his findings, see page 41.

The Facilities Division is organized to develop plans for, establish, and operate national facilities required to meet those research needs in the atmospheric sciences which are clearly expressed by the university and associated scientific community. One such national facility is the Scientific Balloon Flight Station, located in Palestine, Texas, now in operation as a permanent balloon launching site. It is concerned with all technical aspects of scientific ballooning, including balloon development; command and control systems; tracking, launching, and recovery techniques; and safety devices. The results of the Stratoscope II flight which represents the largest flight yet staged at the station are discussed on page 39.

Personnel of the Facilities Division, in conjunction with scientists from the laboratories described previously, are available to serve as the nucleus of planning groups for coordinating the planning and operation of large-scale research programs required because of the global nature of atmospheric problems.

The detailed design plans for the construction of a permanent facility on Table Mountain just outside of Boulder are almost complete. A contract has been let for the construction of a road to the top of the mountain and for providing a permanent water supply.

RESEARCH FACILITIES

Graduate-Level Research Facilities

A very high proportion of the Nation's basic scientific research is performed in the graduate laboratories of our universities. These laboratories are used by faculty members, research associates, and graduate and postdoctoral students working on theses or other independent projects. The increasing amount of scientific activity and research training, much of it supported by the Federal Government, makes it essential that these laboratories be maintained at the highest possible level of productivity, so that there is no waste of scientific talent or of laboratory facilities.

Unfortunately, graduate-level research facilities in the United States are by and large marked by obsolescent equipment, obsolete buildings, and critically overcrowded laboratories. The vast amount of research, the fast pace of technological progress, and the increasing numbers of graduate students, have caused available facilities to be stretched far beyond a reasonable capacity. With the financial resources of our colleges and universities taxed to the utmost to take care of rising costs of the overall educational program, few institutions can undertake expansion of their graduate laboratories.

Consequently the Foundation in 1961 instituted a program to ameliorate the situation by offering support on a matching basis to institutions of higher learning so that they can carry out, at least in a limited fashion, some of the necessary renovation and expansion of these facilities.

University departments offering at least a master's degree in science were eligible to apply for support, if they could provide from non-Federal sources funds in amounts at least equalling those granted by the Foundation. General-purpose laboratory equipment could be included up to 10 percent of construction costs.

For fiscal year 1963, 142 grants totaling $29 million were awarded for graduate level research facilities. Amounts requested were greater in the physical sciences than in the life or social sciences. Of interest is the fact that there was a significant increase in the number of proposals received in the social sciences.

Although grants were almost equally divided in numbers between those for renovation (69) and those for new construction (73), in terms of dollars new construction accounted for 86 percent of the total.

Grants ranged from $2,100 for remodeling facilities for forest research to $1.6 million for an addition to an existing chemistry building. Representative grants include those for construction of new research facilities for electron microscopy and of research laboratories for a new Emperor tandem Van de Graaff accelerator, also those for remodeling of existing facilities to provide a small astronomical instrument laboratory and a laboratory for physiological psychology.

●

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.

This specialized facilities program provides support for: (1) construction, renovation, and improvement of research facilities for inland field stations, marine biological laboratories, and private, nonprofit research institutions; (2) improvement of facilities for maintaining research materials, including museum research collections and other special materials such as microorganism collections; (3) development of new facilities, including unique designs of existing types of facilities such as large controlled-environment laboratories, cytostats for mass tissue culture work, and other new departures.

Twenty-eight grants totaling $3.5 million were awarded during 1963 in this program. The following are examples of the awards made. A grant was made to Indiana University to assist in the establishment of a new field station at Crooked Lake. NSF support provides funds for a 5,000-square-foot laboratory and a small storage building for boats and heavy equipment; university funds cover purchase of lake shore land and construction of dormitories, faculty housing, and a teaching laboratory. Limnological studies will constitute the primary emphasis of the station's research programs. Five other grants provided research facilities for field stations in southern California, Iowa, Texas, North Carolina, and the Canal Zone.

Grants to marine stations include one to the University of Hawaii for a small marine biology laboratory, another to the Cape Haze Marine Laboratory for a collecting boat, a renovation and facilities improvement grant to the Mt. Desert Island Biological Laboratory and a grant for an additional floor for a new marine physiology laboratory at Scripps Institution of Oceanography.

A major grant was made to the Chicago Natural History Museum to effect an increase of storage space for research collections in entomology and invertebrate paleontology. Another sizable grant was made to the Bishop Museum in Hawaii for construction of a 13,000-square foot entomology building to house the collections and research activities of this institution's comprehensive Pan-Pacific entomological program.

A central bio-instrumentation development facility will result from a grant to the University of California, Los Angeles, the purpose of which is to replace and expand the functions of small departmental machine shops to provide custom designing of instruments in a laboratory setting.

●

Specialized Social Science Research Facilities

This program was instituted during the past year in recognition of the need of social scientists for research facilities. These needs differ somewhat from those of the physical and life scientists. Except for specialized application of computers, sound recording equipment, and other data collection devices, the social scientist requires little equipment. He does have great need for research space, facilities for storing collections and data, and specialized (often temporary or short-life) buildings to serve as field station headquarters. Archaeological and enthnological museums, for example, are almost all badly overcrowded. Storage space of specimen collections is extremely difficult to come by or if available practically inaccessible. In economic and sociological research, the growth of specialized research operations has put severe pressure on the work-space available which is needed for the storage of extensive data and the housing of the analyst teams who process them.

In fiscal year 1963, five grants totaling $160,000 were made. These included: two grants for field training stations—one in the United States for archaeological research and one in Pakistan for social anthropological field work; two grants for mobile laboratories that will facilitate the security of psychological test data on school children (one is being "tropicalized" for later field work in Africa), and one grant that will provide housing for a computer-based teaching laboratory where new techniques of teaching will be explored.

●

Oceanographic Research Vessels and Facilities

The Foundation through this program provides assistance for some of the most urgently required additions to the Nation's facilities for basic oceanographic research, both physical and biological. This consisted in 1963 of support for the construction or conversion of ships and the construction or expansion of shore facilities. Fifteen grants, totaling $5.9 million, were awarded.

One of the vessels is the *Atlantis II* of Woods Hole Oceanographic Institution, the largest and most up-to-date oceanographic research vessel ever built for a U.S. institution. Her design was commenced in 1960, and she was launched in September 1962 and delivered in February 1963. The *Atlantis II* is 210 feet overall and displaces 2,300 tons.

On one of her early short cruises she was within 100 miles of the spot where the USS *Thresher* disappeared in April 1963, and at the urgent request of the U.S. Navy was diverted from her scientific operation to

take an active part in the initial search for the missing submarine. Following her release from that duty, the *Atlantis II* made a geophysical cruise to Puerto Rico to study the area for possible location of the site of the Mohole. Shortly after the first of July she sailed for the Indian Ocean,to carry out studies in the Arabian Sea as part of the International Indian Ocean Expedition.

Also in the 1963 fiscal year Stanford University's motor sailer *Te Vega* was converted for use as a biological research vessel and is now participating in the International Indian Ocean Expedition.

Another new vessel is a 100-foot catamaran to be built for The Johns Hopkins University. The catamaran principle—two long, narrow hulls joined by a rigid deck structure—has certain advantages for a research vessel. The long, narrow hulls have considerably less wave-making resistance than a single conventional hull of the same total displacement, and hence they permit much greater speed to be obtained for a given installed horsepower. At the same time, the double hull provides much more stability than a single hull—pendulum roll is eliminated, and the vessel merely adjusts itself to the slope of the sea surface. In the usual research vessel, deck space on which to conduct over-the-side operations is generally at a premium. In a catamaran, however, deck space is maximized and the separate hulls offer the possibility for the scientists to lower their gear through a hatch in the deck between the hulls, thereby facilitating many of their operations.

Since most of the program of the Chesapeake Bay Institute of The Johns Hopkins University is carried out within the sheltered waters of Chesapeake Bay, and much of it involves the necessity of taking quasi-synoptic observations up and down long estuaries, the speed and seaworthiness characteristics of the catamaran are particularly adapted to the needs of that organization. At the same time, the vessel's performance can be observed in the open sea outside the Virginia Capes and a thorough evaluation of the suitability of the catamaran design for adoption in ocean-going research vessels can be obtained.

Additional funds were provided to Duke University and a contract awarded by that institution for construction of a new 117-foot biological oceanographic vessel. Completion of the vessel is anticipated by early summer of 1964.

Among the shore facilities for which support was provided was a $1,400,000 grant to expand oceanographic facilities at the University of Washington. The University of California received funds for the construction of the research laboratory portion of a new marine biological station to be situated at Bodega Bay, north of San Francisco.

●

University Computing Facilities

Computers have become increasingly more useful and essential for research and training in virtually every scientific field. Their use makes possible solution of problems which because of their complexity and magnitude were previously considered insoluble.

The great need of universities for computer facilities compared with the high cost of acquisition makes it essential that the Foundation provide substantial assistance in this area. Consequently, a program to furnish computing facilities was introduced, with the purpose of providing for the needs of the institution as a whole rather than for one project or one department.

Of interest is the pattern that has emerged in the development of computer facilities at those universities with strong research programs. Once an institution has gained experience from a small machine, a full-time, three-shift operation has normally resulted in about a year and a half. The capacity of the computer is thus increased through acquisition of peripheral equipment. This is followed by acquisition of a computer of intermediate or large size. Eventually this system may be replaced by a very large computer. Currently a few universities have outgrown even these machines and are planning the construction of giant computing systems. Since none are commercially available, the cost of such systems may be as much as $20 million each.

This growth pattern is characteristic of computation centers which are very successful in serving the research activities of their institutions. It is not unusual, therefore, for the Foundation to receive and give favorable consideration for a proposal for assistance in acquiring a large computer for an institution which a few years earlier had received a grant for a smaller machine.

Because of the magnitude of the need, the Foundation has been able to provide only limited support. In some few cases institutions have been required to provide as much as two-thirds of the purchase price from a non-Federal source.

A requirement of the Foundation is that the computers to be acquired or rented must be high speed and of advanced design for use in basic research and available to all departments of the university.

In fiscal year 1963, 13 grants were made at a cost of $4,980,000.

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University Nuclear Research Facilities

Nuclear structure physics is a major field of research, presently accounting for about 25 percent of the doctoral dissertations in physics.

The National Science Foundation has played an increasingly significant role in the support of this research. In 1961–62, at the request of NSF, a panel of experts in theoretical and experimental nuclear structure physics made a detailed study of this field—to identify trends, describe the frontiers of research, and estimate present and future needs for equipment and operating funds. The panel report, *Research Trends 1962–1967: Nuclear Structure Physics,* was published in January 1963. It pointed out that recent developments in instrumentation, experimental results, and theory have caused a renewed interest in this field; it also stressed the fact that a major laboratory retooling would be necessary if effective use of manpower was to be achieved and the rare opportunity presented by these new developments fully exploited.

Even before the report was published the interest among university scientists was reflected in a surge of excellent proposals for the purchase and use of new types of accelerators and vastly improved terminal instrumentation. In response to this situation, the NSF expanded its university nuclear research facilities program to include accelerators and other auxiliary equipment for nuclear structure research.

Including fiscal year 1963, grants totaling $15.4 million have been made to eleven universities in partial support of modern accelerator facilities for nuclear structure physics. It is expected that efficient utilization of these facilities, upon their completion, will require an increase of approximately $2.6 million in the annual research operating cost at these universities.

This program also provides facility support for other nuclear research facilities at universities, such as research reactors for nuclear engineering. During fiscal year 1963, NSF made seven grants for accelerators and related equipment and one for a research reactor, for a total of $8,500,000. Under the program NSF provided third stages for each of two multistage electrostatic accelerators (with total energies of 21 MeV and 18 MeV, respectively), a 20-MeV, 2-stage electrostatic accelerator, a 50-MeV variable-energy cyclotron, and a 5.5-MeV electrostatic accelerator. In addition, grants were made to two universities to purchase auxiliary equipment for accelerator facilities, including one for which the university provided funds for the initial purchase of the machine. The research reactor grant was made in order to permit the purchase of a more powerful and improved reactor than the one for which funds were previously made available.

The provision of these facilities will help the United States in maintaining its position of leadership in the important field of nuclear research.

●

University Atmospheric Research Facilities

In keeping with the acceleration of the Nation's research effort in the atmospheric sciences, the number of major university departments engaged in such research has doubled in the past 3 years from 15 to about 30. However, there has been no substantial increase in the availability of facilities.

Most investigations of atmospheric processes, a recent report by the National Academy of Sciences emphasizes, require an outdoor laboratory equipped with batteries of electronic measuring and recording devices, and other observational and analytical instruments. Such installations are costly and the training of personnel capable of staffing and utilizing such a large-scale workbench is a lengthy process.

The Foundation has, therefore, established during 1963 a program of support to universities to enable them to acquire the necessary facilities for field and laboratory research in atmospheric sciences.

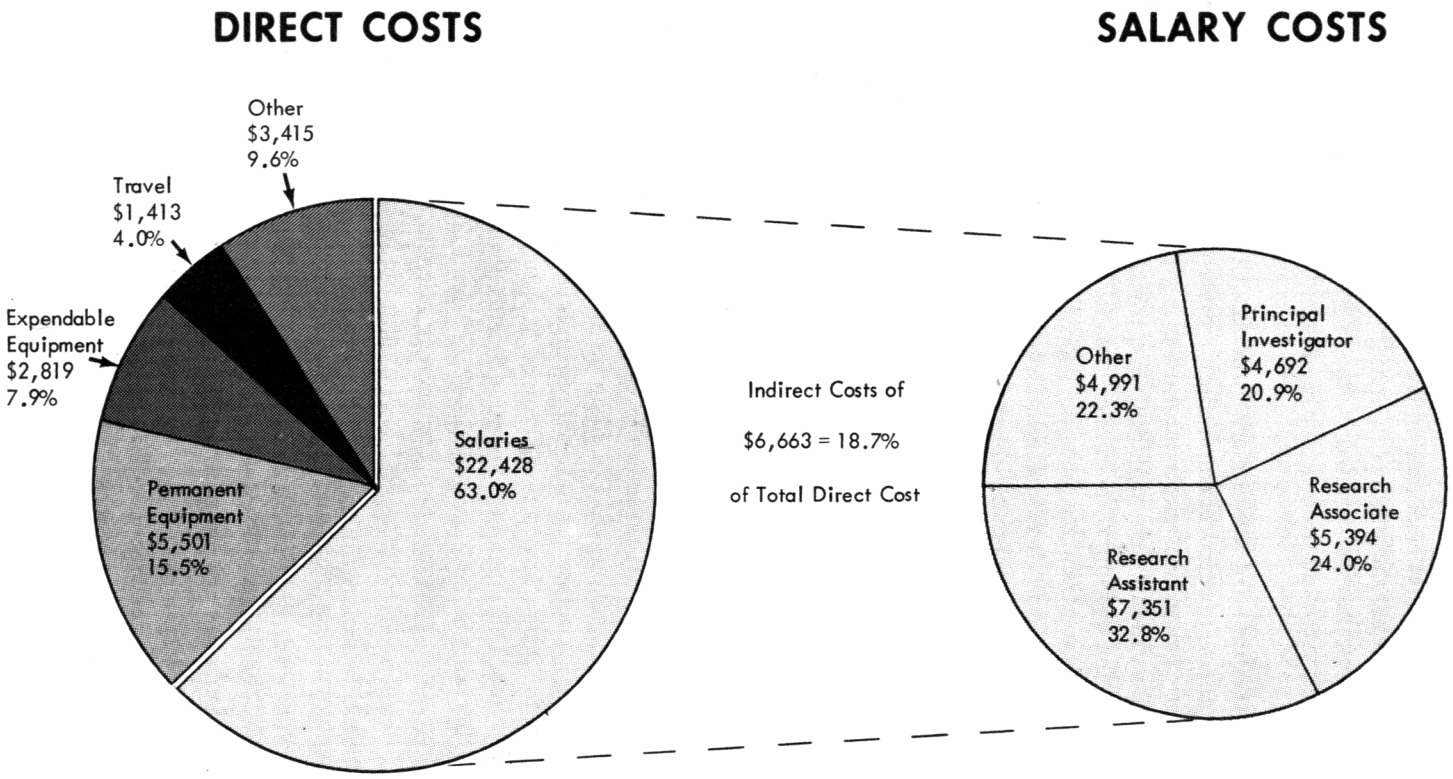
In 1963, five grants were made at a cost of $750,000 for such facilities and equipment. Illustrative of these grants is one for a field station to provide coordinated optical and electrical observation of lightning, and another for equipping a meteorological and hydrodynamics laboratory.

FISCAL ANALYSIS OF RESEARCH PROGRAMS

A total of 2,572 grants were made in support of basic research in the 1963 fiscal year and were awarded to 368 institutions throughout the United States and its possessions. Funds for research activities amounted to $194 million—$117 million for research grants, $53 million for facilities, $14.5 million for national research centers, and $9.5 million for the Indian Ocean Expedition, Project Mohole, International Year of the Quiet Sun, U.S.-Japan Cooperative Science Program.

Research grants in 1963 averaged $42,239 for a 2-year period. In the mathematical, physical, and engineering sciences, grants averaged $49,175; in the social sciences, $40,232; and in the biological and medical sciences, $34,362.

The accompanying table summarizes the research grant program by subject categories. A detailed listing of grants showing institutions, principal investigator(s), title of project, duration and amount is given in appendix C.



Note: Based on Average grant of $42,239

Figure 1. ***Distribution of Research Grant Funds, by Type of Expenditure, Fiscal Year 1963.***

To learn how plants adapt to vastly different environments, botanists at the White Mountain Research Center in California are conducting field studies of vegetation ranging from lichens to the extremely ancient bristlecone pines shown here. This is accomplished through analysis of plant respiration and metabolism while controlling temperature and light. Mounted on the tree is a temperature-controlled respiration chamber which, in conjunction with a gas analyzer, is being used to measure carbon dioxide metabolism.

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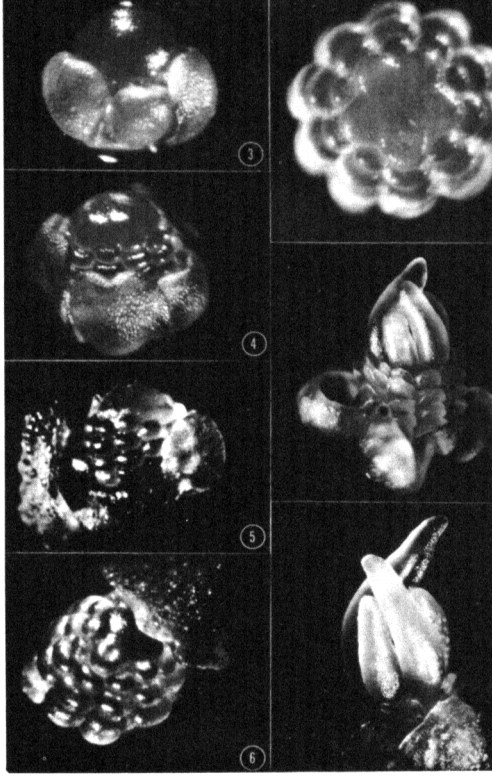
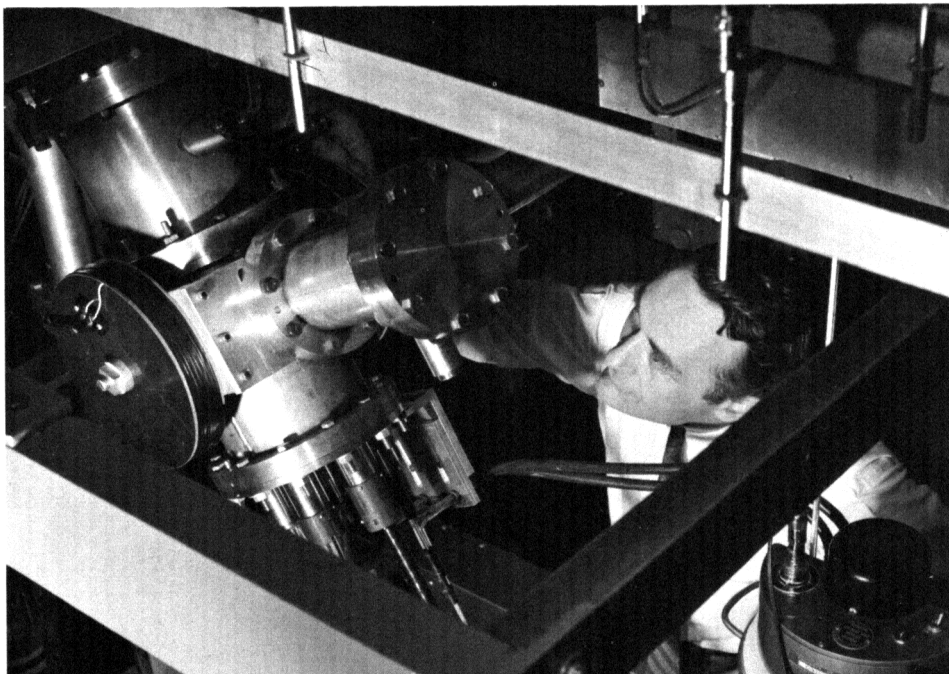
A new electronic mapping technique, developed at the University of Washington, is now being used in an urban renewal study in Spokane. Through the new technique, a computer prints out a given arrangement of land use factors on paper. When the paper is placed under an acetate outline map, the factors fit relative locations on the map.

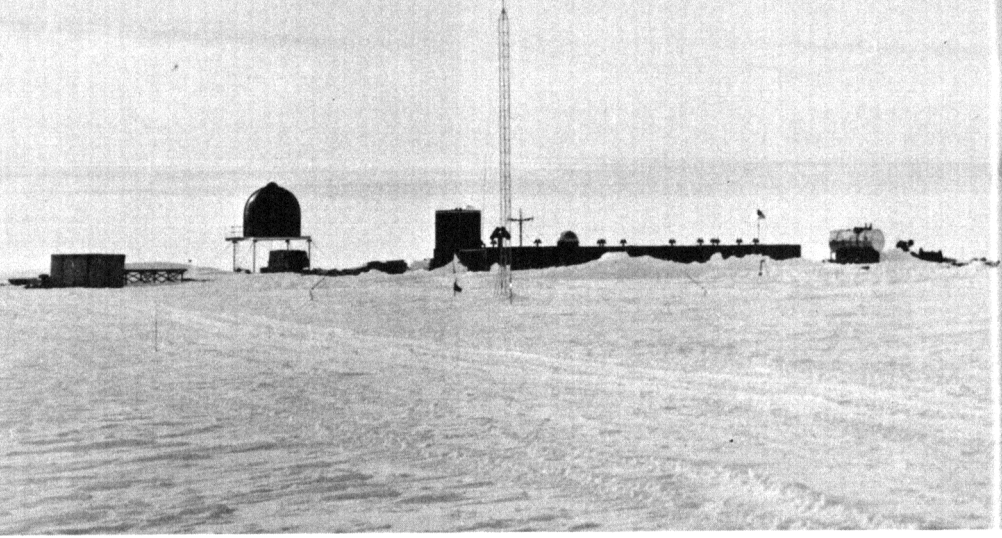
The flask of light-emitting bacteria being examined by a University of Georgia investigator is indicative of the increasing interest of scientists in bioluminescence, the production of light by living organisms. The study of bioluminescence is leading to a better understanding of energy transfer in biological systems.

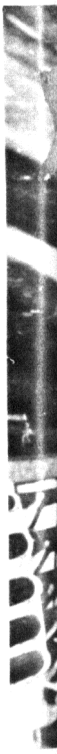


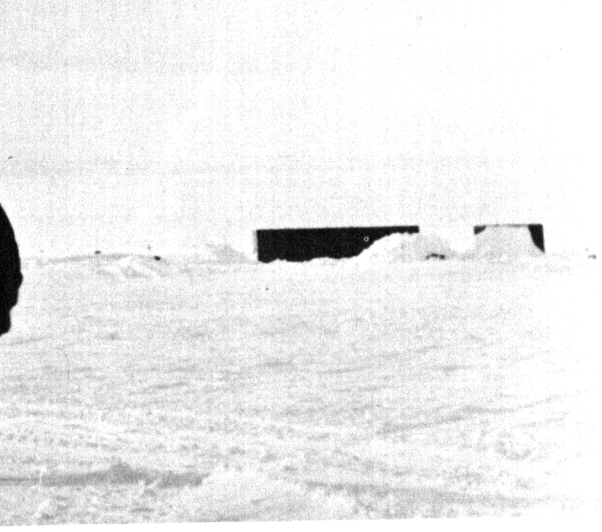
At the University of Oregon, success in growing tiny floral buds on a newly developed culture medium has provided scientists with a means of studying the mechanisms which control development and differentiation of floral structures. Figures 3, 4, and 7 show buds at various growth stages when placed in culture. Later growth, with development of various organs, is shown in figures 5, 6, 8, and 9.

Modern research in chemistry utilizes instruments which increase the speed and accuracy of measurements as well as make possible experiments not possible before. This University of Florida chemist operates a high resolution mass spectrometer in his study of reactions between ions and molecules. New ions resulting from such reactions are sorted out and identified with the aid of electric and magnetic fields.

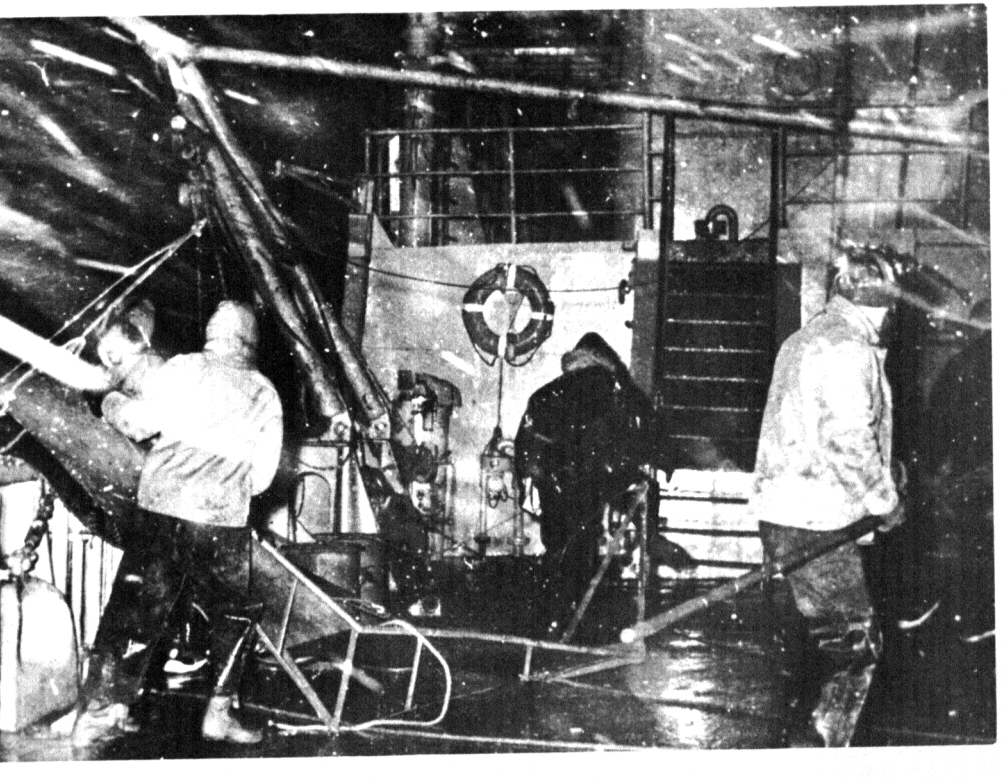




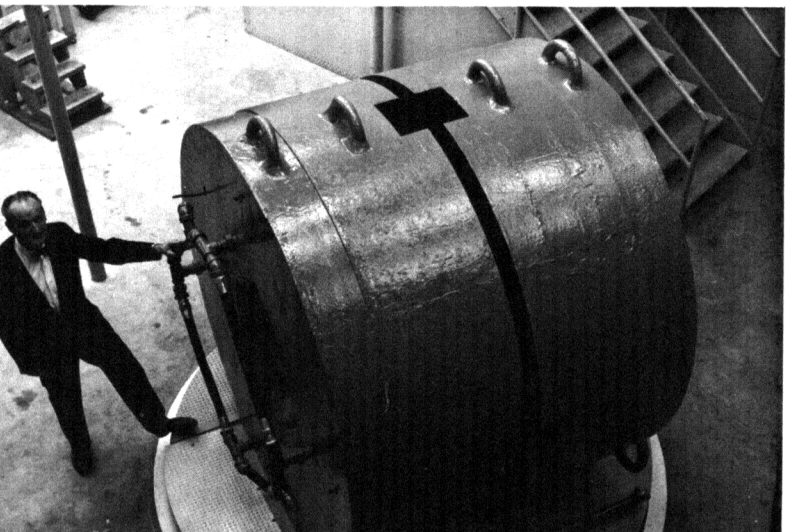


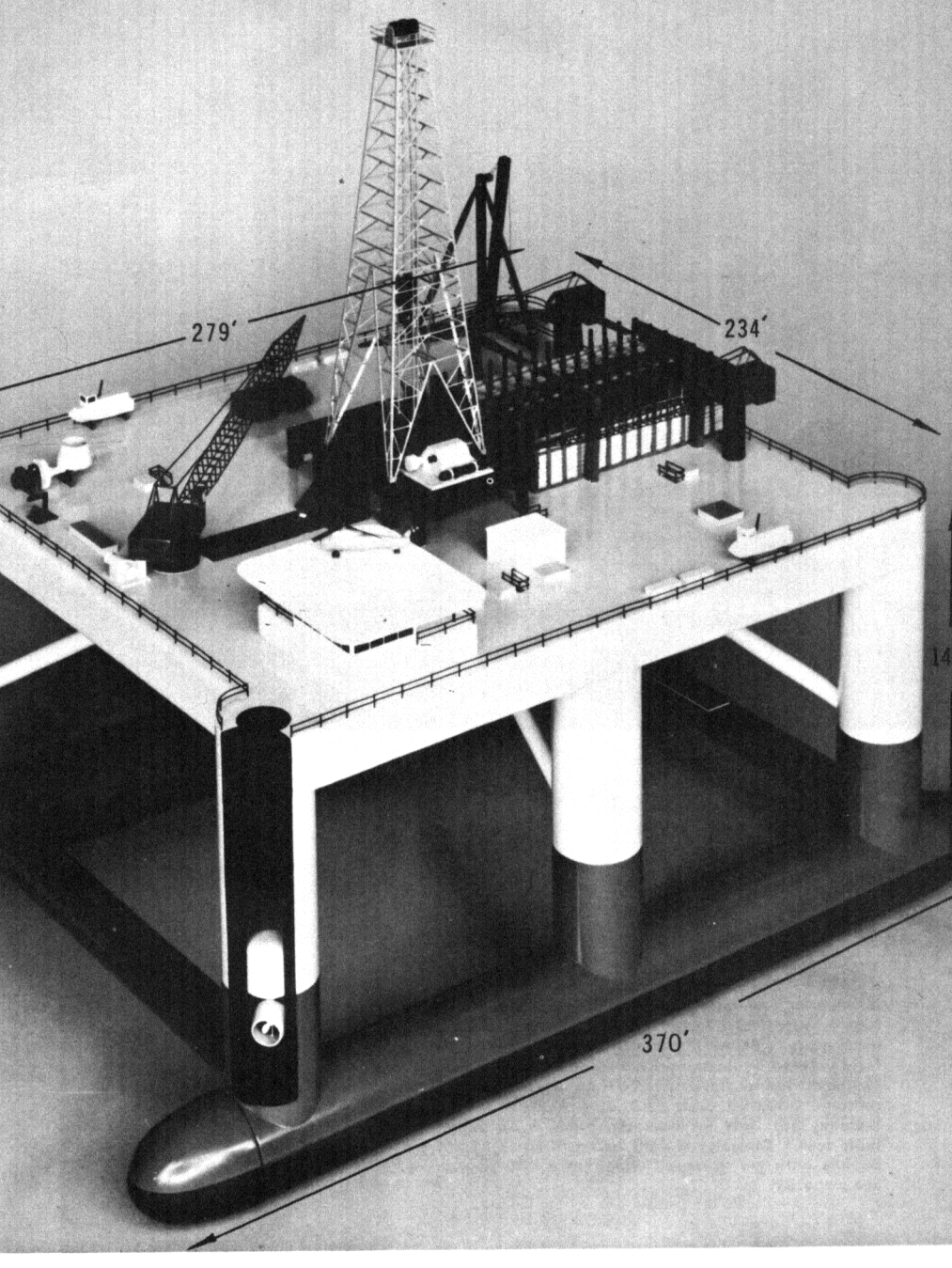


U.S. scientists, with the support of the Foundation, are probing nature's secrets on a broad front. At cold, windswept Eights Station, above, a new U.S. Antarctic Research Program facility established in 1962–63, scientists are conducting studies in upper atmosphere physics. They will take part in the International Years of the Quiet Sun program to begin early in 1964. Below, scientists aboard the research vessel *Eltanin* fight heaving decks, darkness, and a blizzard to haul in a trawl during a cruise in Antarctic waters. Below, left, in a warmer climate biologists aboard the *Anton Bruun*, U.S. research vessel taking part in the International Indian Ocean Expedition, sort specimens brought aboard by net.

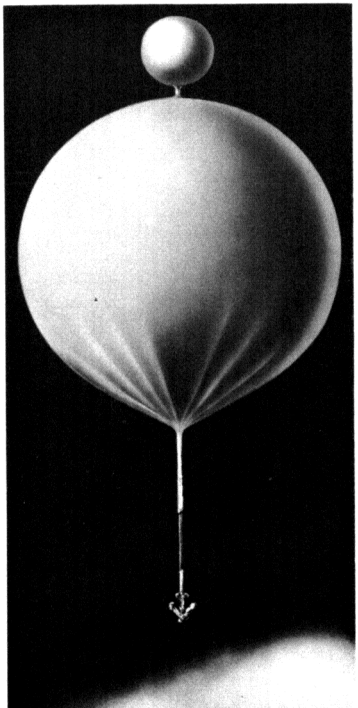


Radio astronomers will have available the most accurate radio telescope of its type in the world when this instrument is completed at the National Radio Astronomy Observatory, Green Bank, W. Va., in 1965. The massive aluminum girders are part of the rigid, 2,500-ton, fully steerable 140-foot antenna which will detect radio emissions from sources deep in space. Below, the intense magnetic field developed by this 45-ton iron-core electromagnet at Ohio State University helps produce temperatures near absolute zero (−460° F.). These temperatures are necessary for the study of superconducting metals—metals which offer no resistance to electric current at extremely low temperatures.





Designed to ensure maximum stability and optimum positioning capability, this drilling platform is being considered for use in carrying out Project Mohole. The upper hull, or platform, has three decks and contains all machinery, living quarters, laboratories, and drilling equipment. The two lower hulls are used for storing food, drilling mud, and ballast. For drilling, the columns are partially flooded and the lower hulls submerged to increase the vessel's draft.



STRATOSCOPE II, Princeton's 36-inch balloon-borne telescope, during balloon inflation prior to the highly successful infrared study of Jupiter and red giant stars. Below is an artist's conception of the fully inflated balloons and telescope at 78,000 feet. The small launch balloon is 75 feet in diameter and contains 300,000 cubic feet of helium; the large balloon, 230 feet in diameter, holds 5.25 million cubic feet. The total weight being lifted is 13,250 pounds with the telescope weighing 6,800 pounds. **See page 39.**

Table 1.—*National Science Foundation Research Grants, by Fields of Science, Fiscal Year 1963*

Field	Number	Amount
Biological and medical sciences:		
Developmental biology	104	$3, 982, 900
Environmental biology	156	4, 693, 900
Genetic biology	85	3, 784, 640
Metabolic biology	121	4, 485, 060
Molecular biology	164	7, 944, 225
Psychobiology	114	3, 282, 500
Regulatory biology	146	5, 149, 300
Systematic biology	208	3, 891, 222
General biology	12	938, 950
Subtotal	1, 110	38, 152, 697
Mathematical, physical, and engineering sciences:		
Astronomy	69	3, 701, 769
Atmospheric sciences (including weather modification)	72	7, 497, 710
Chemistry	238	9, 482, 440
Earth sciences	221	10, 227, 397
Engineering sciences	289	11, 973, 980
Mathematical sciences	242	9, 953, 450
Physics	194	12, 817, 250
Subtotal	1, 325	65, 653, 996
Social sciences:		
Anthropological sciences	94	2, 654, 750
Economic sciences	36	2, 211, 100
History and philosophy of science	29	451, 600
Sociological sciences	64	3, 660, 975
Subtotal	223	8, 978, 425
Antarctic research (life and physical sciences)	57	4, 428, 092
Total	2, 714	117, 213, 210

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INSTITUTIONAL GRANTS

The Institutional Grants for Science Program provides colleges and universities with funds which they may use freely for a variety of scientific purposes. Thus, whereas most Foundation programs support specific, well-defined activities, Institutional Grants may be employed by colleges and universities to offset imbalances or distortions in their science programs, extend or build excellence in self-chosen areas of specialization, or plan and develop new scientific activities. Designed to respect and sustain institutional integrity, the grants afford modest but effectual support for the reaching of goals in science set by the institutions themselves. The grants are "institutional" in a broad sense: the chief administrative and academic officers of the recipient institutions may determine how the funds shall be applied. They are required to use the funds only for science, not for other purposes or for indirect costs, and to report annually on the uses made of the grants.

When the program began in fiscal year 1961, it was intended especially to enhance the research capabilities of colleges and universities already receiving research grants from the Foundation. The flexibility of use of Institutional Grant funds, however, enabled recipient institutions to apply them to instruction in the sciences as well as to research. Reports on the uses of the first year's Institutional Grants show that in many institutions needs in research and education are inseparable and that advancement in one of the two areas may foster comparable advancement in the other.

Since Institutional Grants furnished an ideal way of promoting total institutional advancement in science—both in research and instruction—and the healthy stimulation each gives to the other, an important change was made in the program in fiscal year 1963. In addition to research grants, two programs in science education—Undergraduate Science Education and Research Participation for College Teachers—were added to the base from which Institutional Grants were computed. In this way, the grants reflected the Foundation's desire to encourage high-quality instruction in the sciences as well as high-quality research and to bolster the effort of certain institutions to increase the supply of highly trained scientific manpower. This broadening of the Institutional Grants base brought into the program for the first time a number of undergraduate colleges that have particularly emphasized education in

science rather than faculty research. At the same time, of course, the extension of the program to these additional institutions furnished them with resources to encourage scientific research by their faculties.

Annual reports on the grants made in 1961 show a variety of uses. Among these were: the awarding of small research grants, particularly to young, new faculty members; the purchase of scientific equipment for research or instruction or both; the expansion of scientific libraries; the extension of research opportunities for both graduate and undergraduate students; the inauguration of new areas in science curricula and of new doctoral programs; the payment of honoraria to distinguished visiting scientists; the establishment or enlargement of computer facilities; and the development of cooperative activities in science among neighboring institutions.

In 1963, Institutional Grants totaling $7.6 million were awarded to 397 institutions.

As in the first 2 years of the program, Institutional Grants were computed by formula. In 1963, the formula was as follows: 100 percent of the base to $10,000, 10 percent from $10,000 to $100,000, and 5 percent thereafter to a maximum of $75,000. Twenty-two institutions received maximum grants. Over two-thirds (284) of the grants were for $10,000 or more, and over one-fourth (110) were for $20,000 or more. The 397 institutions receiving grants included colleges and universities in all 50 States, the District of Columbia, and Puerto Rico.

EDUCATION IN THE SCIENCES

Over the period of its existence, the Division of Scientific Personnel and Education has evolved a number of programs under which support is granted to scientists for projects designed to effect favorable changes in the processes of education in the sciences. Some of these programs are intentionally still small and experimental; some have been terminated; some have become impressive in size. One of the things that has been learned is that although small-scale experimental programs are very important in assaying the potential of new programs, they do not themselves initiate massive change. Massive change is effected only by a relatively comprehensive approach. This is not to say, however, that a program must be large enough to involve directly every relevant individual or institution in order to create effects that are felt by virtually all individuals or institutions. Rather, given an adequate magnitude—and this magnitude is never precisely measurable—a chain reaction begins which greatly enlarges upon the stimulus.

It is now abundantly clear that the educational programs of the Foundation, most notably the teacher institutes and course content improvement projects, have succeeded in changing the overall aspect of education in the United States. The change affects far more than just science—and it is far from complete.

The change is simply a rebirth of the idea that rigor, scholarship, and intellectual content are important. It is becoming respectable to be a first-rate student or a well-informed teacher. Further, it has become respectable for the eminent scholars to concern themselves with educational matters at all levels. Because the National Science Foundation has a unique relationship with the scientific community, the Foundation's programs have given scientists the vehicle for constructive involvement with educational processes without the feeling of loss of integrity as scientists. Clearly, the Foundation is only one of the organizations influencing modifications in American educational philosophy and practice. But—through its actions rather than through pronouncements or exhortations—the Foundation has become quite possibly the most influential body in American education.

Activities of the Division of Scientific Personnel and Education during fiscal year 1963 further emphasized moving ahead in the improvement of science education in the Nation's schools and colleges. Noteworthy

progress was made in the total improvement effort; more scientists and students of science received support for further training; a greater number of teachers of science, mathematics, and engineering—at all educational levels—were enabled to participate in NSF-supported institute programs; various special projects in science education were given new scope and direction; and course-content improvement activities were appreciably expanded. As emerging needs have been identified, the Foundation has pursued new approaches; as certain programs have fulfilled needs at the national level to the desired extent, support has been shifted to more critical training areas.

Progress in the development of course content materials in science and mathematics for the secondary school level has been most gratifying. By the fall of 1963 commercial versions of texts and auxiliary course materials developed by NSF-supported study groups will be available for the three sciences (biology, chemistry, and physics) generally taught in the Nation's high schools. In addition, a source book for geology and earth sciences has been published. Definitive versions of the mathematics texts, sponsored by the School Mathematics Study Group, are being published and distributed.

It is important to note that success in improving course content at the secondary school level has helped to identify urgent needs at the elementary and junior-high school level as well as the college level. Consequently, support for improvement efforts at these levels has been increased. Improvement of course materials for the social sciences also received increased support this year. In addition to the development of courses and instructional materials in anthropology and the behavioral sciences, some fundamental investigations into the learning process and a number of evaluation studies have been undertaken with Foundation support. Recognition of the usefulness of films for teaching science has increased and Foundation support for film and television presentations has been increased accordingly.

Again many more applications for NSF fellowships were received than could be supported. However, fellowship awards offered in fiscal year 1963 reached an all-time high of 5,092—an increase of 301 over the number offered last year. A new NSF fellowship program—Senior Foreign Scientist Fellowships—was inaugurated by the Foundation this year. The aim of this program is to bring to the United States those outstanding senior foreign scientists whose formal training or teaching and research experience qualifies them to make significant contributions to our graduate training. In its first year of operation the program offered 53 awards.

Training opportunities for teachers of science, mathematics, and engineering provided by NSF-supported institutes increased from 40,700 in fiscal year 1962 to 42,000 in fiscal year 1963. Some 900 institutes received support, most of them offering subject-matter training for secondary school teachers. However there was an increase in the number of college teachers and elementary school personnel participating.

Among the latest developments in teacher-training activities for which the Foundation provided small-scale support in 1963 were: an experiment which may indicate how elementary school teachers can most effectively be trained through the institute mechanism; the inauguration of in-service institutes for college teachers on an experimental basis; a slight expansion of institutes in certain of the social sciences; and the provision of more training opportunities for teachers who teach in technical institutes.

Greater attention was focused on testing new approaches in the special projects in science education area. The Cooperative College-School Science Program, which provides for close association between scientists from colleges and universities and teachers and students from the secondary school level, was given a new direction this year. Grants were made to ten colleges and universities to enable their scientists to work closely with secondary school officials of nearby school systems who desire to introduce one or more of the new NSF-supported science courses into the curriculum of their high schools. In the Undergraduate Instructional Scientific Equipment Program new guidelines for assisting colleges and universities with the purchase of instructional scientific equipment were developed.

COURSE CONTENT IMPROVEMENT PROGRAMS

The Course Content Improvement Program is designed to help bring scholarship of the highest order to the development of curricula, courses, and instructional materials that reflect contemporary scientific knowledge and points of view. Its concern is the improvement of subject-matter content and instructional materials for programs in science and mathematics in elementary and secondary schools and for courses in science, mathematics, and engineering in colleges and universities.

With the successful maturing of this initial curriculum improvement effort, which concentrated on the secondary school program, came increased support for the improvement of teaching of science at the elementary-junior high school level and at the college and university level.

It has become increasingly apparent that curriculum reform in the social sciences is lagging behind the efforts in the biological and physical

sciences and in mathematics. Support for projects in anthropology and the behavioral sciences has been increasing; it is anticipated that this trend will continue and extend over the other areas in the social sciences. In addition to the development of courses and instructional materials in these fields, some fundamental investigations into the learning process and a number of evaluation studies are receiving support. Such projects are expected to be helpful in reinforcing the curriculum reform efforts.

Support for film and television presentations ranging from brief film clips on single topics to complete courses is being increased. This reflects a recognition of the usefulness of films—both for enhancing the effectiveness of teaching and for meeting the manpower shortage. The growing interest in programmed learning probably will lead to the initiation of a variety of significant projects in this area.

A rather striking development in the Course Content Improvement Programs has been the great interest shown by foreign countries in curriculum materials developed specifically for our schools. This country's willingness to share these newly developed course content materials with other nations has generated much good will toward the U.S. The works of a number of the major projects have been, or soon will be, translated and adapted for use in other countries; such efforts have been initiated by foreign scientists and educators and supported outside the Foundation. One desirable result of this development is the enlargement of the arena in which the improved course materials will be tried out; use of the texts, laboratory manuals, and films of several of the larger projects in a variety of educational frameworks and instructional processes should yield valuable information for future curriculum improvement efforts. Also, participation of foreign scientists in some of the study groups has demonstrated that international cooperation is useful not only for the cooperating country, but also provides to the U.S. effort able scientists who can make substantial contributions to the projects.

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Course Content Studies and Development

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. A combination of scientific rigor and pedagogical effectiveness is sought in the treatment of a given discipline or field in order to bring to students at all levels materials presenting accurately

and lucidly current scientific knowledge. NSF support provides for curriculum study conferences, planning groups, and projects to design and develop courses and course sequences, including textbooks, laboratory equipment and procedures, demonstrations, supplementary readings, films and programmed materials, source and guide books for teachers, and other learning and teaching aids. School trial of materials and revisions often are part of the development process. The material thus produced and information about its use are made widely available to schools and colleges. However, the final material must make its way on its own merits and the decision as to its adoption is left entirely to the judgment of the local school systems.

Elementary and Junior High Schools

Four major endeavors received support for preparing materials in mathematics. The School Mathematics Study Group (SMSG), which has produced prototype texts and teachers' guides for grades 4–12, is continuing work on mathematics for the primary grades (K–3). At Stanford University, Professor Patrick Suppes is directing experimentation on new approaches to mathematics for grades K–6. Now that its high school books, prepared with support from sources other than the National Science Foundation, will soon be available commercially, the University of Illinois Committee on School Mathematics has embarked on the development of a mathematics program for grades 7–12 which will take cognizance of improved preparation of students in elementary schools. Under the aegis of Educational Services Incorporated (ESI), a group of eminent mathematicians is re-examining the whole problem of the structure and content of mathematics in relation to the needs and learning capabilities of students through the whole elementary-secondary curriculum.

The past 2 years have witnessed substantial beginnings on efforts that promise to have as great an impact on the teaching of science in pre-high school years as the work carried out since 1956 has had on the reform of high school science and mathematics. A continuing campaign to cope with broad problems in this domain and to stimulate and correlate specific projects is being conducted by the Commission on Science Education of the American Association for the Advancement of Science. Three groups already involve substantial numbers of scientists and teachers and large-scale support. Educational Services Incorporated received additional funds for broad experimentation on science content and materials for the first nine grades. At the University of Minnesota, Professor Paul C. Rosenbloom is leading an effort to devise an integrated curriculum in mathematics and science for grades

K–9. A new project has been launched at the University of Illinois to experiment with still different approaches to science for these grades, with particular attention to the development of a sequential curriculum. Somewhat more modest projects include the continuation of a program at the University of Illinois for developing materials based on astronomy for upper elementary grades; experimental projects at the University of Maryland and Utah State University, at Princeton University development of a junior high school course on fundamental physical principles as revealed by study of the earth; under the sponsorship of Florida State University, the planning of an approach to a junior high school curriculum by scientists and teachers in the Southeast States; and first work by ESI on a ninth-grade physical science course that will draw upon such senior high school materials as those developed by the Physical Science Study Committee and the Chemical Bond Approach Project.

Secondary Schools

Definitive versions of text and auxiliary materials, such as laboratory manuals and teachers' guides developed by three major NSF-supported projects will be available commercially by the fall of 1963: Chemical Bond Approach Project (CBAP), Biological Sciences Curriculum Study (BSCS)—three versions—and Chemical Education Material Study (CHEM Study). These texts and materials are in addition to the PSSC physics text and the SMSG books which are already available.

The School Mathematics Study Group received a grant to continue its work at the secondary-school level, including the development of calculus courses for high school use, preparation of additional mathematics monographs for students (10 have been published to date), continuation of long-term evaluation studies, exploration of interdisciplinary approaches, and production of auxiliary materials, including experimentation with programing. A vector geometry course for senior-high school use and selected topics concerned with the application of mathematics to the physical and life sciences are under development by the University of Illinois Committee on School Mathematics.

Physical Science Study Committee activities, under grants to Educational Services Incorporated, include revision of the teachers' guide, continued work on advanced topics for use in a third semester of high school physics or a combined 2-year course in physics-chemistry, production of a second battery of tests, and filming of additional topics for the acclaimed PSSC film series.

In chemistry, the Chemical Bond Approach Project received funds to complete the final version of text, laboratory manual, and teacher's guides; the Chemical Education Material Study was awarded a grant

to continue the evaluation and testing of the project's course materials, to prepare text materials for publication, and to produce more CHEM Study films.

The Biological Sciences Curriculum Study has been granted additional funds to prepare final manuscripts of the three versions of text, a teacher's handbook, and seven laboratory blocks; to continue development of five additional blocks; to work on methods useful to teaching the less able students and on materials for gifted students; and for further evaluation studies.

Two major grants were made in the earth sciences and meteorology. The American Geological Institute will develop curriculum resources for increasingly popular earth-space courses in secondary schools with initial concentration on the ninth grade. The American Meteorological Society will produce educational monographs in atmospheric science.

A study on new curriculum materials in social sciences in elementary and secondary schools was initiated at Stanford University to identify areas where course development is needed and feasible.

Colleges and Universities

Approximately half the support for college and university level projects went to "nerve center" commissions, whose functions are to act as information groups and to stimulate and coordinate research in course content done by others. For example, the newly formed Committee on Undergraduate Education in the Biological Sciences will center attention on four areas: a thorough study of the advanced undergraduate curriculum, with special emphasis on organization of the substance of modern biology for instruction; the inclusion of proper work in cognate and supportive disciplines in programs for students majoring in biology; better approaches to preparing future teachers of high school and college biology; and the develoment of special opportunities for the study of biology by nonbiology students.

The Committee on the Undergraduate Program in Mathematics (CUPM) was awarded a supplementary grant for 2 years. This group, after developing curriculum recommendations and course outlines for various categories of undergraduates majoring in mathematics, has found the need for suitable courses for preservice mathematics training of elementary school teachers so urgent that it has undertaken to create sample text materials for several such courses. In addition, the Committee will continue to study curriculum needs in mathematics for students majoring in such fields as the physical, engineering, biological, management, and social sciences. It is also arranging summer seminars to meet the needs of college mathematics teachers and beginning a coordinated testing

program of new courses developed by separate projects along the lines of CUPM recommendations.

The Commission on College Physics received NSF funds to continue its activities, which include a survey of on-going projects, the planning of a series of curricular conferences for undergraduate major programs in physics, a program for a series of instructional monographs, the production of materials to introduce modern physics developments in basic physics courses, projects for film production at the college level and for a continuing survey of instructional films, the development and testing of additional teaching aids such as laboratory kits, and the publication of Resource Letters devoted to typical physics course lecture or laboratory topics.

Additional funds were also granted to the Commission on Engineering Education to continue its work in identifying needs and initiating projects for the development of instructional materials, including supplementary teaching aids, and to further the upgrading of engineering faculties.

In addition to grants in support of the activities of coordinating groups, the Foundation made a number of grants for the development of specific courses and materials. Some of these are related to, or stimulated by, the commissions; others have arisen independently.

In engineering, several grants were made to improve laboratory programs and to develop prototype equipment and teaching aids, including programing, in the context of revised courses. Some studies are also under way to improve courses in newer areas of engineering, such as semiconductor electronics and materials science. Of particular interest are two grants made to the American Society for Engineering Education, one for a study of graduate education in engineering, the other for an analysis of the goals of undergraduate engineering. It is hoped that these projects will provide a far-reaching and effective new basis for needed reforms in engineering education.

Recent grants in mathematics have reflected the emphasis on undergraduate mathematics training of prospective teachers, a problem area of national dimensions. However, at least three projects initiated in fiscal year 1963 are concerned with other phases of undergraduate training: Professors R. C. Buck and J. Nohel at the University of Wisconsin will develop an experimental curriculum in engineering mathematics; Professor A. H. Diamond at Stevens Institute of Technology is working on an undergraduate course in mathematical logic; and a grant to the Mathematical Association of America includes funds for producing a filmed course with auxiliary programed material in calculus and analytic geometry, generally regarded to be the cornerstone of the undergraduate mathematics curriculum.

Most projects supported in physics are concentrating their efforts in two major spheres, the development of new approaches and materials for introductory college physics courses, and the improvement of demonstration apparatus and laboratory courses and equipment. For example, a group under the leadership of Professor Charles Kittel is creating a rigorous elementary course which will anticipate the better physics preparation students are now receiving in many high schools. A combined 2-year course in chemistry-physics is under development at Bryn Mawr College. In addition, supplementary grants to continue work on elementary college physics courses have been made to Massachusetts Institute of Technology and Washington University. The American Institute of Physics has established a center for educational apparatus in physics to provide information on apparatus development to colleges and coordinate efforts for improving physics instructional equipment.

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Supplementary Teaching Aids

The purpose of this program is to provide support, through grants made to colleges, universities, and scientific and educational organizations, for the development of audiovisual aids, improved instructional apparatus for laboratory demonstration lectures, and other aids to learning. The program is divided into two categories: The Science Teaching Equipment Development Program (STEDP) and Educational Films and Television.

Science Teaching Equipment Development

This program, instituted in 1959, was set up to receive proposals for the design, construction, and testing of new equipment of potentially wide use in engineering, mathematics, and the sciences. Support is provided for released faculty time, for materials for the design and construction of the equipment, and for trial in classrooms. Grantees make their results available through publication in appropriate journals, through distribution of final reports, and by demonstrations and talks presented at scientific meetings. Commercial production is encouraged when practical.

Educational Films and Television

Projects in this category are intended to increase the effectiveness of teaching by bringing into the classroom certain phenomena not readily available through other means. These include presentations by outstanding teachers and scientists, films describing laboratory techniques,

films to be used primarily for teacher-training purposes, and supplementary teaching aids to alleviate the shortage of adequately prepared teachers at all levels.

The following are examples of such projects in a variety of fields that have been supported by NSF. Grants were made to the Lamont Geological Observatory, Columbia University, for a series of films on the earth and sea to be made during oceanographic research expeditions, and to the American Meteorological Society to continue production of films in meteorology. Several film projects in the social sciences have received support; among the topics to be filmed are Eskimo art, sequences on the current excavations at Tehuacan Valley in Mexico and on the surrounding culture of the existing Mixtec Indians, and a continuation of an extensive effort to record for documentation and teaching purposes the vanishing arts, crafts, ceremonies, and rituals of the Indian cultures of western North America. A number of projects are concerned with capturing on film, for instructional purposes, phenomena exceptionally difficult to treat effectively in the usual classroom or laboratory situations. Among these are projects on low-temperature phenomena and certain topics in fluid mechanics, for example. An area of major emphasis is the in-service and pre-service mathematics training of elementary and secondary school teachers. Several projects which will produce both classroom demonstration and subject content training films were initiated to help meet a problem of national concern, the inadequate mathematics preparation of a majority of this Nation's school teachers.

INSTITUTE PROGRAMS

The Foundation's institute programs for teachers continued to be the largest Federal activity in direct support of education in the sciences. These institutes are designed to improve instruction in science, mathematics, and engineering through the support of group training. Approximately 900 institutes were supported, and about 97,000 individuals filed a total of some 250,000 applications for 42,000 available training opportunities.

Four types of institute programs were supported: (1) Summer Institutes which provide generally 4 to 12 weeks full-time study during the vacation period; (2) Academic Year Institutes, which provide full-time study during regular school sessions for a comparatively small number of teachers who take leaves of absence for a year; (3) In-Service Institutes which provide part-time study for teachers who are simultaneously holding full-time positions in the schools; and (4) College Conferences serving special needs for extending knowledge in specialized fields which

are operated for periods of up to four weeks during times of the year best suited to the schedules of the college faculty members who participate.

Table 2.—*Percentage of Teacher Population Attending Institutes by Teaching Level, 1963*

Teaching level	Training opportunities	Teacher population	Percent participating
College:			
Academic year institutes	100		
Summer institutes	2,100		
In-service institutes	75	110,000	3.0
Conferences	1,025		
	3,300		
Secondary school (grade 7–12):			
Academic year institutes	1,750		
Summer institutes	21,000		
In-service institutes	13,550	180,000	20.2
	36,300		
Elementary school:			
Summer institutes	1,000		
In-service institutes	1,400	1,100,000	0.2
	2,400		
Total	42,000		

The fiscal year 1963 institute programs remained primarily focused upon the subject-matter training deficiencies of high school science and mathematics teachers at approximately the same levels as those of the previous year. However, 38 percent more elementary school personnel and 6 percent more college teachers were supported than in 1962.

The remarkably broad impact of the programs should be noted. During this 1 year, it is estimated that 70 percent of the colleges and universities granting degrees in the sciences had at least one faculty member (the average was between two and three) who attended an institute; the institutes for secondary school teachers probably included teachers from an even larger proportion of the Nation's schools. Although few institutes for elementary school personnel could be supported, they were designed to have maximum effect by emphasizing the selection and training of subject-matter supervisors and "key" teachers from the elementary school systems.

Increased assistance was offered in fiscal year 1963 for teachers who seek advanced degrees, although it is still true that NSF institute programs predominantly support remedial or up-dating training for individuals whose subject-matter background is either insufficient or acquired too long ago. For example, approximately 8,000 of the 21,000 secondary school teachers who attended Summer Institutes were involved in sequential institutes through which many may ultimately obtain a master's degree. Similarly, approximately 40 percent of the 13,545 secondary teachers in In-Service Institutes were enrolled in sequential programs which have a similar objective. In addition, the Academic Year Institutes will enable approximately two-thirds of their 1,865 participants to earn advanced degrees. Thus, the NSF-supported institutes provide not only "refresher" and critically needed short-term training opportunities, but also a very considerable amount of training in depth. (Approximately 34 percent of the individuals who participated in institute training during the past year should ultimately obtain an advanced degree through the assistance of Foundation-supported institutes.)

Grants were made for institutes to be conducted at about 265 different educational institutions, located in all 50 States, Puerto Rico, and the District of Columbia. In addition, new institutes have been designed especially for teachers from Samoa and the Virgin Islands.

Academic Year Institutes

The Academic Year Institutes normally provide full-time year-long study opportunities for experienced secondary and/or college teachers. A typical institute of this type is attended by from 25 to 45 teachers. Frequently, an Academic Year Institute will be attended by both college and secondary school teachers, an intermingling which has often provided extra dividends, particularly when a few college "teachers of teachers" are involved.

During fiscal year 1963, 63 grants were made to support academic-year training for approximately 100 college teachers and 1,750 secondary school teachers.

The following are some of the new developments of special note that occurred within the Academic Year Institutes Program during fiscal year 1963:

(a) Seven institutes were offered in which recent college graduates were eligible to participate as "pre-service" teachers if they had completed all requirements for certification to teach secondary-school science or mathematics, even though they had no actual teaching experience or adequate subject-matter training. These experimental activities were

supported so that their adaptability as programs for use in the original preparation of teachers at advanced levels could be studied.

(b) Eight institutes were offered in which secondary-school teachers of science and mathematics with extensive teaching experience were eligible for special training to prepare them for supervisory or consultant positions in these fields.

Summer Institutes

Summer Institutes were supported for teachers on all levels of the educational system in 1963, with those for secondary school teachers constituting the largest group. The number of individuals participating in such institutes varied considerably, but 50 participants and 7 weeks' full-time attendance were average. Since the institutes offer a single summer project, a participant most often attends a given institute for one summer only. However, it is possible for participants to attend "sequential" institutes at which a coherent program leading to a graduate degree may be followed in successive summers. The program may consist of courses in a single academic field or of related courses in several fields of science.

This year 523 grants were made to enable approximately 2,100 college teachers, 21,000 secondary school teachers, and 1,050 elementary school personnel to attend summer institutes.

It should also be noted that two potentially important experiments were supported during this year. One of these was a project in Vermont to test a promising new institute approach to training large numbers of elementary school teachers. The institute director selected key elementary school teachers from schools throughout the State to participate in a mathematics institute with the expectation that they will return to their schools in the fall and organize in-service programs during the school year for training other teachers under the overall supervision of the institute director. The other exploratory project that may have widespread usefulness in the future involved support for several summer institutes to familiarize subject-matter supervisors and curriculum directors with the major developments in course content improvement. The results expected from this kind of project are that key school officials will become more adequately acquainted with the objectives and potential of current courses and course materials and that the benefits of recent improvements will come to be more extensively and more promptly realized.

Table 3.—*Distribution of Summer Institutes, by Field of Study, 1963*

Field	Elementary school personnel	High school teachers	High school and college teachers	College teachers
Anthropology	.....	1	.....	2
Astronomy	1	2	.....	.....
Biology	4	53	1	6
Chemistry	2	28	1	8
Earth sciences	4	22	.....	2
Economics	.....	1	.....	.....
Engineering	.....	.....	.....	14
History and philosophy of science	.....	1	.....	2
Mathematics	11	117	2	10
Physics	.....	24	.....	4
Psychology	.....	2	.....	1
Radiation biology	.....	12	3	6
Radiation in physical science	.....	4	1	12
Multiple fields and general science	11	148	.....	.....
Total	33	415	8	67

In-Service Institutes

In-Service Institutes offer instruction for secondary school teachers and elementary school personnel during the school year on a part-time basis, at times so chosen that these teachers may participate and still carry on their regularly scheduled classroom duties. A typical institute meets once a week for 3 hours, either during late afternoons, in the evenings, or on Saturdays, with part or all of some meetings devoted to laboratory or field work. These institutes provide an excellent opportunity for the sponsoring colleges and universities to be closely associated with nearby schools in the improvement of science and mathematics instruction. Although the In-Service Institute projects are locally oriented, they are not controlled by particular local school systems but by the sponsoring colleges. The In-Service Institute is an effective mechanism for the training or retraining of a large number of teachers at a low unit cost; it is adaptable to local situations; and it enables the teacher to put the training to immediate use.

During fiscal year 1963, grants were made to enable approximately 75 college teachers, 13,550 secondary school teachers, and 1,400 elementary school personnel to attend NSF In-Service Institutes. The average attendance at an In-Service Institute is about 50 teachers. The principal innovation in this program was the initiation of In-Service

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Institutes for College Teachers. The projects for elementary school personnel were expanded to include about 450 more individuals than was possible during the previous year.

Conferences for College Teachers

Conferences for College Teachers consist of short-term training activities (less than 4 weeks' duration) that are most frequently conducted during the late summer, although they may be held at other appropriate times during the year. Their subject matter is usually specialized, being especially designed for well-qualified teachers who need to be brought up-to-date in some very recent developments in their fields or of some subdivision thereof. This program helps radiate new knowledge, particularly that resulting from the scientific research conducted by graduate schools, to those colleges which do not have graduate schools or to other institutions concerned with such recent developments. During fiscal year 1963, the Conferences program granted support for approximately 1,000 college teachers.

SPECIAL PROJECTS IN SCIENCE EDUCATION

Special Projects in Science Education is the organizational unit concerned primarily with the design, operation, and evaluation of new ideas in science education. Many of the projects involve the continuation of programs initiated on an experimental basis in previous years. Others may be best described as exploratory.

Four major program categories are administered under Special Projects in Science Education: Secondary School Programs, Undergraduate Science Education Programs, Advanced Science Education Programs, and Developmental Programs.

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Secondary School Programs

The basic objectives of the Secondary School Programs are to identify talented potential scientists, mathematicians, and engineers; to reinforce and stimulate their motivation toward pursuing careers in scientific fields; and to advance their scholarly development. A concomitant purpose is, through example and cooperation, to help improve methods of teaching science and mathematics in the secondary schools. These objectives are sought through the especially designed programs described herein.

Summer Science Training Program for Secondary School Students

This program provides opportunities for a limited number of selected secondary school students to associate with scientists during the summer months or, in a few special cases, on a part-time basis during the academic year. Such experience may consist of classroom and laboratory instruction, service as a junior member of a research team, or a combination thereof. Grants are made to colleges, universities, and nonprofit research institutions to carry out these activities. Summer courses occupy the students' full time for a period of from 5 to 13 weeks; academic-year programs provide for approximately the same amount of contact time scheduled over a longer period. The course content of this training does not duplicate regular high school or college courses, and scholastic credit is not given.

During fiscal year 1963 grants for this program totaled 187, providing instruction for 7,000 carefully selected secondary school students. Since the student population in this age group is estimated at approximately 3 million, the program at its present level can accommodate only about 2 in 1,000 of the Nation's students, or 2 in 100 of the top 10 percent.

Cooperative College-School Program

The program is directed primarily toward the upgrading of instruction in science and mathematics at specific school systems. This is accomplished by making available to the secondary schools in a collaborative effort the intellectual resources and facilities of colleges and universities. An outgrowth of the Summer Science Training Program for Secondary School Students, this program too involves the exposure of selected high school students to intensive contacts with qualified scientists in classrooms or research participation situations. The difference is in the inclusion of participating high school teachers who will carry back to their regular teaching duties, first, a better understanding of science and, second, a clearer concept of the capabilities of their abler students.

A new type of activity even more specifically directed at the improvement of secondary-school science education is now supported under this program. It involves close collaboration between a college or university and secondary school officials in the planning, adaptation, and introduction of the newly developed science curricula into one or more nearby school systems.

A total of 46 grants were made in 1963, involving the participation of about 2,400 secondary school students and 730 teachers.

State Academies of Science

A very useful and effective mechanism for communication between the scientific community and the schools of a limited area is the State or regional academy of science. Its membership includes scientists from a broad spectrum of disciplines representing both education and industry. They are familiar with regional conditions and also with personnel of the schools, and they have a definite interest in the improvement of science education in their areas. Fifty grants were made during the year for various activities coordinated through academies such as visiting scientist projects, teacher seminars, junior academy projects, and traveling science exhibits.

Visiting Scientist (Secondary Schools)

This program provides grants to national scientific societies in four disciplines—biology, chemistry, mathematics, and physics—to support visits of outstanding scientists to secondary schools requesting such services. During these visits the scientists make personal contacts with students, science teachers, and administrators, and advise them on matters concerning their problems in science education and career counseling. A primary purpose of the national program is to fill in the geographic gaps where this service is not yet available through a State Academy of Science.

Holiday Science Lectures

Holiday Science Lectures represent a continuing program administered by the American Association for the Advancement of Science. It supports the presentation of lectures on science by eminent scientists in cities located in various parts of the Nation. Attendance is by invitation extended to outstanding students in the area, as well as to a small number of teachers. The usual presentation consists of a series of five lectures delivered in a 5-day period during the Christmas or Easter vacation. NSF made a single grant of $92,000 in fiscal year 1963 to continue this program.

During academic year 1962–63 lecture series were given in New York City, Boston, Chicago, Los Angeles, and Seattle to audiences of 400 to 500 persons in each city, 90 percent of which were students. In the academic year 1963–64, 10 lecture series will be presented.

Traveling Science Libraries

This program has been in operation since 1955. Its purpose is to make available, through temporary loan, sets of selected books on science subjects to elementary and secondary school students, with emphasis on the smaller and less privileged schools. It has been highly successful in stimulating student interest in science and in convincing school authorities that science books should be purchased for permanent use by their libraries.

Circulation of the books to secondary schools was discontinued at the end of the academic year 1961–62 on the ground that sufficient demonstration had been made of their value as permanent accessions to school libraries. For the same reason, a terminal grant of $65,000 was made during fiscal year 1963 to support a final year of circulation of the Traveling Elementary School Library. A total of 3,186 elementary schools have already received this service, and an additional 800 will be served during academic year 1963–64.

Supplementary Science Projects for Students

Concerns of the scientific community with respect to secondary school education result in frequent inquiries as to the possibility of support for projects which fall outside the scope of the categories already discussed. This program provides an avenue whereby a limited number of such projects with exceptional merit can be supported.

During fiscal year 1963 the Foundation awarded 12 grants for this program category. One grant is for the support of a special study to be conducted by a college and a local school system, directed toward the adoption of a new science curriculum; one grant will support a psychological study of high-ability mathematics students; and two will provide partial support for the publication of career information booklets in psychology and statistics. The remaining 10 grants will provide for the direct instruction of secondary school students through a variety of experimental projects outside the guide-lines of the ongoing programs.

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Undergraduate Science Education Programs

The Undergraduate Science Education Programs offer opportunities for undergraduate institutions to raise the quality of their science instruction.

The able undergraduate is provided with the motivation and the challenge needed to inspire his best effort; the teacher with new in-

sights into the problem of improving his entire instructional effort with emphasis on smoothing the transition between undergraduate instruction and graduate study.

Undergraduate Science Education

The Undergraduate Science Education activity has been a remarkably versatile mechanism for effecting improvement in education in the sciences. The original premise—that students of high ability placed in close working relationship with creative scholars will tend to become creative scholars themselves—seems fully justified. The conclusion is not surprising since it is the basic principle of graduate study. The difference lies in the application of the principle to able seniors, juniors, sophomores, and in a growing number of cases, freshmen.

In noting the impact of the Undergraduate Science Education Program on student participants, several other effects of considerable significance should not be overlooked. The growth of institutional interest in providing opportunities for the able undergraduate who is ready for graduate-level study is reflected not only in the rapid increase in the number of Undergraduate Science Education proposals received (1,128 in fiscal year 1963) but in a variety of other ways.

The effect on the faculty may be a most important long-range effect. There are, for example, a number of cases in the universities where graduate faculty members who previously had limited contact with undergraduates are now enthusiastic supporters of undergraduate research. In the smaller institutions many faculty members with good research training, unused because of heavy teaching duties, credit the Undergraduate Science Education Program with giving them the incentive and opportunity to regain lost ground, which comes through close, informal association with questing young minds.

A total of 530 grants were made in 1963, providing opportunities for approximately 6,500 undergraduates.

Three related projects were also supported. One grant, awarded to the Inter-University Committee on the Superior Student (located at the University of Colorado), provides for a study of the relationship between undergraduate research and honors programs in the State universities; two other grants support related conferences at the University of Colorado and at Illinois Institute of Technology, in which attention will be focused on the able student of engineering.

Undergraduate Instructional Scientific Equipment

The colleges and universities of the Nation are facing an ever-increasing tide of applicants for admission as well as increased pressures to

assure that those students with the potential to become the next generation of scientists and engineers are adequately prepared for the necessary advanced study. The dissemination of knowledge, under these conditions, poses major problems which require careful attention to the design of new patterns of instruction and the revision of existing ones. In carrying out the necessary planning and development, substantial progress in upgrading science instruction has been limited by the inability of the institutions to provide an adequate supply of modern undergraduate instructional scientific equipment. To meet a national need in this area, the Undergraduate Instructional Scientific Equipment Program, initiated in fiscal year 1962, is designed to assist colleges and universities offering baccalaureates in the sciences by providing matching funds for the purchase of scientific equipment for undergraduate instruction.

During 1963, grants were made to 409 institutions in 47 States, the District of Columbia, and Puerto Rico. The average grant was for $13,047.

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Research Participation and Scientific Activities for Teachers

Projects supported within this area cover a broad range of activities directed toward improving the subject-matter competence of secondary school and college teachers of science, and toward generating the teachers' interest in the attainment of a broader scientific background and a greater understanding of, and involvement in, the problems of science education. These objectives are approached through research participation programs and through conferences, seminars, and visiting scientists programs.

Research Participation for College Teachers

This program provides the opportunity for college science teachers (including junior college teachers who are qualified) to gain research experience during the summer. Teachers with adequate subject-matter background, but limited research opportunity, have the chance to obtain that stimulation and identity with science which research experience effectively provides.

The program is designed to meet several research needs of college teachers: predoctoral teachers may undertake projects leading to thesis research problems; others may complete such projects. Postdoctoral teachers, particularly those whose home institutions do not have ade-

quate research facilities, are offered an opportunity to again become active in research.

As in past years, academic-year-extension support was provided to selected participants to enable them to carry on at their home institutions research which is an extension or out-growth of work begun in the summer.

Grants awarded under this program provide support for a total of 375 college teachers (193 predoctoral and 182 postdoctoral). In addition, provision has been made for 113 academic-year extensions.

Research Participation for High School Teachers

This program affords a means for a limited number of qualified high school teachers (and junior college teachers not qualified for the companion RPCT program) to gain research experience with competent investigators at colleges, universities, and qualified nonprofit research organizations. Such experience is expected to raise the level of the teacher's classroom teaching by improving his understanding of science and the scientific method. In some cases, teachers are able to carry out research which may lead to an advanced degree.

The provision for a limited number of academic-year extensions has been continued, although the demand has been less than expected. This may be due, in part, to the free time limitations of high school teachers.

Grants made in this program will provide for 304 teachers, and extend support for 92 of them throughout the academic year.

Supplementary Training for Science Teachers

Science teacher-training projects which do not fit into any of the Foundation's established teacher-oriented programs such as fellowships, institutes, research participation activities, and advanced science seminars are considered under this program. The Foundation has encouraged the development of novel approaches to improving the competence of teachers of science, mathematics, and engineering, 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 vehicle 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 subject-matter competence of science, mathematics, and engineering teachers. Twenty-three grants were made in 1963.

Visiting Scientists Program

The Visiting Scientists Program consists of two types of special projects: (a) the "college" projects concerned with visiting American scientists 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 their itineraries.

VISITING SCIENTISTS (COLLEGE)

The major objective of the visiting American scientists projects is to provide to undergraduates 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 faculty, and for guidance to local faculty and administration members on questions relating to curricula and the development of science programs. Visits are usually of 2 days' duration, during which the visiting scientists may give one or more formal lectures, conduct classes or seminars, engage in informal discussions with students, and confer with faculty members and administrative personnel.

During the past fiscal year, 20 proposals were granted support. Fifteen of these were awarded late in the fiscal year for support of programs to operate in academic year 1963–64. In fiscal year 1963 (i.e., during academic year 1962–63) 18 programs were in operation, providing approximately 3,650 days of visits annually to a total of 1,420 science departments. It is estimated that in academic year 1963–64 the number of programs in operation will be 19 or 20, approximately 3,700 days of visits.

VISITING SCIENTISTS (FOREIGN)

Under the foreign visitor program, distinguished foreign scientists are brought to the United States for periods ranging from 3 weeks to a full semester. For the shorter visits, an itinerary program providing for visits of 3 to 5 days is set up by the relevant professional society. For the longer visits, the scientist is usually attached to a major degree-granting institution which serves as his base, and from which he makes visits of 4 or 5 days' duration to other major institutions.

The primary objective of the program is to provide opportunities for broadening the perspective of science faculties and graduate students in the major graduate centers through interchange of scientific knowledge and through discussions of current research problems and research

trends. As in the "college" program, the visitor engages in lecturing, participates in seminars, and confers with faculty members and administrative officers.

During fiscal year 1963, six proposals were granted support. In fiscal year 1963 (i.e., during academic year 1962–63) nine programs were in operation, providing approximately 2,200 days of visits annually.

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Specialized Advanced Science Education Projects

Two major functions are linked with the general effort to improve the quality of education in the sciences under this activity. One function, programmatic in nature, involves the administration of the Advanced Science Seminar and the Public Understanding of Science Programs; the other function, under the title Science Education Developmental Projects, is less restrained by the usual "programmatic" bounds and is concerned with the search for, and support of, more comprehensive plans for major improvement of the science education programs of departments or institutions.

Advanced Science Seminars

Advanced Science Seminars are focused on areas of science of a highly specialized nature or are based on a treatment of subject matter which is "advanced" relative to the formal backgrounds of the participants. Although the seminars are customarily intended for specialists in the field involved, participants are drawn not only from segments of the community of practicing scientists (universities, colleges, industry, and government), but also from appropriate levels of the body of "scientists-in-training" (talented graduate or undergraduate students) depending upon the level and nature of the subject-matter involved. Awards were made for 37 such seminars during the year. (See appendix G for list of seminars held during 1963.)

Public Understanding of Science

The Public Understanding of Science Program is concerned with the development of programs and materials designed to increase the scientific literacy of the general public. The principal devices thus far supported include conferences between scientists and representatives of the mass media of communications, such as editor, science writers, and public information officers; the planning and preparation of science programs for television; adult education programs; and public information services. Through such devices the program aims to develop in

the nonscientific public some appreciation of scientific methods and the significance of the term "research," the historical and sociological implications of science, the limitations of science, and the value of opinions voiced by scientists, both as experts in their fields and as private citizens. A secondary aim of this program is to keep those who have had appreciable training in science abreast of scientific developments in disciplines other than their own.

This year saw a further diversification in the kinds of proposals received and grants awarded. One grant was made for a study of the relationships among the natural sciences, the social sciences, and the humanities. Another was made to assist in the maintenance of the U.S. Science Exhibit in Seattle, Washington, for public use and for the development of other educational programs to make further use of this facility. Two grants were made for symposia, with the majority of the audience being composed of scientists. In this instance, scientists were considered to be a special kind of public needing to understand disciplines other than their own. In addition, a grant was made for a new public information service designed to test the feasibility of translating newsworthy articles in physics journals into the language of laymen for the use of science newswriters.

Science Education Developmental Projects

These projects, experimental in nature, are directed toward support of integrated programs for raising the level of science education at colleges and universities. Requests for support usually originate in a single college department or disciplinary unit which, to reach a desired quality level, requires support for a range of activities not offered through any individual Foundation program.

In fiscal year 1963 a total of 10 grants were made. Included in these grants are support for such comprehensive and diverse activities as: summer fieldwork for graduate students; a massive study of current status and future directions in engineering; faculty study sessions aimed at graduate curriculum revision; teaching graduate students in chemistry how to teach chemistry; integration of computer techniques and ideas into all phases of education in a small technical institution; and a conference to consider training and manpower problems in mathematics.

FELLOWSHIP PROGRAMS

National Science Foundation fellowships are designed to strengthen the Nation's scientific potential by (1) enabling U.S. citizens and nationals of unusually high ability to increase their competence in science,

mathematics, and engineering through the pursuit of advanced scientific study or scientific work, and (2) enriching graduate training in this country through in-residence awards to outstanding foreign scientists. Since the inception of NSF fellowship programs in fiscal year 1952, approximately 28,000 individuals have been offered awards in 8 fellowship programs. Fellowship recipients were selected on the basis of their ability from among some 96,000 applicants. The eighth program, the Senior Foreign Scientist Fellowship, was inaugurated during the past fiscal year.

Table 4.—*NSF Fellowship Programs, 1963*

Program	Number of applicants	Number of awards offered
Graduate fellowships	6, 122	1, 880
Cooperative graduate fellowships	4, 588	1, 300
Summer fellowships for graduate teaching assistants	2, 123	906
Postdoctoral fellowships	918	245
Senior postdoctoral fellowships	298	95
Science faculty fellowships	983	325
Summer fellowships for secondary school teachers	1, 305	288
Subtotal	16, 337	5, 039
Senior foreign scientist fellowships	60	53
Total	16, 397	5, 092

The extramural fellowship programs for U.S. citizens—North Atlantic Treaty Organization (NATO) Postdoctoral Fellowships in Science and the Organization for Economic Cooperation and Development (OECD) Senior Visiting Fellowships—normally administered by the Foundation for the Department of State, were inactive in fiscal year 1963 due to changes in funding procedures. It is anticipated that both programs will be reactivated in fiscal year 1964.

This year the Congress amended the National Science Foundation Act. As a result the National Science Board was given authority to refuse or revoke an award—ability of the applicant or fellow notwithstanding—if it were determined that such an award was not in the best interests of the United States. In addition, the "disclaimer" affidavit requirement was repealed and was replaced by (a) a penalty clause which makes it a crime to apply for a fellowship under certain conditions, and (b) a requirement that applicants file a supplementary statement listing previous criminal convictions and pending criminal charges.

Graduate Fellowships

This program enables students with demonstrated ability and special aptitude for advance training in science to complete their graduate studies with the least possible delay.

In fiscal year 1963 there was an increase of only 2.7 percent in the number of applicants over that of fiscal year 1962—the smallest increase in recent years. The number of applicants seeking fellowship renewals reached a new peak of 1,154. As many as 1,016 of them were offered the desired support. Among the 4,968 new applicants, only 864 could be offered awards with available funds.

Cooperative Graduate Fellowships

Introduced in fiscal year 1959, this program also is aimed at supporting unusually able graduate students, but differs from the Graduate Fellowship Program in that applicants apply through, and are initially evaluated by, the institution at which they propose to study.

For fiscal year 1963 the "recommendation numbers" assigned the participating institutions were the same as in fiscal year 1962, with every school being permitted to recommend at least 20 applicants for fellowships. The number of applicants (4,588) and the number of awards offered (1,300) reached new highs, representing increases of 11.4 percent and 8.3 percent, respectively, over the figures for fiscal year 1962.

Summer Fellowships for Graduate Teaching Assistants

These awards make it possible for Graduate Teaching Assistants in science, mathematics, and engineering to continue their academic studies on a full-time basis during the summer.

The number of applicants increased again this year—16.7 percent over the number for fiscal year 1962—under the system in which institutions are encouraged to recommend as many individuals as they consider qualified for these awards.

Postdoctoral Fellowships

Postdoctoral Fellowships enable persons who have recently obtained science doctorates to undertake additional advanced training as investigators in their specialized fields. Although there was a slight increase in the number of applicants, the number of awards offered was the same as last year (245).

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 298 individuals (28 more than in fiscal year 1962) and 95 awards were offered (only 3 more awards than in the previous year).

Science Faculty Fellowships

These fellowships provide an opportunity for college and university teachers of science, mathematics, and engineering with at least 3 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.

The 325 awards offered in this program for fiscal year 1963 represent the same number offered in fiscal year 1962. However, the number of applicants increased from 864 to 983.

Summer Fellowships for Secondary School Teachers of Science and Mathematics

This program emphasizes study by awardees in the natural sciences and mathematics at a level acceptable to their fellowship institutions as satisfying requirements for the traditional advanced degrees in science and mathematics. As contrasted to the group study programs existing at institutions, these fellowships are for individual study programs.

Both the number of applicants and the number of awards offered decreased for the third consecutive year. The number of applications received for fiscal year 1963 totaled 1,305, which represents a decrease of 264 as compared with the number received in the previous year. The present level of approximately 300 new awards per year appears to be optimum for this program.

Senior Foreign Scientist Fellowships

In November 1962 the Foundation inaugurated the Senior Foreign Scientist Fellowship Program—in cooperation with 80 participating U.S. universities. This program is designed to bring to the United States those outstanding senior foreign scientists whose formal training or teaching and research experience qualifies them to make significant contributions to graduate training in this country. Awards were made only in the mathematical, physical, biological, and engineering sciences and in interdisciplinary fields comprised of two or more of these sciences. Fifty-three awards were offered this year.

DISSEMINATION OF SCIENTIFIC INFORMATION

The Foundation, through its Office of Science Information Service, has continued to carry out its program for improving the availability to U.S. scientists of the results of worldwide scientific and technical research. The program is grounded in the conviction that no research project is complete until its results have been made available for use in further research, and that maximum scientific progress requires maximum effectiveness in the dissemination of research-produced knowledge.

Presidential and congressional directives in 1958 and 1959 charged the Foundation with responsibility for promoting the development of an effective national scientific information system. They place special emphasis upon supplementing, not supplanting, present Government and private efforts, and upon effecting coordination of numerous and varied existing scientific information programs.

THE CHANGING ENVIRONMENT IN THE FIELD OF SCIENTIFIC INFORMATION

The Federal Government

Since 1958, efforts of the Federal agencies with research and development programs, of the Office of Science and Technology (OST) and the Federal Council for Science and Technology (FCST), of Congress, and of the National Science Foundation have combined to create within the Government a vastly improved climate for developing an effective total Government scientific information program. In support of this statement, the following specific actions can be cited:

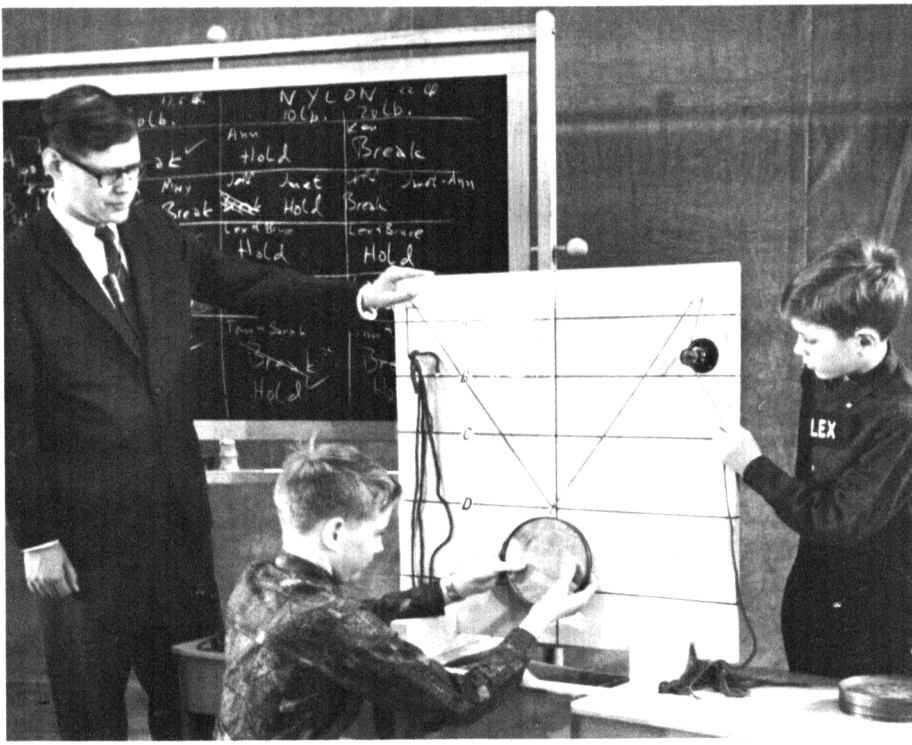
1. Every Federal agency with a significant program of research and development has designated an individual to be responsible for that agency's scientific information activities.
2. All such agencies have developed, or are developing, strengthened information programs. Examples include: the National Library of Medicine's Medical Literature Analysis and Reference Service (MEDLARS) and the proposed Drug Information Center of the Department of Health, Education, and Welfare; the Scientific and Technical Aerospace Reports (STAR) proj-

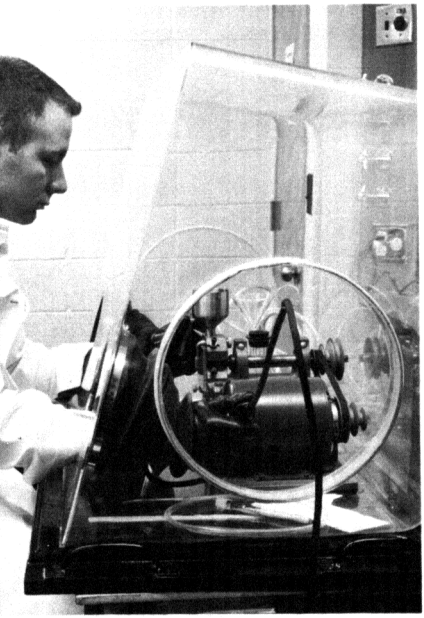
ect of the National Aeronautics and Space Administration; the Defense Documentation Center (successor to ASTIA) of the Department of Defense with its experimentation on indexing and other bibliographic problems; NSF's establishment of an information center on Antarctic research.

3. The FCST has established a standing, and very active Committee on Scientific Information. One of its principal current projects is the development of Federal policies on a variety of phases of information control and dissemination.
4. The major technical report issuing agencies—NASA, Atomic Energy Commission, and Department of Defense—are coordinating various aspects of their report processing and handling.
5. The Department of Commerce, in cooperation with NASA, AEC, DOD, and NSF, has extended the coverage of *U.S. Government Research Reports*, its subscription abstracting journal, to include abstracts and/or indexes of all of the unrestricted, unclassified reports of these agencies, and is making copies of the complete documents available for purchase; the Department, with Foundation assistance, also has established 12 regional centers with collections of these reports on which they provide loan, reference, and other services.
6. A Science Information Exchange has been established in the Smithsonian Institution to provide data on federally supported research in the life, physical, and behavioral sciences. It succeeds the former Biosciences Information Exchange.
7. A National Referral Center, set up in the Library of Congress, acts as a source of information on where the most authoritative scientific and technical data in any field can be obtained, inside and outside of Government.

The Scientific Community

In the nongovernment sector of the scientific information field, Foundation attention has been directed primarily to the activities of the professional scientific societies, both national and international. Of secondary, though still major, interest to the Foundation is the information role played by universities and commercial organizations. Among each of these groups, as with the Government agencies described earlier, the last 3 or 4 years have brought distinct changes of attitude and a growth of concern about the information problem. A wide variety of activities has been stimulated by this increased concern, ranging from a general questioning of the effectiveness of long-established communication media to an increase in university-directed documentation re-





In this scene from a classroom film, seventh grade students test calculations made about the breaking strength of yarn. The film, designed to help teachers learn new approaches in teaching mathematics, was prepared by the Syracuse University-Webster College Madison Project under an NSF program aimed at course content improvement. Left, an NSF Fellow at Auburn University uses radioactive techniques to study the effects of a herbicide on plants. The Foundation awarded over 5,000 fellowships in 1963.

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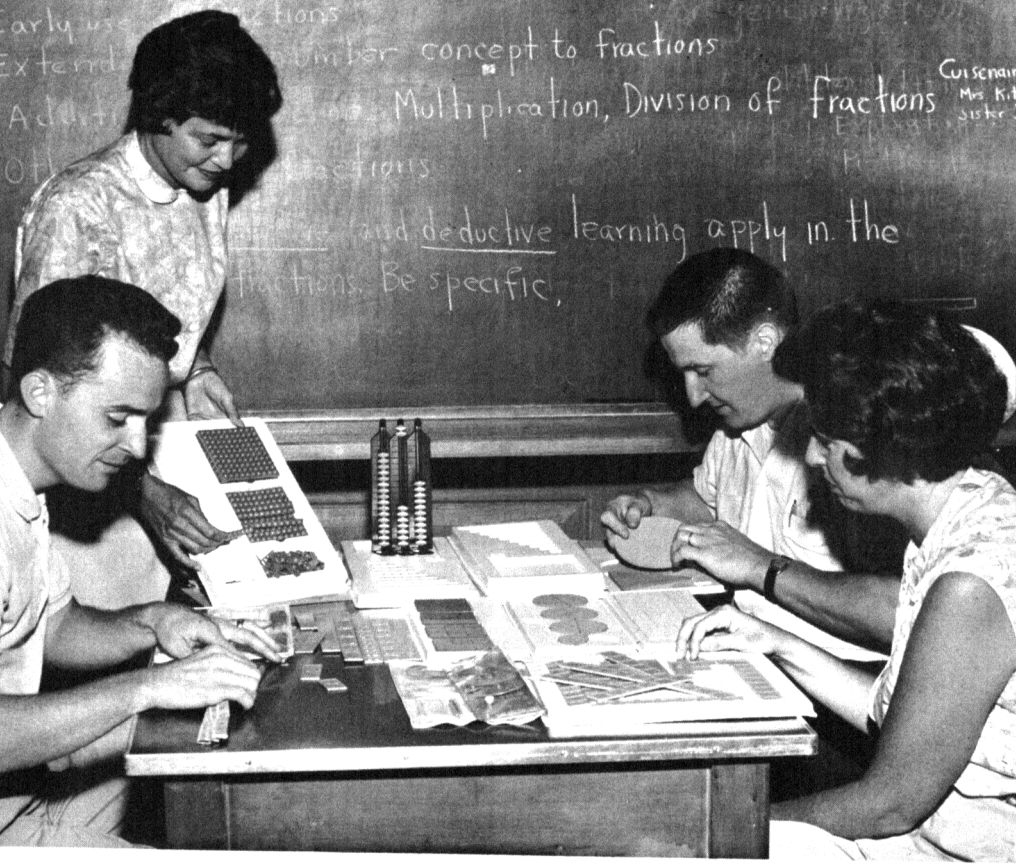
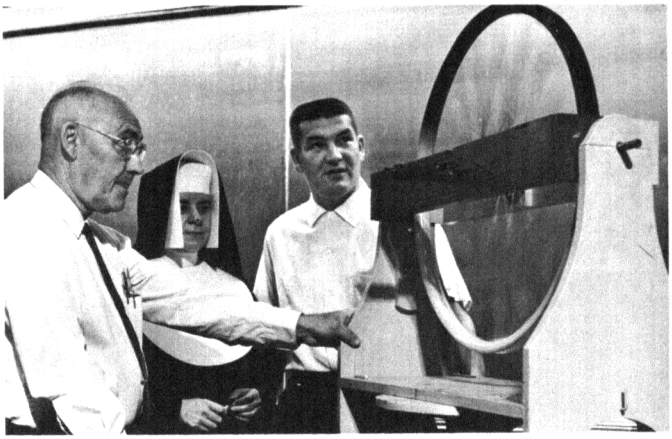
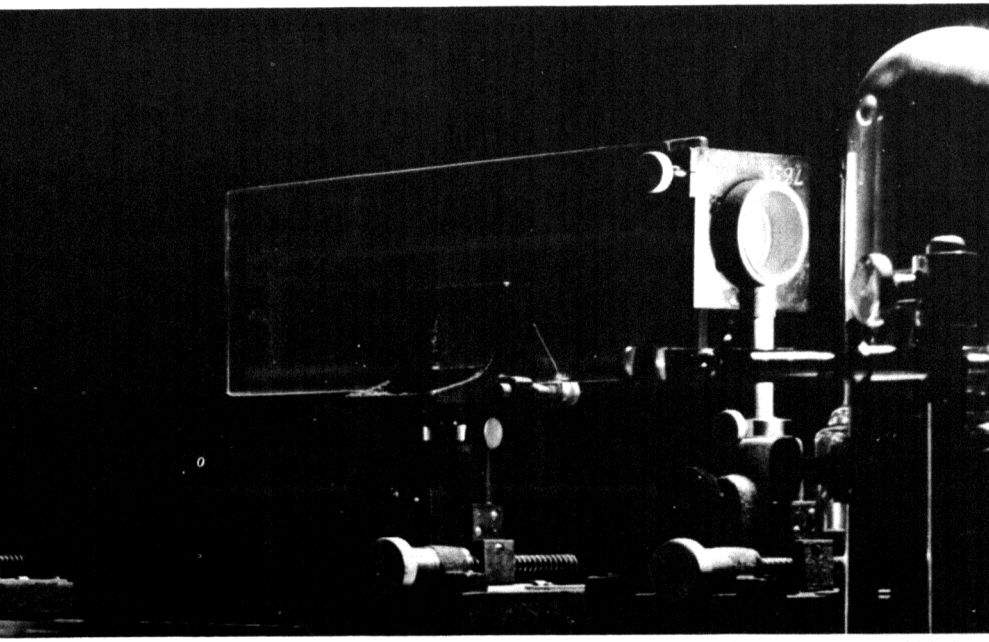

concept to fractions
Multiplication, Division of Fractions
deductive learning apply in the



Designed to improve instruction in science, mathematics, and engineering, the Foundation's teacher institute programs are the largest Federal activity in direct support of education in the sciences. Representative of the activities at some 900 institutes held in 1963 are: Left, elementary school mathematics teachers at the University of Vermont study materials for teaching the early use of fractions. Above, a physics professor at Pennsylvania State University demonstrates the principles of a gyroscope to two secondary school teachers. Below, at an institute in basic atomic and nuclear physics at the University of Arkansas, a high school teacher uses a Lloyd's mirror to measure the wave length of monochromatic light.



This high school science teacher explains the operation of specialized chemistry apparatus to a group of superior secondary school students at St. John's University. All, including the teachers, received advanced instruction at St. John's in an NSF-supported cooperative college-school science program. Other scientifically talented high school students take part in research at colleges and universities. Below, this student concentrates on observation and notes during an investigation of hydrogen overvoltage on bright platinum at Newark College of Engineering.

search and the development of new college curricula for information specialists. With, in many instances, the encouragement and financial backing of the Foundation, a number of new approaches to scientific publication are being tried; for example, the major abstracting and indexing services in this country are cooperating with each other to extend and improve their coverage of the research literature. International groups such as the International Council of Scientific Unions (ICSU), International Federation for Documentation (FID), and United Nations Educational, Scientific, and Cultural Organization (UNESCO) are also devoting more effort to improving communication in the sciences.

Typical of the scientific societies' growing interest in information and communication are two broad studies underway in psychology and physics. Supported largely by NSF, analyses of the communication and information practices of research workers in these fields are underway. Studies include the coverage and readership of pertinent professional journals and the information exchange function of meetings. Abstracting and indexing services are being studied and new and different types of publications and other information services are being tried experimentally.

Among the first of the new approaches tried by private organizations with NSF encouragement and support was the biweekly journal *Chemical Titles,* which Chemical Abstracts Service initiated early in 1961. It is a permuted title index in which papers from more than 500 journals are announced on an average of some 2 weeks after they appear in a primary journal. A Foundation grant, awarded in 1959, made possible a 4-month trial of the publication. Enough subscriptions were received during the first year of publication to make further Government aid unnecessary. Also during 1961 Biological Abstracts, Inc. launched the semimonthly *BASIC* (Biological Abstracts' Subject in Context), a permuted title index to the abstracts in *Biological Abstracts. BASIC* is being published both with the abstracts and as a separate journal.

Citation indexing is another new technique being investigated experimentally with NSF and NIH funds. Citation indexes provide a means for tracing bibiographic "descendants"; conventional indexing methods trace bibliographic "antecedents." The studies, one in genetics, the other in statistics, are designed to test both the usefulness of citation indexes and the methodology of their preparation.

Another area of scientific communication in which the Foundation has assumed leadership is the development of procedures for publication of significant research results—more rapidly than is possible with the usual journal form. For example, the American Institute of Physics,

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with NSF support, has experimented successfully with two new "letters" journals, which publish brief articles on important new experimental developments. The first, started in 1958, is *Physical Review Letters;* its more recent counterpart, *Applied Physics Letters,* was started in 1962. With these two journals, which are published by photo-offset from typewritten copy, publication delays are measured in weeks instead of months. The success of this form of publication and its acceptance by the scientific community has encouraged several societies to consider other, more radical, experiments with the long-established research journal form.

Joint Government-Private Efforts

Many of the activities mentioned above involve Federal assistance to non-Government groups through grants or contracts for specified time periods. In another category of information effort, however, joint Government and private participation is much more intimate and occurs on more of a continuing partnership basis. Most activities in this group concern the general area of scientific publication.

NSF's specific responsibility in this area, plus the growing concern of the FCST, the OST, and the Congress about the scientific information problem, led to increasing recognition within Government of the need for consistent, overall Federal policy affecting Government support for non-Government scientific publication. The first concrete result of this concern was the enunciation by the FCST in 1961 of its approval of the use of Federal R&D funds for the payment of page charges for the primary publication of the results of Government-supported research. This Council action dealt, however, with only one phase of the total publication support problem. In cooperation with the FCST Committee on Scientific Information, the Foundation has continued to study other aspects of the support of non-Federal scientific publishing by Federal agencies. Other policy recommendations can be expected in the near future.

A somewhat different kind of Government-private cooperative effort is exemplified by the activities of the National Federation of Science Abstracting and Indexing Services (NFSAIS). The membership of this association, founded in 1958 under the leadership and with the support of NSF, includes 20 of the Nation's leading private and Government scientific abstracting and indexing organizations. Its objective is to foster cooperation among the member services to improve their ability to serve the total scientific and technical community. Among its major projects is the development of a national plan in this field.

DOCUMENTATON RESEARCH

The primary mission of the Documentation Research program is the stimulation, support, and coordination of research directed toward development of new or improved methods, including mechanized systems, for making scientific information available. Research directed toward this objective includes fundamental studies of the communication practices and information needs of scientists and the development of techniques for organizing and disseminating information to meet the scientists' needs.

Communication Practices and Information Needs of Scientists

Extensive studies of information problems and practices by the American Institute of Physics (AIP) and the American Psychological Association are being supported by the Foundation. One of the AIP studies nearing completion is a survey of the types of questions physicists would like to be able to put to an ideal searching system. A thorough analysis of the concepts contained in these questions, as compared with entries in existing indexes, is in progress. Based on results thus far obtained, an improved system for indexing physics research papers is being tried experimentally in *Applied Physics Letters* and may be tried in other journals. The American Psychological Association has prepared a series of reports on its studies of the dissemination of information in psychology. Drexel Institute of Technology has undertaken a survey of information needs and practices of engineers, a survey of particular interest to the Engineers Joint Council. A related study is being made by Herner & Co. of the character and degree of use of published index data and of the indexing thesaurus in the field of chemical engineering.

Automatic Language Processing and Mechanical Translation Research

Research in automatic language processing is essentially long range. The accomplishments of any year, therefore, consist primarily of a steady increase in the understanding of language phenomena; further development of grammars for various languages for eventual use in analyzing texts and producing machine output in intelligible language; compilation of dictionary information; and development of improved, and in some cases automated, techniques for handling data and facilitating research in this field.

Among recent results stemming from NSF-supported research in language processing are: the Harvard computer program for the automatic-

syntactic analysis of English; a five-volume set of *Chinese Character Indexes,* produced with the aid of a computer and published by the University of California project; the Massachusetts Institute of Technology computer program for a French grammar and parallel computer programs for grammars of Arabic and English; and a new tool in mechanical translation (MT) research called the "Translation Error Detector," a computer program developed by the Thompson Ramo-Wooldridge project, which compares experimental MT output with a human translation of the same text.

Organization and Searching of Information

One of the NSF-supported current projects in this area is an experimental comparison at the Harvard Computation Laboratory of three different models for the analysis of document content. One employs high frequency words or word groups, a second introduces hierarchical structures with cross-references and synonym lists, and a third employs a form of syntactical analysis. Procedures for automatically indexing abstracts of scientific papers are being studied at Western Reserve University. The hope is that workable procedures can be devised that will not require full syntactic analysis of the sentences of the abstract.

Other studies include: investigation at Advanced Information System, Inc., of search strategies and of the organization of large information retrieval files, with special attention to the possibilities of automatic self-organization of the files according to amount of use; and research at the Cambridge (England) Language Research Unit and the System Development Corp. on automatic techniques for grouping related items in an index.

Testing and Evaluation of Information-Handling Systems and Techniques

Carefully designed experimental tests and objective evaluations of information systems and techniques are essential to an assessment of their merits and weaknesses. The Foundation has therefore undertaken in a preliminary fashion the support of urgently needed research in the development of such test methods and evaluative criteria.

A 2½-year test program of a retrieval system for metallurgy, developed by the Western Reserve University, has been completed and the final report is being prepared. This program included: full-scale operation of a partially mechanized searching service covering technical literature of interest to metallurgists, as well as compilation of data on cost, value, and efficiency of the service. These data have been analyzed

by a special committee of the National Academy of Sciences-National Research Council (NAS–NRC); its evalution report is expected shortly.

Under other NSF grants, MIT is developing a test environment in which to study information systems based on clerical and automatic techniques for processing physics papers and matching them to the interests of the physicists participating in the test program. An NAS–NRC study of chemical notation systems in current use in the U.S. has been completed and is being extended to cover systems in use in Europe. An NSF grant has also been made to the University of Pennsylvania for analysis of the two major chemical notation codes to check for uniqueness, avoidance of ambiguity, and efficiency.

Surveys and Reports

To inform both administrators of documentation research programs and researchers of current activities in the field, an extensive survey of current projects here and abroad, entitled *Current Research and Development in Scientific Documentation,* is published by the Foundation every 6 months.

To provide state-of-the-art reports on selected areas of documentation research, the Foundation continues to furnish partial support for the Research Information Center and Advisory Service on Information Processing at the National Bureau of Standards. During the past year, two reports have been issued and others are in preparation. A Foundation grant to the Department of Commerce will make possible the establishment, within the Office of Technical Services of a master collection of research reports on documentation research and development. The Foundation has also contracted with the Thompson Ramo-Wooldridge Corp. for a study of the needs of researchers for texts in machine-usable form; its main purpose is to determine the desirability of establishing a center to store machine-usable texts for use in documentation research and to provide researchers with services in connection with these texts. In accordance with the wishes of several cooperating agencies, the Foundation made a grant to Wayne State University for centralized compilation of information on Russian words and phrases for all research groups working on Russian-English mechanical translation.

SUPPORT OF SCIENTIFIC PUBLICATIONS

The objective of this program is development of the optimum publication system for information dissemination. Such a system must enable scientists to publish the results of their research promptly and in adequate detail and format (primary publications). It must also facilitate scien-

tists' access to what they need from the ever-increasing volume of research information (secondary publications). Projects supported are of two types: those providing emergency assistance to present scientific publishing services; and those investigating new or improved systems, providing faster, more comprehensive services at the lowest possible cost.

Primary Publications

Key grants for support of journals were made last year for *Applied Physics Letters* and *Reviews of Geophysics.* The letters journal was described previously on page 120, as the second experimental rapid publication journal of the American Institute of Physics. *Reviews of Geophysics* was initiated by the American Geophysical Union to provide a periodical review medium to bring together elements of the very diverse and rapidly growing field of geophysics.

Six other widely differing journals received Foundation funds last year to help them overcome particular, short-term difficulties. These included *Solar Energy, Journal of the American Rocket Society* (prior to its merger with *Journal of the Aerospace Sciences,* also a Foundation grantee), the *Journal of Glaciology* (sole English language journal in its field), *Journal of Heredity, Computers in Behavioral Science,* and the *Transactions of the American Society of Lubrication Engineers.* This last journal is serving a growing field that involves an unusual interrelation between science, engineering, and technology.

Some 33 monographs, catalogs, and handbooks were awarded publication grants in 1963, including works on Antarctic research, botany, zoology, mathematical psychology, and the history of science.

Secondary Publications

Grants in support of secondary publications underscore the importance that the Foundation places upon the development of a national network of superior, comprehensive abstracting and indexing services. *Biological Abstracts, GeoScience Abstracts, Meteorological and Geoastrophysical Abstracts,* and *Sociological Abstracts* received grants to further increase the amount of research information they collect, screen, and redistribute in summarized form.

Support of bibliographies and special indexes was limited to those for which there was a clearly demonstrated need or which were of an experimental nature. Grants were made for publication of specialized bibliographies or indexes in botany, linguistics, astronomy, and seismology.

Studies and Experiments

Several specialized bibliographies were produced experimentally by Chemical Abstracts Service through its computer-centered development program which is supported in part by NSF. The CAS type of development promises relatively simple, fast, specialized bibliographies that treat their topics comprehensively. Biological Abstracts, Inc., is experimenting with "prepacking" biological information through publication in microform. The experiment is in response to a long-felt need for an inexpensive means by which individuals can regularly receive only those portions of a comprehensive abstracting-indexing service containing information of recurring interest to them. The American Chemical Society is analyzing the role that computers may be able to play in the reproduction, distribution, and retrieval of scientific papers and data. On the national level, support, financial and otherwise, was provided the National Federation of Science Abstracting and Indexing Services for its secretariat, for preparation of a *Guide to the World's Abstracting and Indexing Services in Science and Technology,* and for the development of a national plan to improve abstracting and indexing products and services.

One of the most interesting and potentially significant communications experiments undertaken in some time is the "Science and Engineering Television Journal," spearheaded by the American Association for the Advancement of Science and supported cooperatively by the Foundation, educational station WETA–TV, New York, and 12 professional scientific and engineering groups which prepared programs. The programs, ranging in length from ½ to 1½ hours, were produced for scientists rather than for the general public.

On the international level, cooperative support was continued through the mechanisms of the Abstracting Board of the International Council of Scientific Unions and the International Federation for Documentation (FID).

FOREIGN SCIENCE INFORMATION

Because the quality and quantity of scientific research in many countries is increasing at a rate comparable to our own, it is essential that American scientists have ready access to the results of this research. Because much of it is published in languages unfamiliar to American scientists, it must be made available in translation. The Foundation's Foreign Science Information Program has therefore been designed to:

1. Increase the scope, quality, and quantity of translations of the most important foreign scientific publications.

2. Provide data on sources and availability of foreign scientific information and increase the current awareness of the U.S. scientific community.
3. Promote the effective acquisition of foreign scientific publications through purchase and exchange between U.S. and foreign organizations.
4. 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

Almost two-thirds of the funds available to the program in fiscal year 1963 were used to support the translation, publication, and dissemination of 41 of the Soviet Union's leading physical and life sciences journals. More than 84,000 pages were translated during the year and made available to about 21,000 subscribers. The number served through libraries and information centers may be estimated at several times this. In addition, two Japanese electronics journals and one Communist Chinese mathematics journal were translated.

The National Science Foundation continued support of U.S. scientific translations programs in Poland, Yugoslavia, and Israel, using foreign currencies which accrued to the credit of the United States. During this year, 10 Polish and 9 Yugoslav scientific journals were translated into English. The Israeli program produced English translations of Soviet journals, serials, patents, abstracts, books, and monographs. The translation effort in these 3 countries produced 42,500 pages of scientific and technical literature for the benefit of U.S. scientists.

Sources of Current Information on Foreign Science Activities

The Foundation supports preparation, publication, and announcement of bibliographies, directories, guides, studies, and reviews; the convening of conferences and symposia; the establishment of information centers; and the "use" studies—all designed to assist the U.S. scientist in learning "what," "who," and "where" in the realm of foreign science. Examples of Foundation supported projects in this area are:

1. Publication of the *World List of Future International Meetings, Part I,* by the Library of Congress.
2. Continuation of the Bureau of the Census series of *Bibliographies of Foreign Social Science Periodical and Monographs.*

3. Completion by the Battelle Memorial Institute of a *Directory of Selected Scientific Institutions in the USSR,* listing 1,135 Soviet scientific institutions.
4. Publication by the Library of Congress of *International Scientific Organizations: A Guide to Their Library Documentation, and Information Services* (1962). This 792-page book lists 449 intergovernmental and nongovernmental organizations, each with a description.

Acquisitions and Exchanges

The Foundation continued its efforts to foster the acquisition and exchange of important foreign scientific publications. In May 1963, 40 titles of 1963 Communist Chinese primary scientific and technological journals were received on exchange from Peking by the National Federation of Science Abstracting and Indexing Services (NFSAIS). The American Mathematical Society (AMS) continued its exchange agreement with the Academy of Sciences of the U.S.S.R. The AMS is now receiving more than 1,200 subscriptions, an increase of 296 over last year. In turn, the AMS exchanged U.S. journals with the Soviet Academy. Efforts were continued to develop acquisition and exchange programs with the East European countries.

RESEARCH DATA AND INFORMATION SERVICES

The Research Data and Information Services program is concerned with promoting improvement in, and developing a better understanding of, specialized data and information services. Efforts in 1963 fell into the following four broad categories: national information planning studies, coordination and improvement of Federal Government information activities, survey and study of specialized information and data services, and support and encouragement of improvements in library services.

National Information Planning Studies

To increase understanding of questions implicit in any consideration of national patterns of information dissemination and utilization, studies are being made to (a) assess the effect of centralization on information handling, and (b) ascertain the significant factors relating to the development of an effective information network serving users on a national and regional basis.

Under contract to NSF, A. D. Little, Inc., is studying the effect of varying degrees of centralization on the information dissemination

process. This study, phases of which are still incomplete, indicates the need to interconnect existing services and systems rather than to superimpose a single centralized system.

Another study, undertaken by Information Dynamics Corp. with NSF support, is focused on broad questions concerning information centers and services operating within the national system. Still in its early stages, the study will develop economic and other guidelines for comparing and assessing the relative advantages of subject-oriented and regional-oriented information centers as means of providing the Nation's scientific community with adequate information services.

Coordination and Improvement of Government Information Services

Major emphasis continued to center upon improving existing Government services and providing new services. A new Government information service began operations in the past year—the National Referral Center for Science and Technology in the Library of Congress. The Center serves to interconnect the potential science information user with the Nation's best sources of the desired information. The Center also plans to publish, on a selective basis, up-to-date directories of information resources.

NSF support was also provided to the Science Information Exchange to expand its coverage of current research in the physical sciences as well as to continue its established service to the life sciences, and to the 12 regional technical report centers of the Commerce Department's Office of Technical Services (OTS). Other support was given OTS for publishing *Keywords Index,* an experimental report title index provided to subscribers of *United States Government Research Reports.* Additional steps taken to improve Government information services include placement in the OTS system of the documents of the National Science Foundation, the Department of the Interior, and the National Academy of Sciences. Other measures were taken to effect compatibility in the physical form of reports being produced by large Government information producers such as AEC, NASA, and DOD. A continuing inventory of Government information activities was being provided by publication of *Scientific Information Activities of Federal Agencies,* an NSF information bulletin series. Descriptions of the information services of the Air Force, Army, and Navy are currently underway; 17 bulletins have been published to date.

Survey and Study of Specialized Information and Data Services

A study was made of the data produced by the 1961 survey of specialized science information centers in the physical and biological sciences revealed trends in the history, growth, geographical distribution, subject coverage, types of services offered, and methods of communication utilized by these centers. A similar survey was initiated for the social sciences. Continued NSF support of the Office of Critical Tables and the recent establishment of the National Standard Reference Data System by the National Bureau of Standards mark the beginning of a new era of closer coordination in the dissemination of critically evaluated data in the physical sciences.

The NSF publication *Nonconventional Technical Information Systems in Current Use* issued during the year provided a comprehensive survey of mechanization and other nonstandard information-handling principles employed by specialized information services.

Support and Encouragement of Improvements in Library Services

Emphasis has been directed toward broad-scale improvements rather than to specific support of individual libraries. West Virginia University is conducting a study of interlibrary loan operations involving a large univeristy and its association with small colleges and the industrial community within the same region; and the Johns Hopkins University is studying the possible application of operations research and systems engineering concepts to a large university library. Two grants were made to support specific library mechanization activities. One is concerned with mechanizing conventional library processes. The other deals with the development of a mechanized cooperative cataloging activity.

STUDIES OF SCIENCE RESOURCES

The welfare, security, and economic well-being of the Nation are dependent on the continuing strength of its scientific and technological effort. It is, therefore, essential that the resources of skilled manpower, facilities, and equipment are available to meet current and future needs.

This requires fact finding and analytical studies, many of which are conducted or sponsored by the Foundation in fulfillment of its statutory responsibilities. Such studies provide a basis for science resources planning pertinent to the development of national policy for research and education in the sciences and engineering. They provide an understanding of the present organization, interrelationships, and allocation of such resources among these activities. Periodic surveys provide information on research and development activities and scientific manpower which make possible the projections of growth of resources. By comparing trends with estimated needs, it becomes feasible to determine what additional national effort is necessary. Other studies, of a nonrecurrent nature, are undertaken to provide reliable data on subjects of particular interest. For example, they may deal with various aspects of science education, science organization, and needs for science facilities and equipment.

These studies and surveys are conducted or directed by the Science Resources Planning Office, Office of Economic and Statistical Studies, and Scientific Personnel and Education Studies Section of the Division of Scientific Personnel and Education.

The results of these studies are used by many organizations both public and private. However, the primary use is by the Foundation itself, the Office of Science and Technology, the Federal Council for Science and Technology, and other Government agencies. In addition to these studies carried on by the Foundation, the efforts of other organizations, such as the National Academy of Sciences, are also of great value in providing a complete and comprehensive picture of the Nation's scientific and technical resources.

Trends in Manpower for Science and Technology

The Foundation completed a study of the characteristics of the Nation's scientific manpower with projections to 1970 of employment trends (ref. 1). It showed that the Nation employed ½ million

scientists, nearly 1 million engineers, 1 million technicians, and ¼ million teachers of science and mathematics in secondary schools. This specialized manpower in science and technology presently accounts for 3.6 percent of the labor force. The figure was about 1.5 percent in 1940 and is expected to reach 4.7 percent in 1970. (See table 5 and figure 2.)

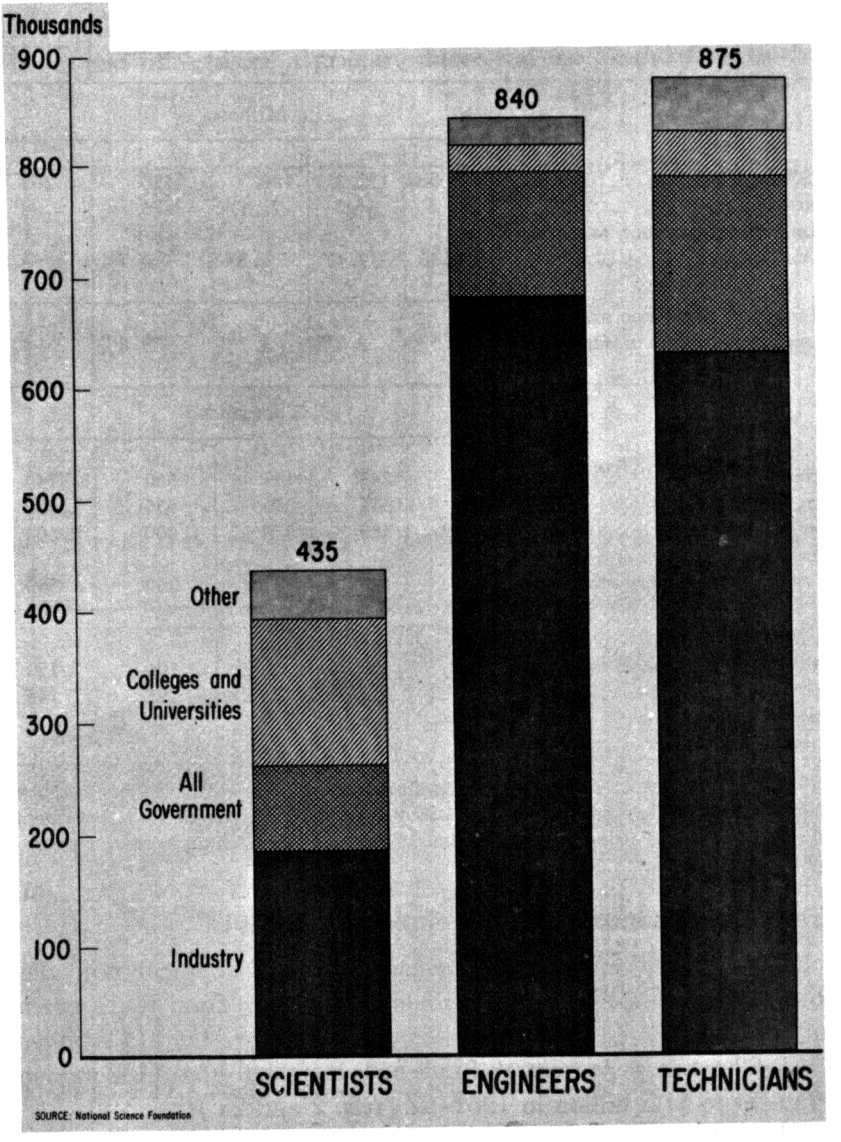


Figure 2. ***Scientists, Engineers, and Technicians, by Sector, 1960.***

Further findings indicated that about 1 scientist in 5 and 1 engineer in 100 has a doctorate. Industry in 1960 employed about one of every four scientists, and about four of every five engineers. Half of the Nation's scientists and engineers work in six States—California, Illinois, New Jersey, New York, Ohio, and Pennsylvania.

Table 5.—*Trends and Projections in Manpower, by Category, 1940–70*

	1940	1950	1960	1963 estimate	1970 estimate
	Millions				
USA population	132.0	152.3	180.7	190	209
Labor force	56.2	64.7	73.1	76	86
Manpower in science and technology	0.86	1.47	2.37	2.7	4.0
Manpower in science and technology as percent of labor force	1.5%	2.2%	3.2%	3.6%	4.7%
	Thousands				
Scientists	145	245	435	500	740
Engineers	300	545	840	935	1,400
Technicians	300	550	875	1,000	1,600
Teachers of science and mathematics in secondary schools	110	130	220	250	300
Doctoral scientists and engineers	28	45	89.2	106	170
Scientists	27.5	43.5	81.7	96	153
Engineers	0.5	1.5	7.5	10	17

NOTE.—Estimates shown for 1970 represent neither a forecast of supply nor a statement of future need. They are projections based upon current trends in employment in relevant fields, and upon the assumption of no substantial changes in economic and political conditions.

Trends in Research and Development Funds

A time series on funds for research and development is available covering the period 1953–54 through 1961–62. Total R&D expenditures have increased from $5.2 billion in 1953–54 to the $14.7 billion in 1961–62, while basic research funds have increased from $432 million in 1953–54 to $1.5 billion in 1961–62 (refs. 2 and 2a.)

The total for research and development in 1961–62 represents about a $1-billion increase over 1960–61. If the latest estimate of Federal

expenditures for research and development holds firm, the national total of R&D funds for 1962–63 will probably be about $16 billion. These funds have risen from 1.41 percent of the gross national product in 1953–54 to 2.84 in 1961–62. (See figures 3 and 4.)

The data on R&D funds are obtained from surveys of each sector of the economy. (Figure 5 indicates in what sector the R&D funds originated and in what sector they were spent for work performed.) Of the 1961–62 total, $10.9 billion was spent by industrial firms, with $6.3 billion coming from the Federal Government for contractual work. Colleges and universities, a primary interest of the Foundation, in that

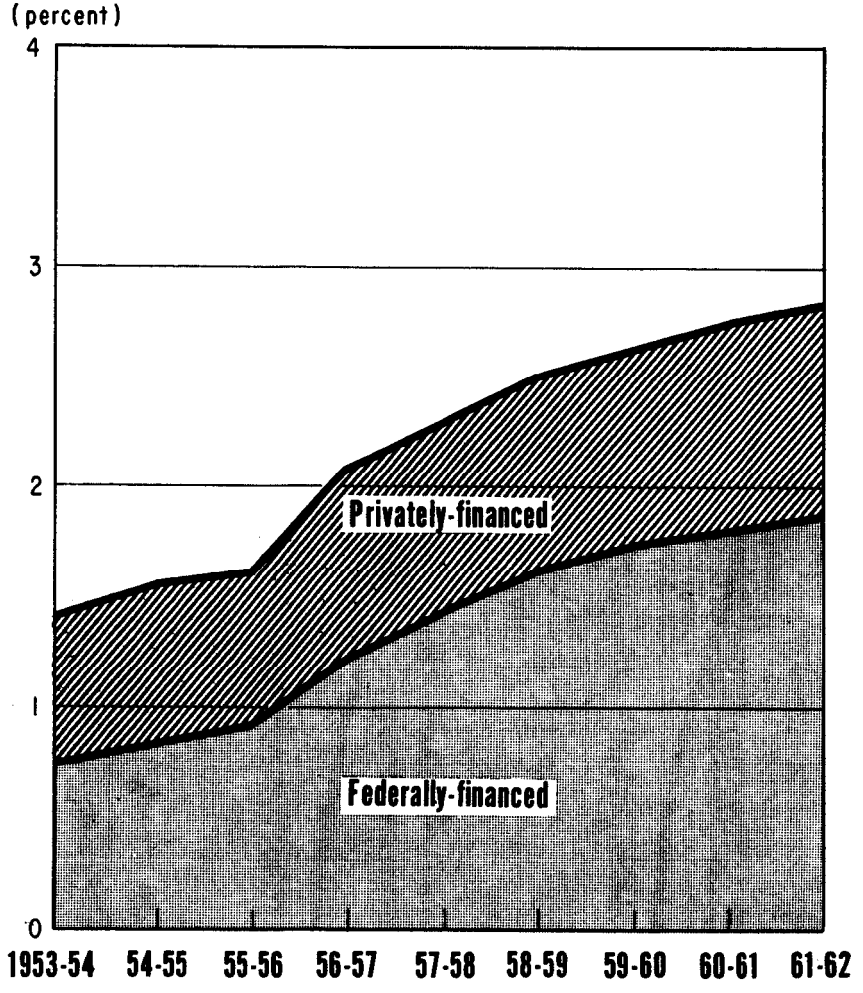


Figure 3. ***Research and Development As a Percent of the Gross National Product, 1953–54—1961–62.***

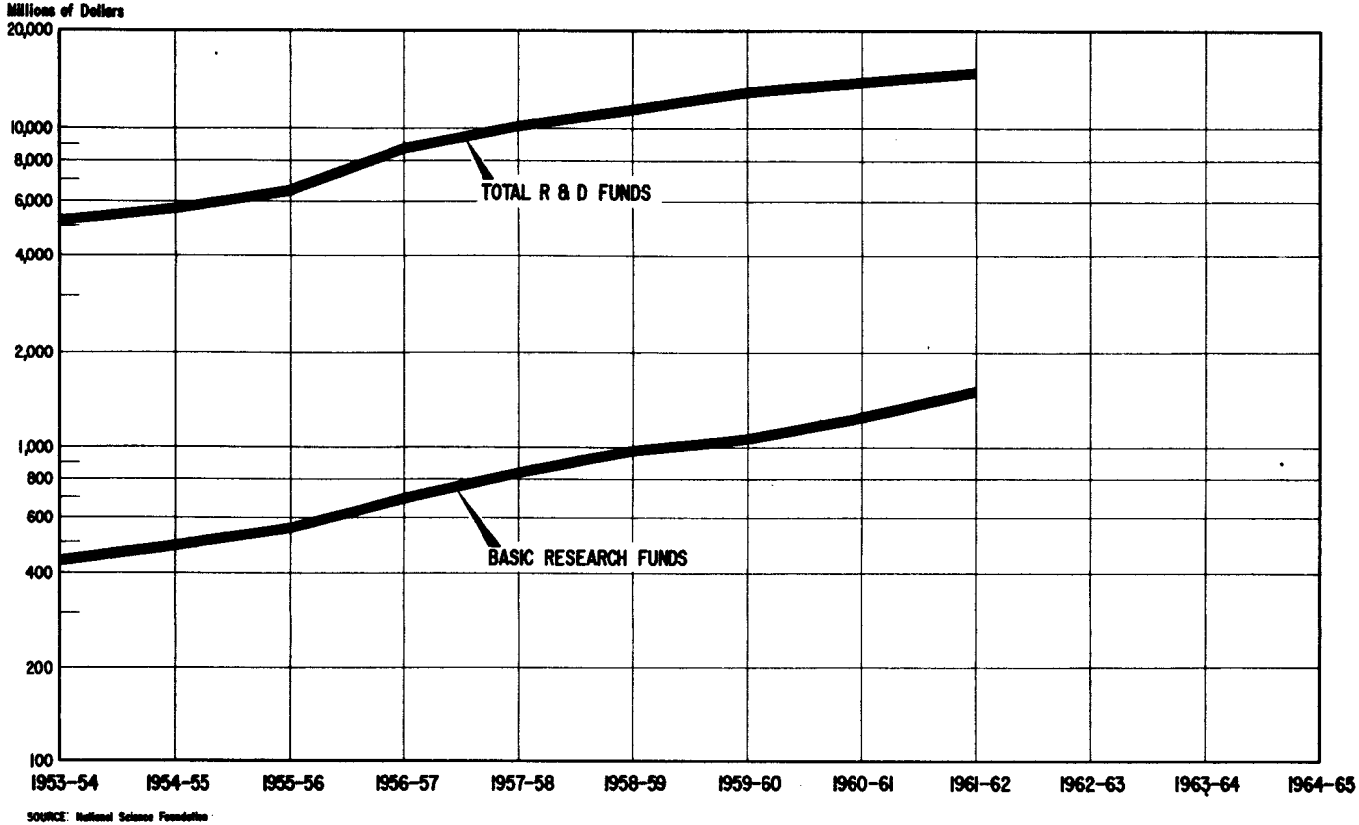


Figure 4. ***Trends in Research and Development Funds and Basic Research Funds, 1953–54—1961–62.***

(Millions of Dollars)

SOURCES OF FUNDS USED	RESEARCH AND DEVELOPMENT PERFORMERS						PERCENT DISTRIBUTION R&D SOURCES
	FEDERAL GOVERNMENT	INDUSTRY	COLLEGES & UNIVERSITIES		OTHER NONPROFIT INSTITUTIONS	TOTAL	
			PROPER[a]	FED'L CONTR. RESEARCH CENTERS			
FEDERAL GOVERNMENT	$2,090	$6,310[b]	$600	$450	$200[b]	$9,650	65
INDUSTRY	-	4,560	55	-	90	4,705	32
COLLEGES & UNIVERSITIES[c]	-	-	230	-	-	230	2
OTHER NONPROFIT INSTITUTIONS[c]	-	-	65	-	90	155	1
TOTAL	$2,090	$10,870[b]	$950	$450	$380[b]	$14,740	100
PERCENT DISTRIBUTION, R&D PERFORMANCE	14	74	6	3	3	100	

[a] Includes agricultural experiment stations.
[b] This amount includes funds from the Federal Government for research centers administered by organizations under contract with Federal agencies.
[c] Data include State and local government funds.

NOTE: All data are based on reports by the performers.

Source: National Science Foundation.

Figure 5. *Research and Development, 1961–62—Intersectoral Transfers of Funds Used for Performance (Preliminary)*

year spent $1.4 billion, $1 billion of this representing Federal grants or contracts with academic institutions; the remainder, $0.4 billion, came from colleges and universities themselves, other nonprofit institutions, or industry.

Similar information was obtained on funds for basic research. Following the pattern of the totals for all research and development, these sums show a rapid rise in this component of research and development.

Federal Government Studies

A report published in March 1963 presented organization of the Federal Governmentt for scientific activities (ref. 3). Based on information obtained from the 40 Federal agencies involved in scientific activities, the report covers scientific research and development, extramural training in science, scientific and technical information, scientific general-purpose data, and scientific testing and standardization. (See fig. 6.) Included are descriptions of advisory and coordinating mechanisms, installations and field stations, and federally supported research centers. Also, historical trends in R&D funds and scientific manpower and other major characteristics are described by agency.

The eleventh annual volume in the series, *Federal Funds for Science,* was published during the past fiscal year (ref. 4). This report deals with Federal support of research and development and of scientific and technical information, in terms of obligations and expenditures. The data provide answers to questions such as what amounts of funds are administered by the Federal agencies, what types of organizations perform the work, what the character of work is (basic and applied research and development), and what fields of science are being supported.

Collected as a part of the Civil Service Commission's annual white collar survey, the data on R&D personnel in the Federal Government are published by the Foundation as a separate report (ref. 5). The report gives the distribution of scientists, engineers, technicians, and other specialized personnel employed by Federal agencies.

College and University Studies

A survey of the number of scientists and engineers employed in colleges and universities in 1961 was completed and the results published. It identified scientists and engineers as faculty members or as other professional personnel and indicated the organizational units in which they were employed, the field of science in which they were working, and how many were engaged in teaching or in research within each field. The findings indicate that scientists and engineers engaged in research and

development were concentrated in relatively few institutions of higher education (ref. 6).

A final report on a survey of colleges and universities was published during the past year. It covers expenditures and manpower engaged in research and development in colleges and universities (ref. 7).

To augment the data on resources for science and education in colleges and universities, two major studies are underway. One deals with need for scientific and engineering facilities and apparatus required for teaching and research during the next 10 years. It is intended to show anticipated facility requirements as well as the capabilities of educational institutions to meet the costs of expected expansion. The other is even broader and deals not only with facility requirements, but also with manpower (undergraduate and graduate student populations, faculty required for teaching, and research investigators and supporting personnel), course content improvement, etc. This study projects total costs to the Nation for academic science for the 1965–75 period and analyzes non-Federal funds likely to be available.

A case study was completed of support of university proposals for scientific and engineering research. The project sought to determine what factors influenced the acceptance or rejection of such proposals by outside sponsors. The study was conducted by New York University and the University of Michigan, under contract with the Foundation, and undertook to trace the flow of formal research proposals initiated by their respective staffs and submitted to the Federal Government, private industry, nonprofit institutions, and State and local governments during the period January 1, 1958, to December 31, 1959 (ref. 8).

Industry Studies

During the past year, the Foundation published two reports on surveys of research and development performed by industrial firms, one on preliminary findings of a 1961 survey and the final report of a survey covering the previous year (refs. 9 and 10). These annual surveys of industry provide dollar measures of research and development in terms of volume, industry distribution, size-of-company composition, and character of the work, as well as data on R&D personnel employed by industrial firms. Trend data collected in these surveys are used in conjunction with other economic variables to forecast long-term projections and to assist in business and Government economic decision-making.

Complementing the survey of funds was one, conducted by the Bureau of Labor Statistics, dealing with scientific and technical personnel in

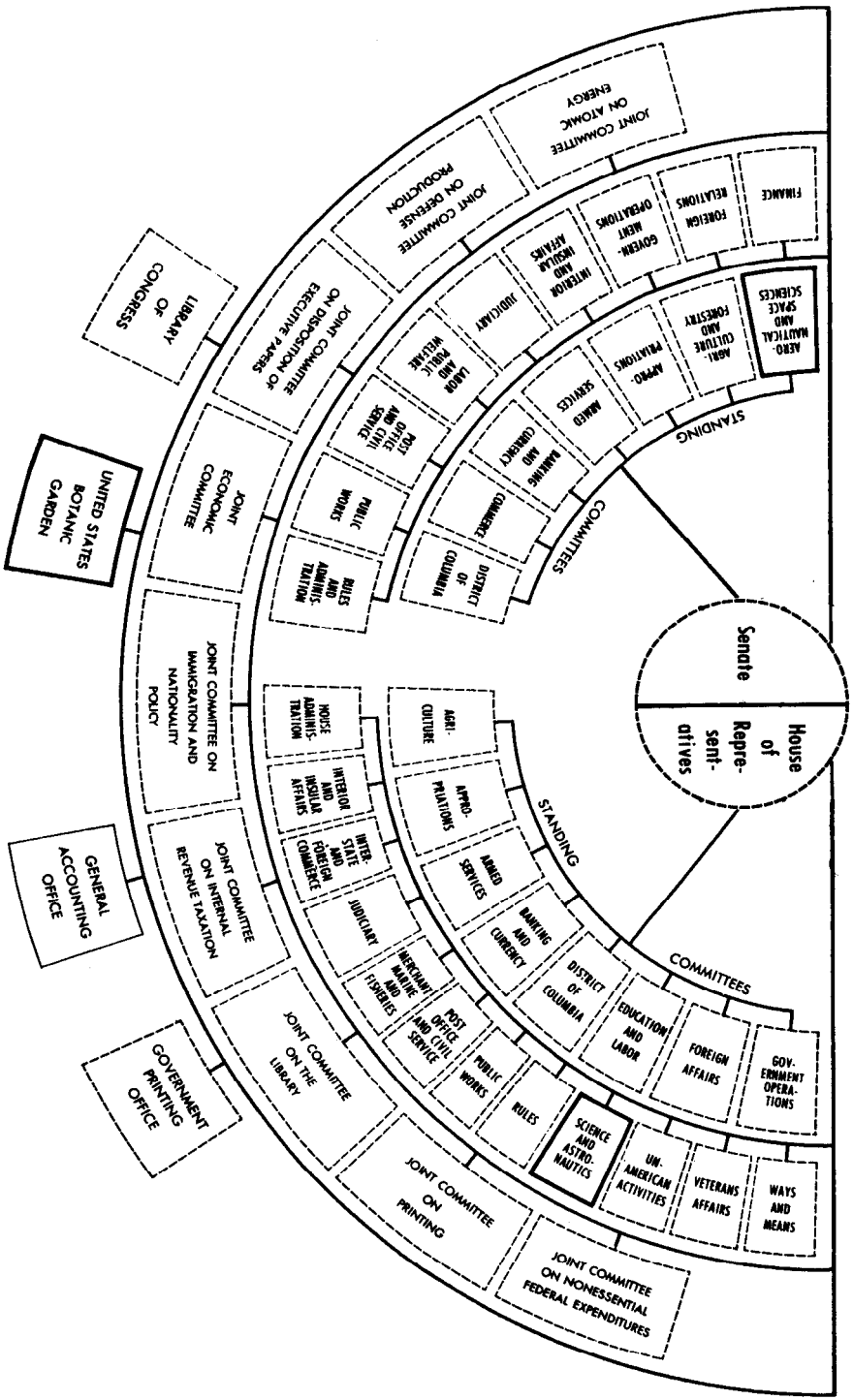
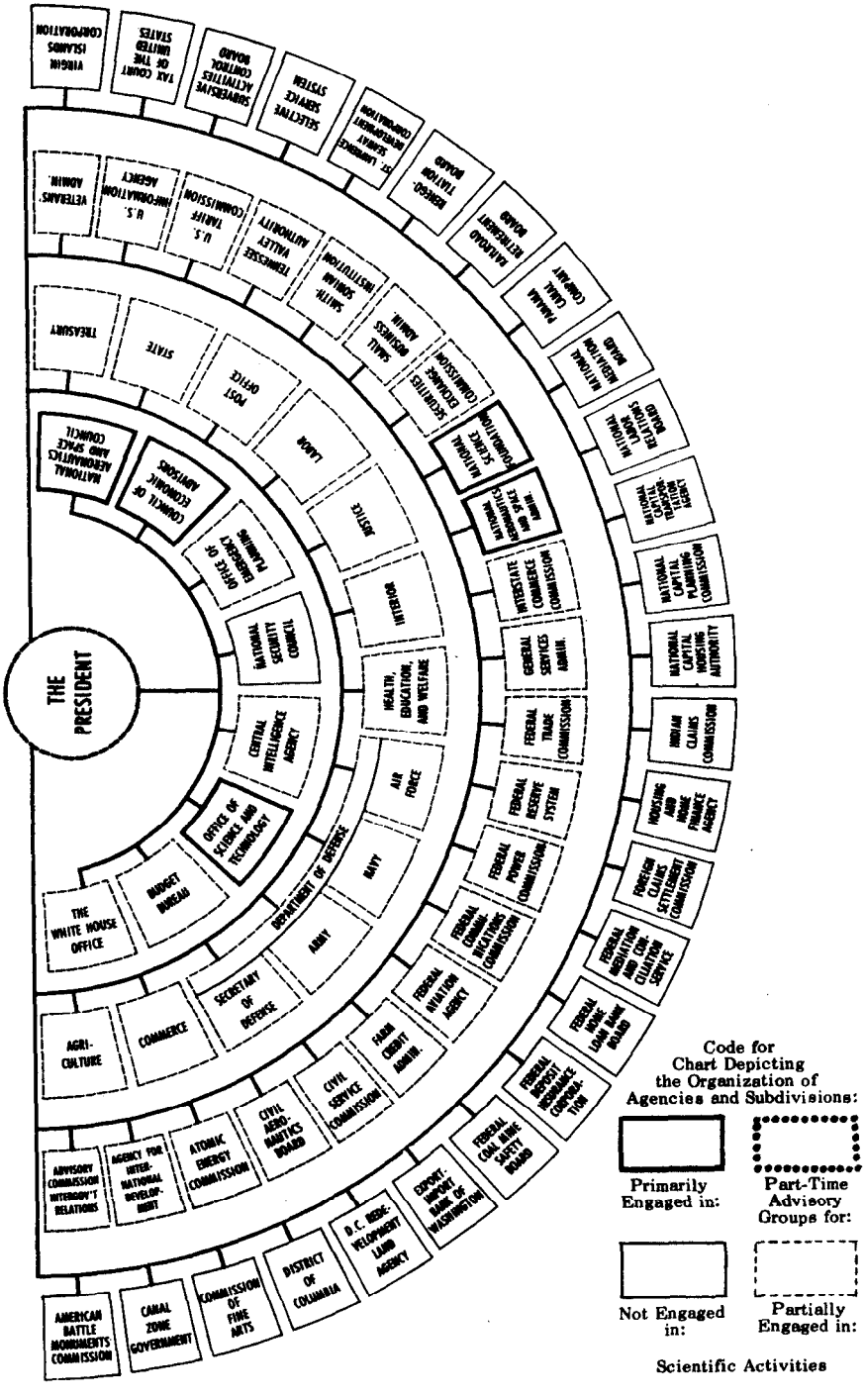


Figure 6. Organization of the Executive and Legislative



Branches of the Federal Government for Scientific Activities.

industrial firms. The findings for the year 1961 were in process of publication (ref. 11).

A series of reviews of selected industries was inaugurated during the year (ref. 12). The first in the series treated the aircraft and missiles industry, the largest performer in terms of dollars spent in performance of research and development. (See fig. 7.)

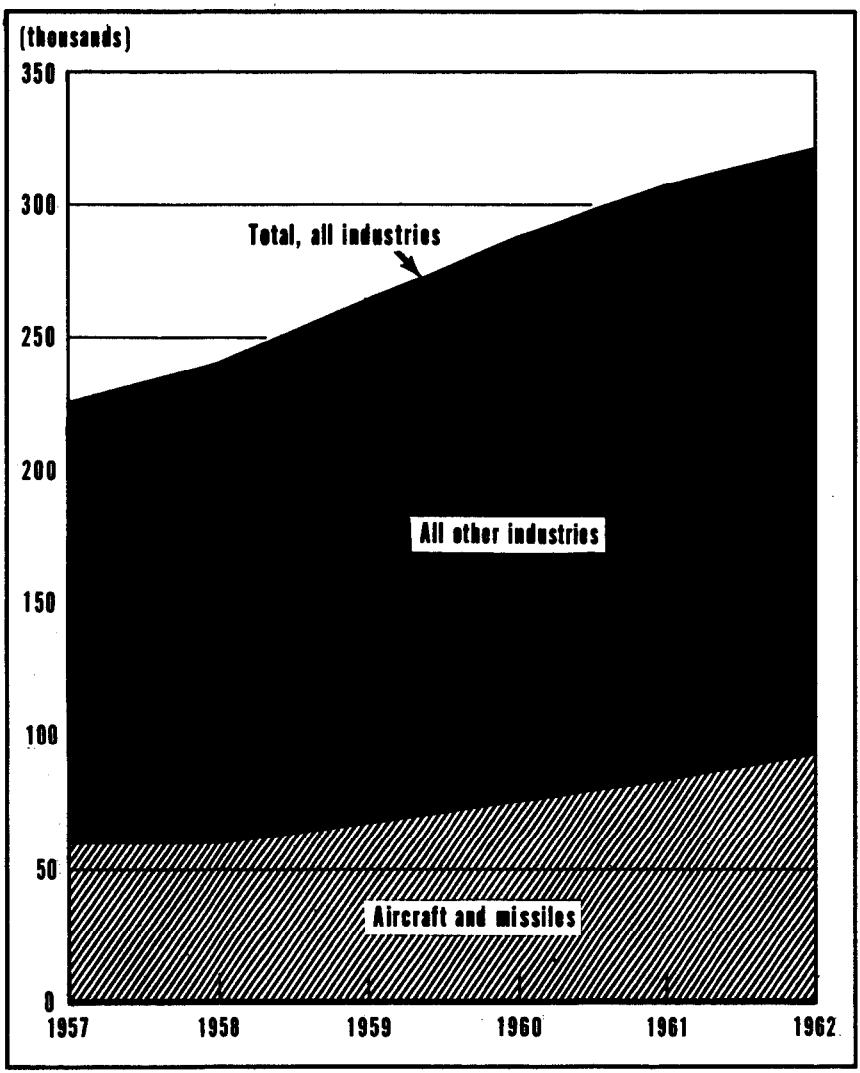


Figure 7. *Full-Time Equivalent Number of R&D Scientists and Engineers Employed in the Aircraft and Missiles Industry Compared with Number Employed in All Other Industries, January 1957–January 1962.*

A study of technological change was completed. Three bulletins reported various phases of the project dealing with the spread of innovation, interfirm differences, technological change, and the relation between innovation and research and development (refs. 13–15).

Other studies include those dealing with R&D decision-making, organization of industrial firms to receive and exploit scientific findings, relation of industrial R&D statistics to other economic variables, research and development in small business firms, and social science research in industry, labor market behavior of scientists and engineers in jet and missile production, and a pilot study on occupational detail of engineers in industry.

Other Science Resource Studies

In addition to studies of major sectors of the economy, the Foundation conducts studies of activities not limited to any one sector, but dealing with a particular type of scientific activity or of scientific manpower.

As part of its responsibility for maintaining a national register of scientific and technical personnel, the Foundation conducts biennial surveys (ref. 16). Preliminary results of the 1962 survey are summarized in table 6. Also see figure 8.

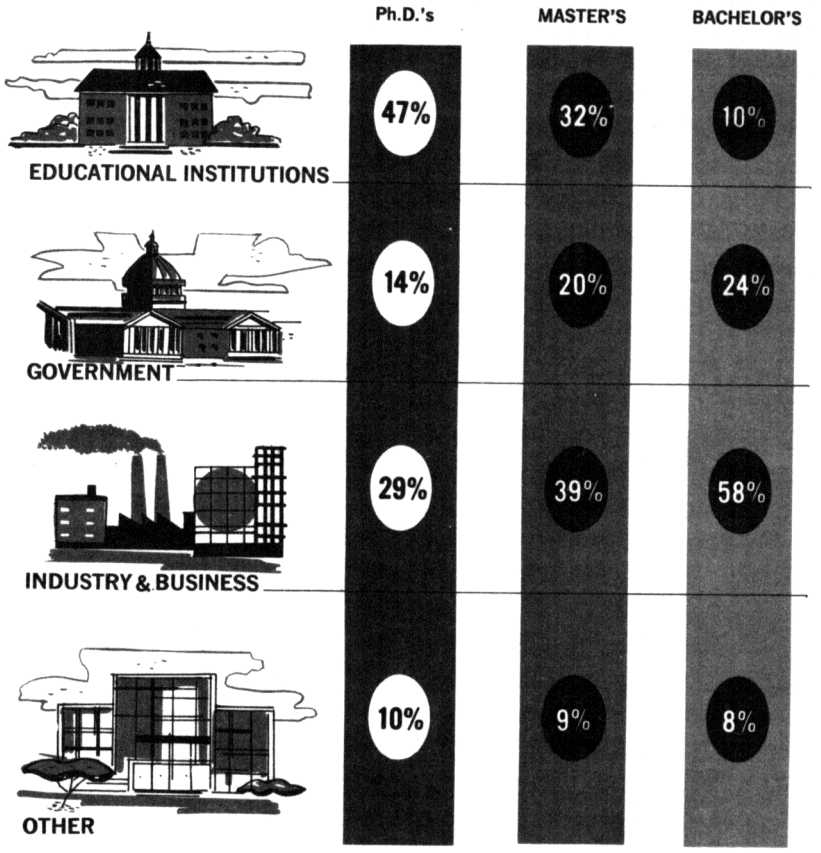
Table 6.—*General Characteristics of U.S. Scientists in the National Register of Scientific and Technical Personnel, 1962*

Characteristics	Number	Percent
Registered scientists	214, 940	100
Men	200, 362	93
Women	14, 578	7
Fields of science:		
Agricultural sciences	12, 389	6
Biological sciences	25, 554	12
Psychology	16, 791	8
Earth Sciences	18, 725	9
Meteorology	5, 379	3
Mathematics and statistics	18, 189	8
Physics and astronomy	25, 725	12
Chemistry	54, 130	25
Sanitary engineering	4, 923	2
Other fields	33, 135	15
Highest degree:		
Bachelor's	78, 574	36
Master's	56, 660	26
Professional medical	5, 693	3
Ph. D	66, 133	31
No report and less than bachelor's	7, 880	4

Table 6.—*General Characteristics of U.S. Scientists in the National Register of Scientific and Technical Personnel, 1962*—Continued

Characteristics	Number	Percent
Age group (median age, 38):		
20–29 years	39, 145	18
30–39 years	81, 143	38
40–49 years	56, 177	26
50–59 years	26, 705	12
60 years and over	11, 288	6
No report	482	.....
Employment status:		
Full-time civilian employed	185, 191	86
Active military duty and Public Health Service	5, 325	3
Students	13, 085	6
Other	11, 339	5
Type of employer:		
Educational institutions	60, 319	28
Government organizations, including Military and Public Health Service	43, 488	21
Nonprofit organizations	9, 445	4
Industry and business	90, 800	42
Self-employed	5, 095	2
Other	5, 793	3
Work activity:		
Research, development, or design	75, 679	35
Teaching	33, 907	16
Management or administration	48, 226	22
Other	57, 128	27
Professional experience:		
1 year or less	5, 508	3
2–4 years	32, 261	15
5–9 years	43, 563	20
10–14 years	44, 454	21
15–19 years	21, 537	10
20 years or more	50, 608	23
No report	17, 009	8
Salary distribution of full-time employed scientists:	1962 salary	
Lower decile	$6, 000	
Lower quartile	8, 000	
Median	10, 000	
Upper quartile	13, 000	
Upper decile	16, 000	

Another study by the Foundation was the fourth annual inventory of social science research projects concerned with the economic and social implications of science and technology. The survey covered only educational institutions (ref. 17).



SOURCE: National Register of Scientific and Technical Personnel, 1962

Figure 8. ***Type of Employer of Scientists Holding Bachelor's, Master's, and Ph.D. Degrees.***

A pilot study has been completed and a report is being prepared on the nontechnical aspects of the use of instruments and equipment in research and development; data were obtained on expenditures and the impact of these resources on the organization of the scientific personnel involved.

Another survey is under way on R&D expenditures and scientific personnel in certain regions in relation to the surrounding economic and educational development.

A study of the supply and demand of scientists, engineers, and technicians in the 1960's was completed and is in press (ref. 18).

Highlights of manpower developments in 1962 were contained in a report issued during the year which contained selected papers delivered at the Eleventh Scientific Manpower Conference (ref. 19).

The Foundation undertook a project on the work and study patterns of college graduates (see fig. 9). A report was issued during the past year on a 1960 survey of 1958 college graduates (ref. 20).

Other representative science manpower studies under way include offerings and enrollments in science and mathematics in nonpublic secondary schools, identifying high-level talent at the secondary school level, financial status of graduate students, doctorate production in U.S. universities (1920–61), factors influencing the number and quality of

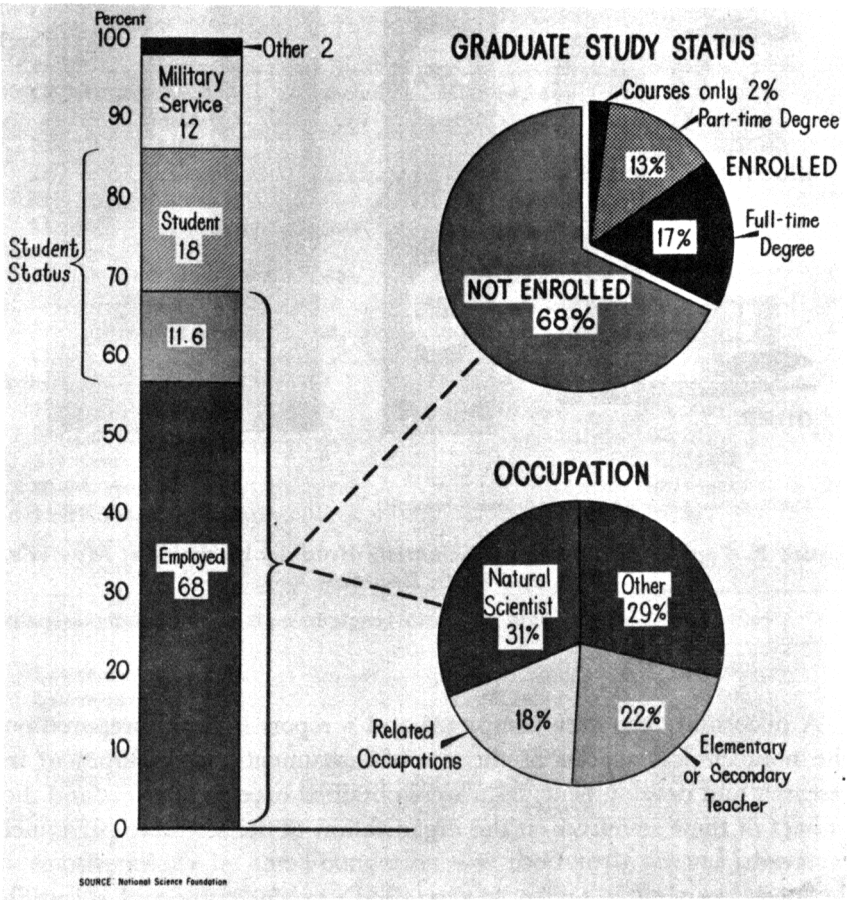


Figure 9. ***Activities of Male College Graduates in the Natural Sciences Two Years After the Bachelor's Degree, 1960.***

persons entering engineering, and status and career orientation of college faculties, 1963–64 registration of high school science and mathematics teaching, and survey of technicians.

A study of secondary school teachers of science and mathematics yielded information on their salaries, levels of education, and workload, and types and sizes of high school employing them (ref. 21).

In progress are studies leading to a global inventory of resources. They pertain to the U.S.S.R., Communist China, Sino-Soviet countries, and the Middle East. They deal with education and training of scientific and technical manpower, economic aspects of science and technology, R&D expenditures, and organization and management of science.

A specialized study provided information on immigration of scientists and engineers to the United States over the past decade (ref. 22). Also published were studies of the Organization of Science in Germany and India (refs. 23 and 24).

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