

NATIONAL SCIENCE FOUNDATION

Program Activities

of the

National Science Foundation

SUPPORT OF SCIENTIFIC RESEARCH

Although the course of scientific progress cannot be predicted with much accuracy, we do know that it is dependent on the performance of research by competent scientists and engineers. Science supplies not only the information needed to solve specific problems but, more importantly, it opens up new opportunities which usually cannot be foreseen until the new knowledge is obtained. To insure such new opportunities, research support is required for the acquisition of new fundamental knowledge across the entire spectrum of the physical, life, and social sciences—basic research.

The National Science Foundation has as a primary function the promotion of basic research through providing the scientist with the support necessary to carry out his creative work—the equipment, the assistance, and the time.

Historically, the National Science Foundation has supported basic research primarily through grants to colleges and universities for projects proposed by the scientist, who would carry out the research. These projects include not only specific scientific problems, but also projects in coherent areas of science—extremely broad in scope. The latter may involve the work of a number of investigators in several related disciplines.

Funds for this kind of support increased in the 1961 fiscal year to \$69 million from \$62 million in 1960. However, requests for support increased much more rapidly to \$256 million from the 1960 figure of \$163 million.

This increase in applications reflected not only the expanding national effort in research and the higher cost levels, but also three other significant factors.

1. More scientists are turning to the Foundation for support.
2. The Foundation is being asked to support a higher proportion of the actual cost of performing research.
3. Scientists are no longer satisfied with inadequate equipment and assistance, but request support which will make their research efforts as efficient as possible.

The Foundation endeavors to keep informed of those areas of science which become critical because of major breakthroughs or because of national needs. In consequence, increased support has been made available for oceanography and atmospheric sciences. Among the most recent areas being surveyed are tropical biology and forestry research.

The Foundation has been assigned Government-wide responsibility for a number of national research programs. These are programs that are best planned, coordinated, and funded on a national basis and include weather modification, Antarctic research, and Project Mohole—the effort to drill through the earth's crust, into the mantle.

It has been apparent for several years that a "facilities gap" was developing in the national research effort because Federal funds have been channeled primarily into research operations, but have not usually been available for buildings and other permanent facilities. The Foundation in fiscal year 1961 therefore, made available \$15 million for research facilities, including \$8.5 million for construction and modernization of graduate research laboratories. This represents an increase over 1960 of about \$3 million. Funds were provided for university computing facilities, oceanographic research vessels, specialized biological facilities, and the Hawaii Institute of Geophysics.

Although National Science Foundation policy in general calls for support of research in existing institutions, especially in universities, there have been three national research centers established, each a Government-owned facility operated under contract with a nonprofit corporation. These are the National Radio Astronomy Observatory, at Green Bank, W. Va.; the Kitt Peak National Observatory, at Tucson, Ariz.; and the National Center for Atmospheric Research, at Boulder, Colo. Support for the Centers totaled approximately \$8 million in 1961.

The Foundation's programs for support of scientific research are administered through the Division of Biological and Medical Sciences, Division of Mathematical, Physical, and Engineering Sciences, Division of Social Sciences, Office of Antarctic Programs, and the Office of Institutional Programs.

Research Programs

BIOLOGICAL AND MEDICAL SCIENCES

CURRENT RESEARCH SUPPORT

The purpose of basic research in the biological and medical sciences is to gain an understanding of living processes which are to be found in both plant and animal materials. Historically, field observation,

the dissecting scalpel, taxonomic analyses, and other classical biological and medical science techniques made it possible to describe the structure and function of living creatures on a macroscopic scale. In purpose, modern biological and medical research is similar to that which characterized classical biology, but it is vastly different in outlook, techniques, and procedures.

Current trends in the basic biological sciences relate to many factors, two being particularly significant: (a) a recognition that organic evolution is but a part of cosmic evolution, with the corollary interest in the history of living organisms and the origin of life as a part of cosmic evolution; and, (b) a fundamentally and drastically changed subject matter, with biological science inevitably moving in the direction of finer and finer units of living matter until it is now routine to deal with processes at the molecular level.

Of these two factors affecting biology, the first is important in that it establishes the setting and stakes out the extent of modern biological and medical science. The second factor, the study of processes at the molecular level, has recast the entire content of life science, has profoundly modified its techniques, tools, and research procedures and has restructured its relationship to other natural sciences. In dealing with processes at the molecular level, it has been necessary to develop the techniques of electron microscopy, micromanipulation and ultracentrifugation. For its experimental material, modern biological research requires preparations *in situ*, within the cell itself. As a result of these developments it has become possible to attack new problems by performing experiments of a type which could not have been envisaged a few decades ago, as for example, the study of successive links in cellular metabolism or the molecular structure of genetic material.

In performing its primary function of supporting basic biological and medical science, the Biological and Medical Sciences Division of the Foundation is organized in a manner which reflects this evolution in life science areas. From its inception the Division has been oriented toward research problems in contrast to orientation toward classical teaching disciplines. The Division encompasses the following eight areas: *molecular biology*, *genetic biology*, *developmental biology*, *metabolic biology*, *regulatory biology*, *environmental biology*, *psychobiology*, and *systematic biology*. This structure, when taken together, covers the total spectrum of basic biological and medical science on a "functional level" basis, ranging from "classical" biology to the most modern experimental problems.

Molecular Biology

The Molecular Biology program is concerned with studies of the molecular structure and function of living substances and the physical and chemical changes which occur in these substances within the life processes. The limits are difficult to define because molecular biology is the connecting link between the two broad disciplines of biology and the physical sciences. In physiological terms, the program is concerned with aspects of muscle activity, transport, membrane and bioelectric phenomena, replication, photobiology, immunochemistry, perception, secretion, biogenesis, and geochemical influences, all on the molecular level.

Theoretical and technical advances in physics and chemistry have been of prime importance in the development of this area. Electron microscopy, X-ray diffraction analysis, mass spectrometry, ultraviolet and infrared spectroscopy, radioactive measurements, nuclear magnetic and electron spin resonance, and ultrasonic techniques represent a few of the practical contributions of physical sciences to molecular biological studies.

The major portion of the program deals with molecular structure, the biokinetics and thermodynamics of such compounds as proteins, polysaccharides, and the nucleic acids. The complexity of the proteins, due to the number, size, and arrangement of the amino acids, has presented formidable problems. Recently several biologically active polypeptides containing up to 23 amino acids have been chemically synthesized. Similarly, relatively large molecules such as ribonuclease have been degraded and analyzed chemically by the techniques of Singer so that now we at least know one amino acid sequence. Research in this field consists largely in examining parts of the molecules, probable arrangements of these parts in individual proteins, and the chemical and physical behavior of the intact protein.

Polysaccharides comprise another large group of macromolecules; they consist of the carbohydrates, cellulose, starches (both plant and animal), the dextrans of yeast and bacteria, the levans, galactoses, and mannoses, and many others widely distributed in nature. Many polysaccharides are immunologically specific to man and studies are underway to find out more about antibody formation in reactive sites, chemical interactions, and molecular configuration. The nucleic acids include desoxyribonucleic acid (DNA), the stuff of heredity, contained in the nucleus and thought to bring about the synthesis of ribonucleic acid (RNA) molecules which contain the specific genetic configurations. The mechanisms in the transfer of the genetic or hereditary material is the central theme of molecular biology. One investigator recently has

determined that one strand of DNA, a double helix molecule, can form a hybrid helix with one strand of RNA, suggesting a possible transfer mechanism. The chemical likeness or differences of the basic composition of DNA of various organisms from simple to the more complex is another type of study being carried out. Systematic knowledge such as this should provide fundamental information on organic evolution and on the way the basic genetic components are put together.

Next in area of concentration are the investigations dealing with bioenergetics, biosynthesis, photobiology, and immunochemistry. All living matter depends upon electron transport systems for converting energy into a chemically utilizable form. Energy conversion systems all have in common a series of oxidation-reduction reactions. Free radicals obviously play a significant role in these reactions. Studies of how they do so and the determination of substrates involved are being pursued. Photobiological studies include the role of vitamin A in vision, the function of the photosynthetic pigments in plants, and the mechanisms of bioluminescence and fluorescence. Immunochemistry deals with studies of the antigen-antibody reaction, of the forces involved in the very specific interactions, and of the autoimmune response.

There are significant studies in enzyme conjugates, viruses, and membrane structure. All cells contain units called mitochondria which contain many enzymes, enzymes mostly concerned with converting food energy to a form the cells can use. These conjugates are being studied cytochemically to determine the sites of action for oxidative enzyme activities. Other investigations underway include the origin of new mitochondria, their interrelations with other cell structures, their role in the synthesis of proteins, and in electron transport. Viruses are being studied not only because they are composed of the "basic units" of life and so may shed light on structure of life matter but also because such studies may supply information about the mechanism of replication. Membrane structures of such organelles as mitochondria, microsomes (RNA-carrying particles), and cell walls are all basic to studies of the unit particle of life substance. There are a few scattered studies dealing with the electrical charges involved in membrane transport, the phenomena involving locomotion, the origin of life, biological coding, molecular morphology, replication, and theoretical biology. The program shades off into such areas as geochemical influences, nerve condition, sensory perception, and neurosecretion.

Genetic Biology

The Genetic Biology program is charged with the support of studies on the nature and organization of the genetic material and its replica-

tion, mutation, recombination, and transmission; the nature of the genetic code and the transfer of coded information to primary gene products; gene action and its regulation; gene interaction; origin of somatic cell differences; genetic processes in populations and the operation of evolutionary mechanisms; and the analysis of continuous variation.

Scope of the research support is illustrated by the following areas in which research projects have received new or continuing support during the past year.

Among the most challenging problems of present day genetics are those of unorthodox inheritance in higher organisms. Grants have been made for continued support of work on the phenomenon of paramutation and for the study of exceptional (noncrossover) derivatives of a complex locus in maize. Other work on complex loci includes the study of the "dumpy" locus in *Drosophila*. Fine structure is being mapped and attention is being given to the processes of recombination with regard to "conversion" and "negative interference." Parallel studies compare chemical and radiation mutagenesis at this locus.

Projects directed at improving our understanding of chromosome structure and stability have been supported by grants to investigators making a broad attack on the problems of metabolic control of mutation processes, the organization of the genetic material at the chromosomal level, the relationship between DNA and protein in the chromosome, and mechanisms of replication and recombination.

Support has been provided for work on the molecular basis of chemical mutagenesis in bacteriophage, for studies on the relationships between genetic changes and changes in the structure of viral protein, and for studies on episomic elements in bacteria in relation to the control of enzyme synthesis; also for the very promising work on nuclear, cytoplasmic, and environmental control of immobilization antigens of *Paramecium*, and on the nature of the structural changes which alter the biological properties of these proteins.

Grants have been awarded for developmental genetic studies on the control of pattern in various mutants affecting the development of sex combs in *Drosophila* and on sex differentiation in vertebrates.

In the areas of evolutionary and population genetics, continued support is being given to a productive project, studying evolution in the genus *Gossypium* (cotton). Another project, using data collected in Hawaii, is concerned with the estimation of genetic load in first and subsequent generations following racial outcrossings in humans; it is also studying the contribution of lethals and detrimental to genetic load in a laboratory population of *Drosophila*.

Of the work that is being supported in quantitative genetics, particular note may be given to a project using two systems of selection for a quantitative trait, involving different levels of inbreeding. These studies will provide a basis for predicting the results of selection for quantitative characteristics under various conditions, and will add to the understanding of the nature and stability of gene complexes under selection. Another project aims at the development of sampling plans that will enable the investigator to evaluate the possible effects of interaction between loci and the effects that linkage may have on quantitative characters being subjected to genetic analysis.

The support of work in mammalian cytogenetics includes two projects—one concerned with mammalian heterochromatin and with trisomy in mammalian cells in tissue culture, the other with sex-determining mechanisms in mammals.

Research in behavioral genetics is also supported through this program. Grants have been made in this area for the continuation of promising studies of genetically determined variation in alcohol preference in mice and for a conference on behavioral genetics to help the behavioral geneticists bring the problems of their emerging field into sharp focus.

Two other grants of special interest may be mentioned. One is assisting in the development of *Chlamydomonas* as a genetically useful organism for studies of problems of recombination, gene action, etc.; the other is assisting a Nobel-laureate physicist in undertaking research in molecular genetics.

Developmental Biology

Research supported by the Developmental Biology program has as its objective understanding the principles governing the processes of cell division, growth, and tissue transformation, as these are involved in development. To accomplish this, studies on differentiation, defined as any regularly predictable protoplasmic change, are undertaken in all forms of life, exploiting technical advances made in many scientific disciplines. These studies inevitably involve the interactions of the intrinsic machinery of the cell with its genetic endowment and with extrinsic factors in the cellular environment.

Developmental biology at the organismal level includes microscopic and macroscopic changes in morphology during the life history of the organism, starting with the zygote and ending either with fully differentiated germ cells (from which originate a new generation of zygotes) or with *ante mortem* changes (terminating a generation). For example, development of individual muscles in closely related species of amphibia is being studied in an effort to demonstrate evolutionary and taxonomic

relationships. Detailed descriptions of a parasitic trematode demonstrate striking cellular transformations during a single complex life cycle. Growth of leaf primordia at the tips of developing plant stems has been analyzed numerically and a model has been programmed for testing in a computer. Development of asymmetry in the wing of the chicken has shown that a 12-hour determination period plus a 3-day latent period precedes cellular morphogenesis. Study of plant cells indicates that unique orientation of cellulose fibers deposited inside the walls apparently explains expansion of this rigid system during growth.

Developmental biology at the cellular level includes tissue and cellular changes that can often be causally associated with cellular interactions or morphological effects of products of one cell type upon cells of a different type. Characteristics of the induction phenomena are commonly studied on the basis of metabolic interdependency of cells. For example, cells of different types when put into a prepared mixture of cells appear to be capable of correctly assorting and adhering to those of their own type. Prior to this, however, cells have an alternative type of behavior, i.e., cells of a given type in mixed culture can become transformed into an alternate type. Patterns of movements of cells in the early, two-layered stages of development of the chick have shown that the anterior-posterior axis and bilateral symmetry of the embryo is established during the first few cell divisions of the fertilized egg. Tissue interactions (induction) have shown that (a) morphogenesis of prospective cartilage cells is directed by an influence emanating from the dorsal neural tube, (b) to be effective, the responding cells must have at least 14 hours of exposure, and (c) morphogenesis into cartilage cells occurs 3 days after the exposure.

Developmental biology at the subcellular level hopes to delineate intermediary biochemical pathways associated with differentiation. Developmental biologists today study fine structure, subcellular particles, macromolecular compounds, cytoplasmic duplications, chromosomal differentiation, immunological specialization, enzyme patterns, DNA-RNA-protein relations and synthesis of proteins. Biochemistry, intermediary metabolism, and ultrafine structure have become particularly active areas for investigating developmental biology.

Illustrative of the research being supported at the subcellular level are cytochemical studies on proliferation and synthesis of DNA in cells of the onion root tip that have shown that during irradiation, DNA synthesis is actually stimulated in spite of mitotic inhibition. Such studies on cytochemical deviations during development will enable scientists to make distinctions between synthesis, replication, and mitosis. Nucleic acid metabolism during early development of the

frog has shown that both the nucleus and the cytoplasm of the frog egg contain hundreds of times more DNA and RNA than ordinary diploid liver nuclei. Furthermore, there is more than one type of RNA in the egg, as determined by solubility studies and by base ratios. Discovery of the relation of these unusual nucleic acids to early development will be most enlightening. Studies on cell division are exploiting a plant tissue in which cell divisions are predictable and synchronized. A hypothesis is being tested that deoxyribosides serve as active components of metabolic processes during preparation for cell division before the ribosides are passively incorporated into duplicated DNA for the daughter cell. The inductive influence of the nervous tissue on differentiation of precartilage cells has shown that a small nucleotide complex has the specific capability of transforming the responding cells. This is one of the best examples of progress being made on detecting the chemical basis of an embryonic inductor. Experiments with RNA have shown that labile cells can be converted to the type from which the RNA was taken. Although the interpretations have been questioned, the basic finding remains unchallenged and these studies have far-reaching implications concerning the chromosomal control of differentiation.

Electrophoresis of embryonic tissues has shown that certain proteins, although classifiable as a single enzyme, can be separated both by electrophoresis and by reactions with substrate analogues. These enzymes, labeled "isozymes," differ from tissue to tissue in the animal and change with time during development indicating genetic control of changing isozymes during differentiation. Nuclear control of enzyme synthesis is being studied as a sequel to the classical experiments on morphogenesis in *Acetabularia*. Species differences exist with respect to phosphatase enzymes found within the cells, and in at least one species the synthesis of this protein enzyme remains under control of the cytoplasm irrespective of the type of nucleus in the cell.

Metabolic Biology

The object of research in the Metabolic Biology program is learning to understand the processes by which the materials that living things are composed of are built up and broken down. Enzymes are the so-called living catalysts which carry out these processes. All information concerning control of the rate of enzyme function, and the conditions under which these catalysts work, fall within the province of metabolic biology. Thus, studies of carbohydrate and lipid metabolism, nucleic acids and protein synthesis, hormone synthesis and metabolic action, im-

munology and infection, role of cofactors in metabolism, bioenergetics, photosynthesis, amino acid synthesis, and virus-host relationships.

Examples of current research are investigations of the role of nucleic acids in specifying the synthesis of proteins. One such project involves the use of pyrimidine analogues as a means of altering the coding pattern during the synthesis of nucleic acids. Another area of research which promises to enhance substantially our understanding of the relationship between enzyme sequence and structure involves the reconstitution of the complex enzyme systems which occur as morphological entities in most living systems.

Other promising areas of research are those attempting to elucidate the synthesis and mechanisms of actions of antibodies, complements, and related substances which are fundamental to a genuine understanding of the basis of resistance to infection, allergic reactions, and tissue transplantation problems.

Research is also being supported on control and regulation of enzyme synthesis and activity. One grantee is investigating control of penicillinase synthesis by examining conditions affecting formation of a repressor of the enzyme.

Regulatory Biology

Regulatory Biology deals primarily with research on whole organisms and their organ systems and on the regulatory systems which control their behavior. It includes most of what may be termed classical plant and animal physiology, as well as, considerable research in pathology, nutrition, and transport of materials. Research in endocrinology, plant hormones, and neurophysiology forms an important part of the program. Organisms studied vary in size and complexity from bacteria and one-celled algae to birds, camels, and humans, and the methods used are equally diverse. Perhaps the scope of research can be shown most clearly by some examples of projects being supported.

Aid is being provided for work on the regulation of intake of food (eating), breathing, and body temperature in animals. Attempts are being made to localize the region of the brain which controls eating and drinking by stimulating or destroying certain areas and observing the effects on intake of food and water. Apparently the control center is located in the hypothalamus. Another investigator is attempting to learn how changes in carbon dioxide concentration of the blood produce signals in the brain which affect muscles of the chest and diaphragm and regulate the rate of breathing. A study also is being made of control of breathing at low and high altitudes to learn how adjustments are made to exercise at high altitudes.

There is continued interest in the factors controlling migration of birds and the methods by which homing pigeons and other birds orient themselves in flight. Research is underway on the physiology of salmon and other fish that migrate to certain streams to spawn. Several studies of the structure and endocrinology of the reproductive organs of birds and animals also are being supported.

Research on nutritional problems of both animals and plants continues to be active. Several investigators are attempting to grow such diverse organisms as nematodes, rotifers, and snails in axenic cultures (cultures of known composition). Another investigator is attempting to grow mites (red spiders) on artificially prepared media to learn more about their nutritional requirements. The existence of a previously unrecognized growth factor for guinea pigs in leafy vegetables was established and its exact nature is now being investigated. A number of interesting studies of feeding habits of insects are in progress. Some are intended to learn why a certain kind of plant is eaten while another kind is avoided; one study involves an attempt to change the feeding habits of the insects by selection through several generations.

There is increased interest in pathology, particularly plant pathology. Several investigators are attempting to learn why some varieties and species of plants are more resistant to pathogenic fungi than others. This problem has been studied for at least 75 years without much success, but the development of modern biochemical methods has renewed interest in the problem and raised hopes of more rapid progress. Causes of resistance to nematodes and other parasites are also under study.

There has been a definite increase in proposals dealing with research on plants during the past year, especially research on trees. Currently supported research on trees includes investigation of the effects of water supply on growth and cell structure, effects of water balance on photosynthesis, dormancy, and geotropism. Some progress is being made in explaining differences in cold and drought resistance among various species of plants. The mechanism by which length of day controls flowering is under study and attempts are being made to isolate a flower-inducing hormone.

Several new projects were supported on transport of materials in plants and animals and the uptake of ions by cells. Among the numerous other projects being supported are studies of salt secretion by animals, water and heat balance of camels, diseases of insects, symbiotic relationships between bark beetles and associated fungi, relation of composition of guttation liquid to fungus spore germination, response of algae to gibberellins, diurnal rhythms in photosynthesis, and bioelectric potentials in plant cells.

A number of the projects supported by this program make use of single cells or bits of tissue, merely as a means to an end. The general objective of such research is to increase our understanding of the regulatory mechanisms which integrate the complex of processes and transform an aggregation of cells and tissues into an organism.

Environmental Biology

Living plants or animals, including man, are sometimes defined as being self-regulating and self-perpetuating physicochemical organisms striving to attain equilibrium with their environment. Everything and every force external to the organism must, in the final analysis, be considered to constitute its environment; none can escape from an environment, each is influenced by it throughout the entire life period, and, in turn, each has an influence upon its environment.

The gross relationship between the environment and the organism is quite evident in almost every field of biology. Energy, without which life cannot exist, is derived from the environment; physiological processes are influenced, directly or indirectly, by environmental fluctuations; factors of the environment influence growth and development; external forces and substances affect the sensory mechanisms of animals and plants; genetic systems of organisms are influenced by environmental isolation; behavior reflects a response to factors of the environment; variations in environmental conditions have produced the present distribution of animal and plant life; and, various features of the environment have influenced the survival of organisms, thus forming the natural selection basis for the evolution of living systems. Thus, the field is broad and covers or impinges upon a number of inter-related areas of biological interest.

One area of investigation supported through the Environmental Biology program is that associated with the interdependent phenomena of energy systems and biological productivity. The efficiency of an aquatic system, as measured by the level at which energy of sunshine is utilized by plant life (primary producers) and transferred to the first groups of animal consumers, is illustrative of currently active studies of this nature. Another investigation of energy systems is concerned with the primary productivity and nutrient cycle of a grassland ecosystem as related to variations in rainfall, temperature, and length of growing season.

The largest single category of research efforts supported by the program continues to include those pertaining to the biological and physical factors in the fresh water or marine environment which influence the

distribution, abundance, growth, and reproduction of all life forms contained therein.

Because certain organisms are identical or closely related to fossil forms, analyses of the relationship of modern plants and animals to existing environmental conditions permit us to speculate with some assurance relative to the conditions under which the earlier forms lived. The use of pollen chronology to interpret the vegetation and, thus, the climate of earlier geological periods may be subject to several sources of error. A study initiated recently is expected to reduce one type of error and lead to the development of a new and more readily interpretable method for expressing the frequency of fossil pollen in sediments. The research is also expected to provide considerable information on the relationship between present vegetation and the quantity and nature of pollen now being deposited in sediments under certain conditions.

Another very dynamic and challenging area of research receiving the attention of the program is that involving population ecology. Of special interest are the studies involving the use of mathematical models to demonstrate population theory and to predict population growth, a necessary intermediate step in the application of such theories to situations in the field. These introductory investigations may lead to the use of advanced electronic computer techniques for the analysis of population control mechanisms.

Although the taxonomic positions of many organisms have been well established, the details of their life histories are frequently not as well known. The program, therefore, continues to provide aid for life history analyses of a variety of animal forms, including mollusks, insects, fish, and turtles.

Studies of animal behavior and orientation have been greatly assisted in recent years by the utilization of electronic techniques. The use of miniature radio transmitters for continuous identification and location of animals has made possible the collection of information on heretofore obscure aspects of life history, behavior patterns, and population phenomena. Quantitative analysis of nocturnally migrating birds using radar techniques are being made in order to establish the course, speed, and numbers of such birds at different times of the year and to ascertain their responses to different weather conditions.

A large part of the program is devoted to general studies of the responses of animals and plants to their external environments. One group of these projects involves a study of the physiological mechanisms underlying the relationship of the organism to its environment, for ex-

ample, the organism's response to magnetic and other physical fields, photosynthesis and respiration of alpine plant communities, and the climatic stress effects on desert vertebrates.

Psychobiology

The Psychobiology program embraces the biological aspects of psychology and many of the behavioral aspects of zoology. Its focal point is behavior. Some investigators seek neurological correlates of behavior; others study uniformities of behavior in such areas as learning, without regard to neurological aspects. Some concentrate on psychological responses to stimulation; others seek to link these responses to sense-organ structure and function. Some confine themselves to laboratory studies; others concentrate on field observations of behavior. These varied approaches to behavior reflect a variety of traditions within psychology and zoology. Each has developed a substantial body of information and of research techniques. Equally important are the many efforts to adapt the findings and techniques of a number of approaches to specific problems.

Approximately one-fifth of the grant awards in the Psychobiology program involve some field work in animal behavior (usually with some laboratory experimentation as well). The remaining four-fifths are laboratory studies, about equally divided between human and nonhuman subjects.

Four examples suggest the kinds of research being supported in the general area of animal behavior. One study deals with the genetic basis of behavior and the effects of experience on the development of behavior in the African Parrot genus *Agapornis*. Another study is concerned with the evolution of structure and behavior patterns of nyssonine digger wasps. An experimental analysis of homing behavior in field mice is being made in the hope that the findings will contribute to the understanding of the physiological basis of homing behavior in a wider variety of forms. Advanced techniques of sound recording and analysis are being used in a study of Galapagos finches.

Among the laboratory investigations, work on operant behavior and reinforcement continues to be prominent, both as a direct object of study and as a technique for exploring such problems as the sensory capacities of animals. One investigator will seek to determine which reinforcement patterns lead to the most efficient learning and retention. He will also examine the extent to which performance schedules and interactions among them will explain "choice" and "decision making." Another investigator is continuing his work on reinforcement and resistance to extinction, concentrating attention on the licking response, which has

proved to be a productive research tool. In a new pilot project, instrumental conditioning techniques will be used to determine the feasibility of obtaining comparable data on color and brightness vision for several species of fish.

Within the general area of physiological psychology, one investigator is examining neurophysiological mechanisms of attention and learning by recording from implanted electrodes and by studying the effects of the removal of critical areas of brain tissue. He hopes to gain further insight into such problems as the modifications induced in sensory information arriving at the cortex due to repetition without reinforcement, to reinforcement by combination with new sensory input, or to reinforcement by activation of hippocampus and/or brain stem. Another investigator is studying the major characteristics of aversive autonomic nervous system conditioning, using a curarization technique which allows him to study autonomic conditioning in dogs whose skeletal musculature is immobilized. The function of taste cells is being examined with special attention to the effects of growth, aging, and degeneration on sensory functioning. Other studies deal with biological clocks, self-regulatory functions, and the relations between thalamic connections of the auditory system and behavior.

A substantial number of investigators are studying problems of human learning, perception, and thinking. Illustrative projects include research on mediated generalization in human conditioning and performance, experiments on the consolidation time or development time of a visual percept, an examination of context effects in relation to auditory and visual perception, an approach to problems in the visual perception of shape in terms of communication theory, and a series of studies within the framework of information theory to investigate some implications of the generalization that choice reaction time is proportional to transmitted information. Several research workers at one university are exploring the basic processes of human learning, seeking to extend and refine the methods used in investigating human learning, and to develop increasingly close links between the psychology of human learning and neighboring disciplines such as psycholinguistics and statistics.

Systematic Biology

In his recent book, *PRINCIPLES OF ANIMAL TAXONOMY*, G. G. Simpson points out that "Systematics is the scientific study of the kinds and diversity of organisms and of any and all relationships among them." The program for Systematic Biology provides support for research in the systematics of numerous kinds of plants and animals, both living and extinct, that occur in widely diverse habitats. Research activities are

not limited by geographic or national boundaries; they extend to remote areas of the world and treat a wide variety of subjects. As is evident from the description of the Division's program, which follows, subjects investigated range from fishes of the South Atlantic to small mammals of the Scilly Isles, from the land flora of the Antarctic continent to the flora of southern Brazil, from Carboniferous bryozoans of the Ukraine to Pleistocene mammals of Colorado.

No living or fossil organism is excluded from systematic attention. Studies by 170 or more specialists, reported in the *TREATISE ON INVERTEBRATE PALEONTOLOGY*, are making available to paleontologists, zoologists, and geologists a comprehensive and up-to-date treatment of fossil invertebrates, including their phylogeny, morphology, ecology, and distribution. Investigations on the growth stages of extinct Mesozoic tree ferns are helping to clarify the taxonomy of this group as well as to give a dynamic picture of "fossil life." Morphologic evidence from the flowerlike cones of these plants may indicate whether the tree ferns are ancestral to more advanced plants. Rocks of the Beaufort series of the Karroo region of South Africa yield one of the best fossil records in the world of later Permian and Triassic terrestrial vertebrate life. Recent field work in the Beaufort series has resulted in an outstanding collection of at least 188 specimens of mammal-like reptiles. This collection will be available in the United States for study and comparative purposes. These specimens will allow further consideration of diversity and adaptation among these reptiles, as well as serve for anatomical reference in studies of other reptiles or of mammals.

As man penetrates more deeply into the oceans and ocean floor and as interest in the atmosphere grows greater, the systematist finds an ever increasing need for his knowledge and skills. Research on zooplankton and other marine invertebrates, marine bacteria, and algae becomes increasingly significant. The snapping shrimps are among the most commonly occurring crustaceans on coral reefs of the central Pacific. They have attracted considerable attention in recent years, not only for the sound they produce but more importantly for their interference with submarine radar. Some of these occur in a diversity of habitats and others are limited to extremely narrow ecological niches, making them excellent subjects for studies of distribution and speciation. Field and laboratory investigations, including study of the reproductive apparatus and embryo sporophyte, are helping to clarify relationships among marine algae of South Africa. More complete information on these algae will contribute to research studies on seaweeds throughout the world by facilitating comparative investigations.

Systematists are constantly striving to achieve a natural basis for classification rather than an artificial grouping of organisms that tends to obscure relationships, and they employ many different approaches to this end. The classical approach usually involves studies of morphology and distribution. Monographic treatments and revisions of families, genera, and species of plants and animals are a culmination of such studies. Sample research projects of this sort are in progress on Embioptera, web spinners of tropical Asia; caddisflies of the world; North American species of mushrooms; marine red algae of Pacific Mexico; and Orthoptera of North America.

Knowledge of life cycles also may be of systematic value. Except for a few incomplete investigations, the observed facts about eggs of various orders of insects have not been correlated with systematics. Examination of moth eggs of 50 species, representing 10 families, shows distinct differences and that evidence from the eggs can be utilized in determining relationships among moths. Behavioral characteristics have a use in systematics. Relationships among the New World tyrant flycatchers, which are morphologically rather uniform but extremely varied adaptively, are being investigated through behavior patterns.

Biochemical techniques also offer much in the way of clarifying certain phylogenetic problems. Early serological studies showed that the degree of similarity between the proteins of animal species can be of value in determining relationships. Electrophoretic and other chromatographic studies on egg-white proteins are now under way in an attempt to determine relationships among various groups of birds. Considerable attention is being focused on the hawks, eagles, and their allies, and on the passeriforms (perching birds). Often the protein studies confirm evidence for relationships based on anatomical and other findings, but where other evidence is equivocal, they may throw light on the true relationships. Chromatographic approaches of phylogenetic importance are being applied also to plants. The biochemical constituents of legumes of the genus *Baptisia* are being correlated with morphological characters. Some hybrids between species of *Baptisia* show a recombination of the biochemical constituents of each parent. In the case of these hybrids the biochemical expression is quantitative. Genetic studies on biochemical inheritance are being correlated with the systematic approach, and possible environmental effects on the biochemical constituents of the plants are being considered.

A major trend in evolutionary research has been an increasing recognition of the importance of the population as opposed to the individual as a basic unit for systematic study. This recognition has led to emphasis on the study of variability in populations. Wild and laboratory

populations of small mammals are studied in attempts to estimate the relative contribution of genetic and nongenetic factors in variation. The variation in a large sample of Pleistocene rodents from Florida is being compared with that in living rodents. The studies are contributing to an understanding of the taxonomic position of the Pleistocene forms as well as to a determination of the rates of evolution of selected traits and of modes of speciation.

The use of digital computers has entered systematics as well as many other fields of endeavor. Pioneering work in numerical taxonomy has been undertaken in order to establish the methodology and gain the experience necessary to make the methods reliable. Although early studies have dealt mostly with taxonomic problems in insects, the methods being developed should prove more general in application. This new numerical approach to taxonomy is controversial, but it will lead to a re-examination and re-evaluation of all methods used in systematics. Further, it may become accepted as an additional tool in determining the relationships among organisms and in understanding their evolutionary development.

Short-Term Research by Medical Students

Under this program grants are made on a merit basis to medical schools for the purpose of providing stipends to support the research of appropriate students during their free summer (or other) periods. The objective of this program is to give capable and well-motivated students an opportunity to undertake basic research and thus to assess first hand their interest in research careers. Criteria for evaluating proposals submitted by the various medical schools include initiative of the school in developing and seeking support for its student research program and in encouraging basic research among its staff, quality and effectiveness of student programs now in operation, and demand for stipends in relation to local funds available.

During the 7 years in which this program has been in existence more than 2,000 stipends have been provided through 116 grants to 70 different medical schools. The size and vigor of student research programs have increased markedly during this period as has the number of medical schools undertaking such special training for their students.

SIGNIFICANT RESEARCH DEVELOPMENTS IN THE BIOLOGICAL AND MEDICAL SCIENCES

AMINO ACID SEQUENCE OF TOBACCO MOSAIC VIRUS PROTEIN DETERMINED—Tobacco Mosaic Virus or TMV is made up solely of RNA and protein. The RNA contains all the biochemical information necessary

for replication and synthesis of the structural protein. The amino acid sequence of TMV has recently been determined by an investigator working under a Foundation research grant. This protein is made up of subunits consisting of 158 amino acids and except for a few minor details the order of these residues in the protein molecule has been determined. This is the first viral protein whose amino acid sequence has been worked out. It is also the longest.

It should now be comparatively easy to study the effects which alterations in the RNA structure have on the amino acid sequence of the protein. This type of approach will help to solve the problem of how nucleic acids code information and thus control the genetic makeup of living cells.

* * *

GUTTATION WATER HAS EFFECT ON SPORE GERMINATION—There is little or no correlation between differences in disease resistance among plant species and growth of the causal organisms on extracts prepared from tissues of resistant and nonresistant plants. However, recent experiments have shown that spores of the ergot fungus germinate readily in guttation (droplet) liquid from rye which is susceptible to the fungus, but do not germinate or grow well in guttation water from wheat which is resistant to the ergot fungus. The guttation liquid, which exudes through pores at the tips of grass blades and along the margins of other types of leaves, is water forced out of the xylem by root pressure. This liquid seems to be more representative of the environment encountered by germinating spores as they penetrate leaves than extracts prepared from ground leaf tissue. If the differences in resistance to the fungus can be correlated with differences in composition of the guttation liquid a significant advance will be made in our knowledge of the biochemistry of disease resistance.

* * *

UNBROKEN DNA MOLECULES PHOTOGRAPHED SUCCESSFULLY FOR THE FIRST TIME—The study of the detailed structure of deoxyribonucleic acid (DNA) is one of the central problems of molecular biology. Previous attempts to obtain clear-cut pictures of DNA molecules by electron microscopy failed because of two technical problems in the preparation of specimen material. Both have been overcome by an NSF grantee and his coworkers. The first, the obtaining of whole length specimens, was accomplished by passing a plastic film with weakly basic ion exchange properties through a solution of DNA. The technique produced long and parallel unbroken molecules stretched out on a supporting membrane. The second, a suitable staining method to make the molecules

distinguishable, was done by interaction of Uranyl salts with DNA. This produces a much more faithful representation of the DNA molecule than "shadowing" has been able to do. As a result of this study, unbroken DNA molecules have been photographed successfully. Heretofore, scientists have been able to determine when mutations occur in genetic materials but have been unable to pinpoint the sites of such defects. This development may well hold the answer.

* * *

SUCCESSFUL SYNTHESIS OF ACTH-LIKE COMPOUND—For the past 10 years hundreds of chemists have been trying to solve one of organic chemistry's most difficult problems—the chemical synthesis of a compound with all the biological properties of ACTH (adrenocorticotropic hormone). An NSF-supported investigator succeeded in this task.

ACTH is produced by the pea-sized pituitary gland at the base of the brain and seems to be a hormone's hormone. When it is carried by the blood to the adrenal cortex it stimulates the production of many other hormones that regulate vital functions of the body. The great difficulty in its chemical synthesis has been that ACTH is a protein, a long chain of amino acid groups linked together like a phrase in telegraphic code, which had to be reproduced in proper sequence and special arrangement. The synthetic copy has only 23 amino acid groups as opposed to 39 of the natural ACTH, but this part of the chain seems to function biologically as well as the whole.

Knowing how to synthesize ACTH will make possible a clarification of the role of the pituitary gland in stimulating the adrenal cortex to produce cortisone and other steroids. Also, the structure can be changed more easily to obtain different biological properties. Finally, the synthesis techniques employed may be used to make other complex polypeptide molecules.

* * *

LIGHT-EMITTING COMPOUND IN FIREFLIES SYNTHESIZED—Bioluminescence is an enzyme-catalyzed chemiluminescence in which oxygen acts as an electron acceptor. So far as an NSF-supported group of investigators can determine, the requirements for bioluminescence are an ionizable substrate (luciferase) which can form a peroxide addition, molecular oxygen, and presumably a fluorescent product molecule (luciferan). In the examination of the light-emitting system of the firefly attempts have been made to isolate and purify the reacting components, to identify the end products and possible intermediates, and to understand the mechanism of the conversion of chemical energy into light energy. The group

recently has been able to establish definitely the chemical structure of luciferan and has completed the synthesis in the laboratory. The ease of acquiring this compound will allow an extensive quantitative study of these substances during light activation.

* * *

NUCLEOTIDES PLAY KEY ROLE IN CELL DIFFERENTIATION—Conspicuous features of the early vertebrate embryo are the mesodermal segments or somites that form as a parallel row on each side of the spinal cord. Most of the cells within the somites have alternative fates, they or their daughter cells are destined to differentiate into either muscle or cartilage cells. It is known that the embryonic spinal cord is capable of directing these cells to forego their muscle-forming potentiality and to become cartilage cells. This directive influence of the spinal cord has been carefully studied and, for example, one can now state when and for how long this influence must be exerted in order to bring about differentiation into cartilage. Recently a cartilage-inducing factor specific to the spinal cord has been isolated by a National Science Foundation grantee through chromatography and found to be a relatively small nucleotide complex. The exciting feature of this and comparable research is that we are getting close to understanding one of the enigmas of modern biology—although embryologists have noted the similarities of different kinds of embryos and embryonic processes, no data exist to explain the mechanism by which two similar embryos are made to diverge so that one invariably becomes a mouse and the other a man. The fact that nucleotides may play key roles in embryology, as well as in genetics of determination, constitutes a major advancement in basic knowledge.

* * *

COBALT ESSENTIAL FOR GROWTH OF NITROGEN-FIXING BACTERIA FOUND IN LEGUMES—Biological nitrogen fixation is a fundamental phenomenon and is important either directly or indirectly in the maintenance of all living organisms. Most of the world's nitrogen supply is maintained by this phenomenon. Data indicating the contribution of free living nitrogen-fixing bacteria to the world's supply of nitrogen is lacking, but it is believed to be very insignificant when compared with the amount fixed by legumes through their symbiotic nitrogen-fixing bacteria. In a series of experiments the effect of cobalt and other elements on the growth, nitrogen fixation, and partial chemical composition of leguminous plants was investigated by an NSF grantee. These experiments proved beyond any doubt that cobalt is essential for the growth of soybean plants under symbiotic conditions. Further

investigations confirmed that cobalt is necessary for the growth of the symbiotic bacteria. These organisms apparently require the element either in or out of legume nodules. This seems to be the first clear cut demonstration of a cobalt requirement for bacteria and for nitrogen fixation.

* * *

ALDER TREES SIGNIFICANTLY INCREASE NATURAL PRODUCTIVITY OF LAKES—One of the many puzzling features of the exceedingly complex relationships associated with the dynamics of a lake is the seeming lack, in some instances, of a recognizable source of the nutrient materials required by primary producer organisms in the aquatic food chain. Such materials are commonly said to enter the lake in runoff water from the adjacent watershed but this explanation is inadequate in instances where the nutrients available in the lake are far higher than the fertility level of the watershed soil. Although alder trees (nonleguminous, nitrogen-fixing plants) have been demonstrated to provide nitrogen for other terrestrial plants, various factors resulted in an underestimation of their role in the primary productivity of certain lakes.

After preliminary work on Alaskan lakes located in volcanic ash watersheds, an NSF-supported investigator initiated a more intensive study of a California lake located in an area of similarly deficient fertility. His efforts have demonstrated that even a few alder trees can play a major role in providing nutrient materials for lakes. The nitrogen-fixing activities of alder roots were found to contribute significantly to the fertility of soils on lake and feeder-spring banks. Equally interesting, however, was the investigator's discovery that leaf fall from alders contained more than four times as much nitrogen as defoliation from other species. Thus, the hitherto unexplained productivity of some mountain lakes and of those in other regions where watershed fertility is deficient may be due to nutrient materials provided by alder trees through direct nitrogen-fixation and decomposition of leaf litter in restricted watershed soils; by alder leaves blown directly into the lake; and, to some extent, by rain or dew drip from living alder leaves. Aside from the very interesting scientific aspects of this research, the results may have rather substantial practical implications in our efforts to improve the natural productivity in certain lakes which are too infertile to support adequate populations of fish or other living forms.

* * *

CAROTENOIDS PROTECT CELL FROM PHOTO-OXIDATION DAMAGE—Carotenoids are orange pigments which occur widely in plants, fungi, and photosynthetic and nonphotosynthetic bacteria. When consumed

by animals they serve as precursors of vitamin A and as such function in the photochemistry of vision. An NSF grantee has now discovered that their primary function in the photosynthetic apparatus is to protect the cell from chlorophyll-catalyzed photooxidative damage. He found that a "blue-green mutant" of a certain purple bacterium which lacks carotenoids completely exhibited great sensitivity when exposed simultaneously to light and air, as did cells of another species of photosynthetic bacterium when rendered 90 percent carotenoid-free by an inhibitor of carotenoid synthesis. The sensitivity was manifested both by destruction of chlorophyll and by cell death. It was further found that carotenoids play a similar role in nonphotosynthetic bacteria and fungi, where such nonchlorophyll pigments as the porphyrins are potentially capable of producing photo-oxidations.

* * *

NEW INFORMATION OBTAINED ON THE STRUCTURE AND FUNCTION OF MITOCHONDRIA—Mitochondria are biochemically active macromolecules occurring in the cytoplasm at the rate of approximately 100 per cell. They are composed of ribonucleic acids, lipids, and proteins, and carry enzyme systems essential for the functioning of the organism. Among these enzyme systems is the one which makes biological energy available to the living cell for the synthesis of vital constituents by means of the coupling mechanism between oxidation (electron transport) and phosphorylation.

A Foundation grantee has obtained new information on the structure and function of mitochondria by first degrading the particulates and then reconstituting some of their major metabolic processes in stepwise fashion. He isolated an electron transport particle (ETP) from beef heart mitochondria which contains all the enzymes and structural elements necessary to transport electrons from the substrate, succinic acid, to molecular oxygen. Further fractionation of the ETP resulted in parts, each carrying a short sequence of the electron transport chain. The investigator was then able to recombine these fractions so that the whole electron chain transport was reconstituted. For the first time it became possible to determine not only new steps in the chain, but also the precise order in which the known steps occur.

Analytical studies of the mitochondria and mitochondrial fractions have indicated the presence in them of a protein which combines with mitochondrial lipids and certain of the respiratory enzymes to form stable complexes. It is concluded that this protein acts as a "cement" in the structure of intact mitochondria.

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MATHEMATICAL, PHYSICAL, AND ENGINEERING SCIENCES

CURRENT RESEARCH SUPPORT

The mathematical, physical, and engineering sciences deal with the various aspects of man's physical environment. They encompass a wide variety of disciplines with greatly different requirements for facilities, research skills and specialties, and research tools. Research support is provided for studies ranging from subnuclear particles to the cosmos, from the ocean to the atmosphere, from the center of the earth to outer space, from reactions taking place at temperatures close to absolute zero to those at a temperature of many millions of degrees. Facilities and equipment used may range from a desk calculator to the most complex computer, from a simple Geiger counter to a high energy accelerator, and from a small microscope to a huge radio telescope.

The Mathematical, Physical, and Engineering Sciences Division is organized into seven programs—astronomy, atmospheric sciences, chemistry, earth sciences, engineering sciences, mathematical sciences, and physics.

Astronomy Program

The Astronomy program is concerned with research on 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 that lie beyond the Milky Way. By observing the radiations coming from the stars and other material in interstellar space our understanding and knowledge of the universe is substantially increased, and this indeed is the principal technique used by the astronomer and the astrophysicist to study the universe. In the past few years, several major developments have greatly strengthened the astronomer's ability to observe the universe—for example, the development of radio astronomy, the use of high-altitude balloons for observation, the use of space vehicles, the development of electronic image intensification, and the establishment of the two national observatories (National Radio Astronomy Observatory at Green Bank, W. Va., and Kitt Peak National Observatory near Tucson, Ariz.). In many of these developments the Foundation has played a prominent role. In the case of the two observatories, the Foundation gives sole support, and these observatories make their facilities available not only to their own permanent research staff but to all qualified astronomers, many of whom are also engaged in other research supported by the Foundation.

The largest single effort of the Astronomy program outside the National Observatories continues to be in the field of balloon astronomy. One such project—Stratoscope I, a 12-inch solar telescope (reported in the 9th and 10th Annual Reports) was so successful that design and development of a 36-inch stellar telescope, Stratoscope II, is now underway by the same team of astronomers.

International attention has been attracted by the recent work at Burbank, Calif. This work, supported by the Foundation, concerns high time-resolution cinematography of solar flares, and resulted in the discovery of extensive wavelike disturbances traveling outward from the explosive flares. The progress of these disturbances along the sun's surface, at a speed of between 1,000 and 2,500 km/sec, can be followed on photographs taken at intervals of 10 seconds in the light of the hydrogen alpha line. It is thought that these disturbances are plasma clouds guided by local magnetic fields, similar to the ones which cause geomagnetic storms, aurorae and slow-drift solar radio bursts. More than a dozen of these phenomena have been studied; they frequently travel distances equal to the radius of the sun and disturb distant prominence filaments. Occasionally, a disturbance was seen to be reflected by strongly magnetic areas, indicating that the magnetic bottle effect may have been observed for the first time. These new observations seem to represent the first direct evidence of solar corpuscular streams, and may greatly increase our knowledge of the physical processes on the sun as well as contributing to interpretation of solar-terrestrial phenomena.

Atmospheric Sciences

The Foundation's Atmospheric Sciences program, established 3 years ago, is broad in concept and not confined solely to studies of the lower atmosphere. Because the field of atmospheric sciences is so far-ranging, the program touches oceanography and earth sciences on the one hand, and astronomy and space research on the other. In particular, the program stresses research on the physics of the upper atmosphere, cloud physics, atmospheric dynamics, solar-terrestrial relations, energy exchange processes and weather modification.

A decade ago it was commonly believed that the hydrostatically supported atmosphere of the earth decreased in density to very low values within a few hundred kilometers of the earth's atmosphere. This view was based on assumed thermodynamic temperatures of only a few hundred degrees, applied to the oxygen and nitrogen atoms which are dominant at these heights. Similar considerations indicated a corresponding confinement of the overlying exosphere—the region where the constituent neutral atoms are free from significant collisions with one

another, and where instead their motions follow ballistic trajectories. As a result of these conclusions, the total extent conceived for the earth's sensible gaseous mantle was limited to heights of a few thousand kilometers at most. These views have, in the past few years, been drastically revised, and regions of the earth's atmosphere out to several earth radii are currently the subject of intensive study by a wide variety of techniques by several Foundation grantees.

An interesting feature of research on the upper atmosphere is the way in which various experiments interlock. Because of this and as a result of improved technology, progress has been rapid. For example, whistler-mode propagation studies lead to improved models of outer ionospheric electron density, which in turn, together with satellite radiation belt measurements and both satellite and ground-based magnetic field measurements, greatly enhance the understanding of auroral and of cosmic ray temporal variations.

The general area of solar-upper atmosphere interactions and of modes of coupling for vertical energy transfer in the terrestrial atmosphere have made good progress during the past year with several Foundation grantees active in this area. However, the problem of coupling between the upper and lower atmosphere is one in which more progress must be made before a really complete understanding of the linkage between solar activity and terrestrial weather is obtained.

Progress in the field of meteorology in recent years has not been spectacular, but technological developments of new instruments which will spark the next advances in the understanding of meteorological phenomena have been breathtaking. A few examples of recent instrumental breakthroughs will show why meteorologists have high hopes for the future. The advent of meteorological satellites, TIROS I and II and the projected NIMBUS series, has given an unparalleled view of both local and planetary scale cloud and radiation patterns. This at first proved to be an embarrassingly abundant wealth of information, but during this past year encouraging progress has been made in learning how to process and use this data. The influence of the TIROS data and results—in which the Foundation played no active part—is already evident in the research proposals being received.

The Weather Modification program of the National Science Foundation continues to support a full range of theoretical studies, laboratory research, field experimental work, and evaluation studies. The research is in the main characterized by its long-term fundamental approach; however, field tests and engineering studies are encouraged as new opportunities for such work are presented.

The interpretation of weather modification experiments is hampered by high meteorological variability which also accounts for the difficulty of designing scientifically sound experiments. Most field experiments need to be operated on a well-planned basis for several years in order to produce enough information to be conclusive. So far very few have had sufficient duration and continuity, and it is a major objective of the Foundation's Weather Modification program to ensure the necessary continuity of support to the best of the field experiments and to the associated laboratory studies.

The largest single research program in Weather Modification includes both laboratory and field studies. The laboratory portion of this program deals with nearly every aspect of the water resources of clouds, including particles, the ice nucleation process, and the growth of ice crystals and water droplets. The field portion of the program is a study of the physical effects of cloud seeding in the Great Plains using silver iodide as the seeding material. Over the flat terrain of the Great Plains measurable increases in precipitation as a result of seeding have not yet been shown. In this study, therefore, silver iodide nuclei are released from aircraft and the resultant physical changes in the clouds themselves are investigated rather than the statistical departures in precipitation. Radar, cloud cameras, and specially instrumented aircraft are employed in the research.

The past year or so has seen an increase of interest on the part of meteorologists in problems of the interactions of the atmosphere and the oceans. This is because a proper understanding of climate and long-period fluctuations in the atmosphere circulation requires a consideration of the atmosphere and the oceans as a coupled dynamic system. Several studies supported by the Atmospheric Sciences program are concerned, in part, with this aspect. Others deal with the constant interchange of matter (water, carbon dioxide, and salt) between the ocean and the atmosphere. All of these studies should help to unravel some of the complexities of the ocean-atmosphere system.

The National Center for Atmospheric Research, which is supported through this program, was established in the past year (see National Research Center, page 59).

Chemistry

Chemistry has made many significant contributions to the general welfare and the economy of the Nation. Many basic problems remain; basic research in chemistry will provide the knowledge required. One of the current tasks of chemistry is to understand how molecules are

synthesized, what their basic structure is, how these molecules interact with each other, and what are the mechanisms responsible for the interaction or reaction. Considerable progress has been made in these areas—experimentally in the use of extreme conditions of environment including high pressures and both very high and very low temperatures, and theoretically in the use of certain aspects of quantum mechanical and molecular field theory to predict and interpret molecular events. But much more remains to be done.

The Chemistry program has continued to provide support for research in the four classical subdisciplines of organic, physical, inorganic, and analytical chemistry. In addition, limited support of research instruments, such as nuclear magnetic resonance spectrometers, mass spectrometers, and ultraviolet and infrared spectrophotometers, was resumed during fiscal year 1961. Assistance provided in the purchase of modern research instruments for chemistry departments of educational institutions throughout the country represents an effective means for the support of research in chemistry.

During the past year a new development occurred in the magnetic cooling problem associated with the production of very low temperatures. By adiabatic demagnetization of metallic copper from fields of 15 kilogauss and starting at 0.01 °K, temperatures of 10^{-4} and 10^{-5} °K were obtained reproducibly by two Foundation grantees. Thermodynamic measurements are now being carried out on hydrogen adsorbed on palladium, and attempts are being made to use the adsorbed hydrogen for nuclear cooling in a new approach to adiabatic demagnetization.

The structure of liquids and liquid solutions is the subject of active research by several Foundation grantees. One group has initiated a program in the X-ray determination of the structure of quaternary salt hydrates, which contain up to 70 percent water. These hydrates have a dodecahedral structure, and extension of this work should provide useful information concerning the structure of liquid water and, perhaps, liquids in general. The use of high speed computers in structure determination work has proved to be of enormous help since it has performed the necessary, complicated and tedious calculations in a minute fraction of the time previously devoted to this, thus freeing the researcher for more productive tasks.

In this present era of space exploration, it has become all too apparent that little basic information is available on the chemical and physical properties of substances at high temperatures. Thus, the density of iron, one of our most important structural materials, was not known at temperatures above its melting point of 1805 °K. During this past year, a

Foundation grantee measured its density from its melting point up to 2200 °K as well as measuring the electrical conductivity, surface tension, and density over a wide temperature range on liquid alumina and on a number of liquid alkali earth metal fluorides. Another interesting high temperature inorganic chemistry study is the use of a nitrogen plasma for synthetic purposes. Mixing a nitrogen plasma with oxygen produces various oxides of nitrogen, particularly nitrogen dioxide. The introduction of titanium and magnesium powder into the nitrogen plasma produces crystals of titanium nitride and magnesium nitride. This unique method of crystal growing can be expected to be of great importance in studying materials at high temperatures.

An area of research of particular interest to chemists as well as biologists and physicists concerns the determination of the mechanism of energy transfer, and a number of Foundation grantees are active in this area. Both theoretical and experimental approaches are being used in systems of gases, liquids, and solids. Allied to this research is the problem of conductivity in organic systems. Here the interest is to elucidate the mechanism of the flow of carriers through solid, single crystal, organic compounds with and without photoelectric effects being present.

Earth Sciences

The Earth Sciences program supports basic research in the geological and oceanographic fields ranging in area from the core of the earth to the surface of the land or water and from Alaska to New Zealand. All of the fields of solid earth science are included—geology in its more conventional sense, geochemistry, geophysics, and all their subdisciplines—plus oceanography. The increased emphasis on the marine sciences during the past few years has resulted in a large growth in the support of oceanography including physical oceanography, marine geology, chemical oceanography, and submarine geophysics. During the past year, grants have been made in subjects ranging from the chemical composition of meteorites to the study of fossil plants found in old coal balls, and from the laboratory study of processes by which igneous rocks and magmas are formed to the charting of deep sea currents by the use of deep floating buoys. In one grant, the principal investigator proposes to attack the problem of the salinity of the oceans a half a billion years ago by studying the boron content of rocks of this age. In another, the investigator hopes to evaluate climates of the recent past by means of the chemical composition of the soils. In still another, the use of a phenomenon known as thermoluminescence is being tested as a means of dating ancient pottery and geologically recent lava flows. Other than

oceanography, the field receiving largest support is geochemistry, a relatively young addition to the geological sciences, which is enabling students of the earth's history and process to learn more about how the crust and mantle of the earth have been formed. Other major portions of the program's budget have been devoted to the studies of seismic propagation, gravity and magnetic studies, and the measurement of electrical conductivity and magnetic properties of rocks.

During the past year new and important results in the measurement of deep sea currents were reported by two Foundation grantees. One investigator working near Bermuda and the other in the North Pacific have charted deep sea currents using the buoys developed previously by one of them. The results in the Atlantic showed that currents are more complicated and variable than previously thought, and that an equatorial under-current existed in the Atlantic similar to the one in the Pacific Ocean. The work in the Pacific by the Foundation grantee clearly demonstrated irregular turbulent motions at various depths in latitudes between 50° N. and 15° N. Yet at 28° N. the motion is quite regular, primarily rotary and clockwise with a 25-hour period. The rotary motion is probably the coincidence of the inertial period (25.4 hours at this latitude) with the tidal periods of 24 and 24.8 hours. An important confirmation of the turbulent nature of the current at 29° N. was made during the test drilling in the early stages of Project Mohole. Direct current measurements from buoys at different depth levels at the site showed current vectors varying randomly in both time and direction.

In the area of geochemistry, a Foundation grantee recently showed that with appropriate amounts of fluxing agents and a reasonable amount of water, rocks with the chemical composition of most granites can partially melt at temperatures as low as 560° C under pressures equivalent to those found at about 15 miles deep within the earth's crust. This suggests that most of the sediments deeply buried within a geosynclinal belt are subject to partial melting. This melting is at once a source of granite intrusions (so commonly associated with the deformation of geosynclines) and also an aid to the mobility of geosynclinal belts during times of compressional stress.

The largest and by far the most dramatic of all projects supported by this program is Project Mohole, which has as its goal drilling through the crust of the earth into the mantle. During this past year, Phase I of the project was successfully completed and proof provided that drilling from a floating barge in very deep water is feasible. The project is now being reorganized for an assault on the longer-range objectives. (See page 39 for a review of the accomplishments of Phase I.)

Engineering Sciences

The National Science Foundation's program in the engineering sciences is exceptionally broad in scope, encompassing the classical sub-disciplines of engineering, such as electrical, mechanical, and chemical engineering, as well as the newer concepts in engineering such as systems engineering. As such, it attempts to undergird and balance the national effort in this field by supporting research which seeks knowledge and understanding that is directly needed in the design of new and improved technological systems. Thus, basic research in the engineering sciences provides the essential information and methods with which existing problems may be solved and new opportunities for advancement may be recognized.

An important research area, supported through this program, is emerging from cooperation between research electrical engineers and scientists in other disciplines, such as experimental psychology, neurophysiology, and linguistics. The area, becoming known as communication science, is concerned with the generation, processing, and transmission of information in its various forms. The theoretical foundations of communication science are largely the basic work of Norbert Wiener on random processes, their prediction and filtering, and on the mathematical theory of communication developed by Claude Shannon. Important also is the development of a theory of the logic of automata and computing devices, switching circuits, and relay circuits. Knowledge in this field is applicable to problems of coding, of efficient transmission of information, of cryptography, of design of computers and automata, in the analysis of speech and language, in the transmission of signals through the nervous system, and in the study of the behavior of groups and of learning itself. Support in communication science has been provided for research in statistical communication theory, processing and transmission of information, communication biophysics, neurophysiology, linguistics, speech communication, experimental psychology, automata and artificial intelligence, sensory aids, physical acoustics, circuit theory and network synthesis, and modulation theory.

The past two decades have witnessed many far-reaching developments in the fields of communication, control, and machine computation. The high level of sophistication in systems incorporating such functions as prediction of time series, recognition of patterns, choosing between alternatives, and adapting to changes in environment has created an acute need for methods of analysis and synthesis of complex systems containing nonlinear, non-deterministic, and incompletely characterized components. This is likely to be even more true of the systems

of tomorrow involving space-relay communication links and large-scale man-machine systems.

It has long been recognized that systems of widely different physical forms may have similar mathematical structures. Thus, from the viewpoint of system analysis what is important about a system is not its physical form but its input-output relationships. This fact is responsible for the growing trend toward abstraction in the methodology of system design and analysis. This trend, coupled with the need for effective means of analysis of the complex systems characteristic of modern technology, has given an impetus to the development of a new scientific discipline, system theory—in effect a general theory of systems irrespective of their physical form.

Support is being provided for research on problems in system analysis that are system-theoretic in nature. A wide variety of problems in adaptive, sampled-data, digital, competitive, and linear time-varying control are being studied, including stability and optimization considerations.

While these rather substantial grants permit a concerted research effort in important, newly developing fields, the program has maintained support of smaller research projects that are usually directed by one faculty member and involve one or two graduate students. This effort is regarded as the heart of the program's activity and covers all areas at the forefront of the engineering sciences. A notable feature has been the exploitation of the digital computer. The research referred to does not merely use the computer in a routine fashion but through its use permits one to solve important complex problems that could not otherwise be attacked in a physically meaningful way.

One of the more interesting engineering achievements which is expected to aid considerably in the solving of some of the problems associated with the Nation's space effort occurred in the field of molecular beams. One group has constructed a high energy beam facility using a supersonic nozzle source to develop high material fluxes. Heavy molecules are accelerated by lighter ones during the expansion of a binary gas mixture, and thus high energies are obtained. Preliminary results have indicated that this facility is capable of generating an intense beam of fast molecules with translational energies in the 0.5 to 10 electron-volt range. This will make it possible to investigate momentum and energy transfer, and scattering and reactive collisions in a region of energies heretofore unexplored.

Another Foundation grantee has been studying fundamentals of adhesion. He has shown that syneresis (the separation of liquid or semiliquid impurities from a solid during its cooling) involving im-

purities present in the adhesive play a part in determining the breaking stress of adhesive joints made with "adhesionable" polyethylene. When these impurities concentrate along the interface between adherent and adhesive a zone of weakness forms and rupture proceeds along this zone. There are many applications where adhesive joining is attractive, and this understanding of the adhesive mechanism should lead to more efficient joining procedures.

During the past year an NSF grantee has developed a new approach to engineering analysis which has attracted international attention. In studying nonlinear, two-degrees-of-freedom systems, the grantee has rigorously defined the term "normal mode" for linear or nonlinear systems. This permits a determination of the normal modes independent of the natural frequencies; the natural frequencies being found afterwards in terms of the normal modes. This procedure is the reverse of the usual approach and yields results of great simplicity which have not been discovered before. The grantee has extended his work to a system of n degrees of freedom. An infinite class of systems, of which the linear system is a member, has been isolated for which the frequency-amplitude curves can be found in closed form.

Another grantee has been studying the use and control of solar energy. The directional spectral reflectances of a number of materials, which could be used as spacecraft surfaces, have been measured, and average solar absorptances of elementary geometrics have been determined. It was found that significant error can be introduced into the analysis and design of temperature control systems if the angular dependence of radiation characteristics is neglected. In addition, measurements of the normal spectral reflectance and of the normal total emittance of a number of materials have been made, and studies on the radiation characteristics in the optimization of solar heat-power conversion systems have been made. The optimization studies showed that when a concentrator is used, the optimum temperature and irradiation of the collector are usually sufficiently high so that the use of selective radiation characteristics can offer only an insignificant advantage over a black body collector.

Mathematical Sciences

One unifying feature in all of the physical sciences is undoubtedly mathematics. Mathematics is the basic language common to all the disciplines which go to make up what is termed the physical sciences, and many of the problems which one confronts in these disciplines are really mathematical in nature. Generally speaking many of these problems require the most advanced techniques available to modern mathematics. The continued development of mathematics is essential to growth and progress in science and technology.

Progress in mathematics has been tied to the discovery of convenient notation. As a trivial example, one notes how much more difficult arithmetic manipulations are with Roman as compared with Arabic numerals. Unfortunately, the development of intricate notation suited to mathematical needs has made communication with the nonexpert very difficult. Another obstacle in the path of easy communication is the trend to abstraction and generalization. This trend has contributed significantly to progress in mathematics, but has also made mathematics a subject intelligible only to the expert. Despite these difficulties an attempt will be made to give the flavor of current research in mathematics by describing recent important developments in group theory—a subject which has had considerable impact in modern physics and chemistry in addition to mathematics as a whole.

Groups are a primitive type of number system based on a single operation for combining numbers. The totality of ordinary integers relative to the operation of addition forms a group, the main ideas being that the sum of any two integers is again an integer, and for each pair of integers there exists an integer which when added to the first member of the pair produces the second. Other examples of groups are: (1) the totality of real numbers relative to addition; (2) the totality of nonzero numbers relative to multiplication; (3) the totality of positive real numbers relative to multiplication. These illustrate the fact that groups occur commonly as part of the structure of almost every type of number system.

However, groups need not consist of what are ordinarily recognized as numbers. Consider, for example, n stones arranged in a line and numbered from 1 to n for purposes of distinguishing one from another. The line of stones may be permuted; that is, rearranged as to the order in which the various stones appear in the line. Each permutation may be regarded as a process, and two such processes may be combined to give a third in the following way. Perform the first of the two given permutations and follow it with the second. The final result is clearly obtainable by a single process, and this latter is called the product of the first two. Relative to this operation the collection of all permutations of n given objects forms a group.

There are many other ways in which groups appear with members which are not ordinary numbers. This provides an indication of the value of the abstract study of groups. The results obtained are applicable to each particular instance in which a group arises. The subject got its first big impetus in the work of Galois on solvability of equations by use of radicals, wherein certain groups of permutations of the roots are significant. Group theory has been useful in many other parts of algebra

as well as geometry and topology. Outside of pure mathematics, group theory has been used in the study of molecular structure, crystallography, and quantum mechanics.

Recently, a remarkable result concerning groups has been proved. Many investigations in group theory lead to a type of group called simple, but these have proven difficult to analyze or construct. The importance of a complete understanding of simple groups rests upon the fact that many types of groups can be represented as products of simple groups. It is a trivial fact that every group whose order (the number of elements in the group) is a prime is a simple group. It is conjectured that all finite, simple groups other than those of prime order have even order. Thus, for example, the order of a simple group might be 7 or 2×7 , but not 3×7 , according to this conjecture. The importance of simple groups and the relative paucity of knowledge about them would make a proof of the conjecture a great milestone in algebra. Recently, two Foundation grantees have proved a theorem very close to the conjecture, and there is hope that their result may lead quickly to a proof of the conjecture itself. Two other Foundation grantees have discovered some new simple groups of finite order. This is a major contribution, since known examples of such groups are rare. Many of these recent developments have received Foundation support.

Physics

In recent years much of the research in physics has centered on nuclear and elementary particles and on systems composed of many atoms such as solids. Today these areas continue to be probably the most challenging ones in physics, and while much has been accomplished already, much more remains to be learned. Considerable progress has been made in our understanding of the various forces which hold the nucleus together and of the interactions between elementary particles. A great deal of this understanding has come as a result of pushing experiments to exceedingly high energies—in some cases to as high as 30 billion electron-volts. The results obtained have answered many questions, but at the same time many other questions have been raised. And as very often happens, some of the theories which have pointed the way to a better understanding in one area of physics have helped unravel some of the perplexing problems in other areas of physics. For example, theories which have been able to account for some of the aspects of superconductivity are being used to great advantage now in certain parts of low-energy nuclear physics, particularly on problems on nuclear structure. This is, of course, one of the great benefits of research—this interchange of ideas between disciplines in science.

For several years intense activity has been centered about the dispersion theory of elementary particle interactions—with particular emphasis on the “Mandelstam representation.” Despite the fact that the status of this highly important Mandelstam conjecture experienced ups and downs and finished the year somewhat more precarious than before, it can be said fairly that owing to the efforts of a group of theoretical physicists, many of them supported by the Foundation, the assumptions, methods, and objectives of dispersion theory were perceptibly clarified. The world-wide interest in this branch of theoretical physics is mirrored in the complexion both of the new and of the continuing NSF Physics grants program.

Support for solid state physics has continued to grow in a most invigorating way, and this now represents a prominent portion of the Physics program. As a matter of fact, NSF support for this field ranks high among the Federal research-supporting agencies. Solid state physicists at our smaller colleges and universities, as well as solid state physicists at the country’s leading institutions, now receive support from the Foundation.

Perhaps one of the more interesting developments in this field during the past year concerned the discovery at one of the leading industrial research laboratories of superconducting magnets. This discovery has stimulated a great deal of interest at low-temperature and solid-state laboratories, and some of our grantees are actively looking into the possibilities exhibited by and the problems associated with superconducting magnets. It can be logically expected that activity in this field will increase even more, especially since the rewards are so great, and that the Foundation will be receiving more requests for support of research directly or indirectly associated with this phenomenon.

Low-temperature physics involving the study of superfluidity and certain aspects of superconductivity has continued to receive strong support from the Foundation. In addition to providing continued assistance for outstanding scientists working in this field, the Foundation has been instrumental in assisting younger investigators in becoming established, thereby strengthening the overall field of low-temperature physics in a significant way.

In spite of the increasing emphasis on large projects, the Physics program has attempted to maintain its practice of broadening the physics research base of the country by supporting many inexpensive but promising projects at smaller institutions. One eminent physicist, who had originally shown some doubt concerning one of these projects, commented on its general success and stated, “During my frequent visits I have seen the exciting change this research program has wrought in the

atmosphere of the department." The Physics program has attempted throughout the fiscal year to maintain a proper balance between large and small research projects.

The high cost and limited facilities in elementary particle physics resulted, in November 1960, in an announcement of a Bev Accelerators Users Program (BAUP). The purpose of this program is to enable universities which do not have large accelerators to do research and train their students at one of the big centers. Four BAUP grants were made this year. These grants will provide for the construction of special equipment, travel and support for extended visits to the accelerator site, and time and equipment for analysis of data obtained.

The program was pleased to learn that one of its grantees had been awarded this year's Nobel Prize; this was particularly gratifying since the NSF grant made in 1954 was the first Government aid given for this research.

SIGNIFICANT RESEARCH DEVELOPMENTS IN THE MATHEMATICAL, PHYSICAL, AND ENGINEERING SCIENCES

FIRST DEEP PENETRATION OF THE EARTH'S SUBOCEANIC CRUST ESTABLISHES FEASIBILITY OF DEEP-OCEAN DRILLING (PROJECT MOHOLE)—Probably the most spectacular of all projects supported by the Foundation during the past year was Project Mohole. A joint venture of the Foundation and the National Academy of Sciences, Project Mohole aims ultimately at drilling through the crust of the earth and into the mysterious mantle, the substance that lies below the crust and of which little is known. During the past year, Phase I of the project, an engineering experiment to prove the feasibility of drilling from a floating barge in very deep water, was successfully completed and will be described in detail.

There is probably no project within the scope of current technical ability that will yield as much new information in geology and geophysics as drilling the so-called Mohole. The crust is a relatively thin film over the earth's interior, averaging only about 10 miles in thickness. Beneath the crust lies the mantle, a layer some 1,500 miles thick that constitutes the bulk of our earth. Separating the crust from the mantle is the "mohorovicic discontinuity" (commonly called the "Moho"), a zone at which the velocity of earthquake waves changes abruptly. Our knowledge about the deep layers of the crust and the mantle is almost entirely from indirect geophysical methods. Actual samples of these materials will be invaluable in the attack on many key problems, such as the actual chemical and mineralogical composition of the deep crust and the top of the mantle, an explanation for the anomalously high heat flow from the

floor of the ocean, a possible answer to the continental drift controversy, the original isotopic composition of the primordial lead and uranium, and the early history of the earth itself.

During the spring of 1961 the first experimental drilling project for Project Mohole was undertaken, off La Jolla, Calif., and Guadalupe Island, Mexico. Cores were taken from under 3,000 feet of water at La Jolla, with the drill bit reaching a maximum depth of 1,035 feet beneath the ocean floor. After five tests holes were dug at this site, the *CUSS I* drilling barge was moved to the site off Guadalupe Island for the first major deep-water drilling test. At this site five holes were dug in 11,700 feet of water, reaching a maximum of 601 feet below the ocean bottom.

At the La Jolla site, punch and rotary cores were obtained ranging from consolidated fine sands to coarse silts with scattered fossil content. At 760 feet the drill encountered carbonate-cemented rock, which X-ray analysis showed to be dolomitic.

Scientific results of the Guadalupe site drilling indicated that the soft section is 560 feet thick and consists predominantly of grey-green ooze. Some of the ooze beds are primarily (as much as 80 percent) microscopic shells of plants and animals (about half siliceous, half calcareous) mixed with volcanic glass shards, ash, and clays. Other beds consist predominantly of clay and volcanic ash. Most of this section was deposited during late Miocene time (12–20 million years ago).

The greenish-gray color of these sediments, and the lack of alteration of the pyroclastic material contrast markedly with the highly oxidized character of a typical pelagic clay. These features of the Guadalupe sediments suggest a rapid rate of accumulation—about 1 centimeter per thousand years. Since about half of the material is clay, the rate seems to be several times higher than the estimated average for Pacific pelagic clays. The higher proportion of biogenous components apparently reflects a higher rate of organic production during this period than found in more recent sediments.

The second layer of the earth's crust (as recognized by seismologists) was reached and penetrated, for the first time, to a depth of 41 feet. It was found to be a common type theoleitic basalt—at least in this place. The higher ratio of $\text{Fe}_2\text{O}_3/\text{Fe O}$ and the higher than normal total water of the basalt may reflect its emplacement in watery muds at or near the interface with ocean water. Its age is, as yet, unknown, but is probably Miocene.

Two important geophysical measurements were made. First, the seismic velocity (i.e. the velocity at which primary seismic waves travel through a medium) of the sediments of layer I was determined at 1.6 km/sec by actual measurements in the hole. This is a sharp reduction

from the 2.2 km/sec previously estimated for these sediments, and may lead to revisions of the thickness of layer I. Second, temperature measurements were made at different depths, so that for the first time we have a geothermal gradient through several hundred feet of the oceanic crust. Prior to this the only data available on sub-oceanic temperatures were the heat flow measurements made on the floor of the sea, from which a temperature gradient was inferred. The actual in-hole measurements at Guadalupe indicate a slightly higher temperature than had been inferred, but one that was close enough to give confidence that the ocean floor measurements are fairly reliable.

Another "first" was the simultaneous measurement of deep ocean currents at four levels simultaneously. These measurements were made with internal recording rotor-type meters suspended on wires from the barge and from a deep-moored buoy. They extended over a period of 3 to 12 hours. Water at the surface, at 50 feet, at 5,000 feet, and at 10,000 feet drifted to the northward for this period of measurement, except during the maximum ebb of the tide. The velocity of drift was about 7 cm/sec near the surface and about half that at depth. Superimposed on this slow general drift is a complicated pattern of eddies with water velocities of 30 cm/sec and local reversals of direction in intervals of as little as 2 minutes.

In addition to the scientific findings the project yielded a great amount of technical experience necessary for the prosecution of the ultimate objective—to reach the Mohorovicic Discontinuity. The feasibility of holding a drilling vessel on station in deep water by dynamic positioning was established. This method combines electronic position sensing and constant maneuvering by means of four omnidirectional propellers operated by pilots at a central control console. The vessel was held to a maximum distance from a point directly above the hole of 3 percent of the depth of water (i.e. 360 feet in 12,000) even in winds of 25 mph and waves 12 feet high. The standard rotary method of drilling was used with only minor modifications. It was possible to recognize the touchdown and to drill into the bottom with safety by paying careful attention to the weight placed upon the bit during rotation in shallow water and, at great depths, to the pressure of the water forced down the pipe during drillings to remove material cut by the bit. Rotation of 40 rpm caused no observable pipe whip (transverse vibration), and heaving of the drilling vessel caused no observable vertical vibration in the pipe. Although no attempt was made at destructive testing of drill pipe and other components, the deep sea operations appear to confirm the earlier theoretical studies of strength.

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EXTRA-GALACTIC COSMIC PARTICLE DETECTED WITH ENERGY 500 MILLION TIMES THAT GENERATED BY LARGEST ACCELERATOR—Since the discovery of cosmic rays, physicists have been puzzled as to where they come from and how they obtain their tremendous energies. This year a group of scientists working at Volcano Ranch in New Mexico, under an NSF grant, concluded that at least some cosmic rays must come from outside of our own galaxy. This important finding resulted from data obtained at a rather unique facility built in the New Mexico desert, an array of particle counters covering 600 acres.

What was believed to be the largest cosmic ray shower ever observed was recorded this year. The shower of 10 billion atomic particles rained on the station in a period of 10 one-millionths of a second. Analysis of this shower by a large digital computer indicated that the primary particle must have had an energy of 10^{19} electron volts, 500 million times the energy that physicists have been able to generate in their largest accelerator.

Reasoning that the magnetic field of the galaxy, 3×10^{-8} gauss, would have caused the primary proton to move in a radius of curvature five times the diameter of the galaxy, the scientists concluded that this particle must have come from space beyond our galactic boundary.

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TIME STANDARD ACCURACY RAISED 100,000 FOLD BY NEW ATOMIC HYDROGEN MASER—Physicists with NSF support have constructed an atomic hydrogen maser 100,000 times more accurate than the best time standard yet known.

According to the quantum theory every atom or molecule has certain natural vibrations which occur at sharply defined frequency. Although most of the time atoms and molecules exist in nonradiating states, there is always some interchange due to thermal and other motions which cause the atoms to absorb energy and move to higher energy states, then decay back by giving off energy at specific frequencies.

Physicists have made considerable progress in their attempts to use the natural electromagnetic oscillations occurring in atomic or molecular configurations. In 1955 it was demonstrated that the molecules of ammonia in the higher energy states could be separated from those in the lower states so that a usable output wave could be generated. The device which used this principle is called the maser and has proved to be important as a time standard and as an amplifier of very high frequencies.

Up to this year it was not possible to produce maser oscillations with gaseous atoms due to the weakness of the magnetic dipole radiation and the difficulty in separating high-energy states from lower ones. How-

ever, Foundation grantees have achieved an atomic hydrogen maser by retaining the atoms within a storage box with suitable walls. This atomic maser, operating at 1420.405 megacycles, will not only allow determination of the hyperfine splitting of the hydrogen isotope to a much greater precision than is now possible, but may also make possible a time standard with greater stability than any yet known.

* * *

EXPERIMENT CONFIRMS QUANTIZATION OF MAGNETIC FLUX IN SUPERCONDUCTORS—According to the quantum theory some effects which appear to be essentially continuous are in reality increased or decreased only in discrete steps, that is, quantized. Several years ago theoretical physicists suggested that the magnetic flux trapped in a superconducting ring should be such a quantized entity. This year, an NSF grantee actually measured this effect.

At temperatures near absolute zero (273° below zero Centigrade) many materials are superconducting (they have the property of maintaining the flow of electric current without the need of external sources). In a particular experiment by the NSF grantee, a current was induced in a hollow superconducting cylinder about $\frac{1}{2}$ inch long and $\frac{1}{1000}$ of an inch in diameter. Measurements of the magnetic field in the tube showed that its magnitude was always an integral multiple of a certain quantity—quantized.

However, the effect was only half of what had been predicted theoretically. A satisfactory theoretical explanation of this phenomenon has now been given by a recent Nobel laureate which is based on the pairing of electrons in a superconductor.

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SEVENTEEN NEW EXPLODING SUPERNOVAE DISCOVERED—During the past year a Foundation grantee discovered 17 new supernovae. Most of these were found with the 48-inch Schmidt telescope on Palomar Mountain. Supernovae are cosmic explosions which, at maximum brightness, radiate as much energy per day as the sun does in a hundred million years. Such a star at maximum luminosity frequently is several times as luminous as the entire galaxy in which it occurs. Study of the phenomenon is of great importance for a number of reasons, but so far very little is known about the physics of an exploding star. Statistically it appears that one supernova flares up in a normal galaxy only about once every 360 years. There are two main types: those of type I are the brightest, with spectra consisting of ill-defined bands which have so far completely defied identification of even one single feature; those of type II are less bright, with spectra showing emission lines of hydrogen, helium

and carbon, which gases are being expelled in great quantities at velocities of about 6,000 km per second.

It is conjectured that a supernova explodes as the result of instability caused by a stupendous nuclear chain reaction at a late stage in a star's evolution when most nuclear fuel has been exhausted. The explosion may serve to re-seed interstellar space with new matter out of which future stars may be formed. A better calibration of the intrinsic luminosity of supernovae of various types would serve as a powerful new tool for determining the highly uncertain distance scale of the universe, because these objects can be seen at distances where galaxies are too faint to register on the photographic plate.

Theoretical astrophysicists are currently developing theories which attempt to explain the enormous output of radio radiation from certain galaxies on the basis of multiple supernova explosions. Accurate data on the rate of occurrence of such explosions can give valuable information on the basis of which these theories can be tested.

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SOCIAL SCIENCES

CURRENT RESEARCH SUPPORT

The Office of Social Sciences was reconstituted as the Division of Social Sciences during fiscal year 1961. This action was an endorsement of the careful and gradual development of a program of basic research support which has stressed imaginative, well-designed investigation of general problems of human behavior and society.

The Foundation has thus indicated its serious and sincere interest in the continued encouragement of fundamental research in the social sciences and its commitment to the support of the kind of social scientist and the type of research career that has hitherto lacked support. The uniformly favorable response of the scientific community to the organizational change has been most gratifying.

The Division is presently organized into four programs: *anthropological sciences*—including ethnology, archaeology, linguistics, and physical anthropology; *economic sciences*—including econometrics, economic and social geography, the economics of research and innovation and those areas of general economics which lend themselves to scientific treatment; *sociological sciences*—including demography, social psychology, psycholinguistics and the sociology of science; and a program of support of the *history and philosophy of science*. The research grants program has emphasized the support of basic research that meets the highest scientific standards of conceptual and methodological rigor.

Anthropological Sciences

The program for basic research grants in the anthropological sciences offers support for investigations into man's cultural and biological development and variation. During 1961 support has been provided for basic research in all phases of the discipline—linguistics, ethnography and social anthropology, physical anthropology, and prehistoric archaeology. Increasing recognition of culture as a dynamic synthesis of social and physical environmental variables is exemplified by several anthropological grants. One study of this kind is being conducted in the Philippines and is a comprehensive ecological and ethnographic approach to the problems of how complex agricultural systems in humid tropical environments have developed and are maintained. This study will elucidate the effects of methods of permanent cultivation on soils, terrain, vegetation, and fauna, as well as on social and cultural patterns. A second example is an integrated research project, planned by the Committee on New Guinea Studies (an organization of six Pacific coast universities), which is a long term study of native groups in interior New Guinea in terms of language and other aspects of culture, the natural environment, and the biological characteristics of the people. This research is of particular urgency owing to the rapid disappearance of societies relatively untouched by Western civilization.

Studies of change through time of social structure, economic behavior, and other social attributes have been planned or are in progress for several African tribes, villages in India, the Hopi Indians of Arizona, mountain groups in Nepal, and other societies or subsocieties. In several cases the principal investigators are returning to societies which they have previously studied to make a direct analysis of the degree and direction of change associated with economic and other innovations which have appeared since the time of the first study.

Because of the impending threat to the historic and prehistoric archaeological sites which will be inundated when the Aswan High Dam on the Nile River is completed, the United Nations Educational, Scientific, and Cultural Organization launched a worldwide campaign and appeal on March 8, 1960, to obtain offers for salvage archaeology in the Nubian region of Egypt and the Sudan. Because of the interest of the Foundation in prehistoric archaeology, it has been called upon by the State Department to provide coordination of the United States effort. Nubia offers a nearly virgin field for the investigation of Paleolithic and Neolithic cultures as well as of geological, geomorphological, and climatological problems. No comprehensive geological or prehistorical studies have ever been undertaken in this area. A team consisting of an archaeologist and a geologist has mounted an expedition for a two-pronged

investigation of the problems of prehistoric culture and environment. Archaeological and geological data will correlate the early human industries of the Sudanese Nubia with the relatively better known sequences of east and central Africa to the south and the Sahara and Egypt to the west and north.

Among archaeologists increasing interest centers on the adaptation of the discoveries and technologies of the sciences to archaeological exploration and analysis. Instruments using electrical and seismic waves are being developed to detect underground features of archaeological interest. Similar machines to discover buried structures through the detection of magnetic anomalies are being tested. Soil and pollen analyses and the identification of prehistoric plant and animal remains will help to determine early settlement patterns as well as aid climatological inquiry.

One of the most significant events bearing on the problems of the origin and spread of agriculture in the New World was the discovery this year of wild maize in Tehuacan in Puebla, Mexico. The development of agriculture is basic to the development of civilization and consequently the problem of the origins of agriculture is of great importance to cultural anthropology. Corn cobs discovered in a deep deposit in Coxcatlan Cave have been dated by radiocarbon analysis, stratigraphy, and obsidian hydration at about 3,600 B.C. and are the oldest known corn in the world. This discovery will throw light on the beginnings of civilization in Mesoamerica where the cultivation of corn was the mainstay of the great Indian civilization.

Much of the NSF-supported archaeology undertaken in 1961 in the New World has been concentrated in the Mississippi River Valley, the northern portion of Mexico, and Alaska. The American Bottoms area of the Mississippi Valley was probably the largest aboriginal population center north of Mexico, and, for the first time, a large-scale excavation program has been undertaken to deal with this area in a unified fashion. Perhaps because of the vastness of the task, very little archaeological work has been done in the American Bottoms before initiation of the present project despite its central importance in midwestern prehistory.

Also of signal importance is the long-term integrated program of five alternating and overlapping field projects aimed at discovering the locations, fluctuations, and influences of the northern border of the Mesoamerican high cultures in pre-Columbian times. Special attention is being given to the investigation of ecological and other causal factors involved in the development and vacillations of the frontier and to their implications for problems of similar frontier situations throughout the world.

The rapidly growing interest in uncovering the prehistoric cultural connections between Eurasia, Alaska, and other areas of North America and the inherent value of the Arctic as an anthropological laboratory is reflected in the increasing number of investigations—archaeological, linguistic, and cultural—being pursued in arctic Alaska. Several expeditions in the area are excavating for data on proto-Eskimo cultures, while others are working on aspects of linguistic and ethnographic problems.

A study is being made of the anthropological problem of geographical variation in culture through a systematic investigation of one aspect of culture, language. Linguistic analysis of distinct cultures sharing a common territorial matrix will serve to verify or disprove the “cultural barrier” concept so frequently called upon to explain cultural differences where no obvious geographical barriers exist.

In addition to the examples mentioned, the wide variety of research is illustrated by studies on the effects of enforced upright posture on the physiology of quadrupeds, the ethnohistory of an African Kingdom, the analysis of prehistoric Peruvian fabric remains, and the effects of culture on personality formation in Japan and Burma.

Economic Sciences

The Foundation’s program in support of basic research in economics is still at the beginning phases of growth and development. The primary emphasis remains on econometrics and mathematical economics, but an increasing number of proposals is being supported in economic theory, in economic geography, and in the economics of science and technology. The total number of proposals received, and grants made, is small in relation to the other programs of the Division, but it is expected that research support in economics will expand considerably in the next year or two. Not only is the number of economists large, but their research horizons are constantly broadening.

One of the grants made this year involves 15 of the leading econometricians in the United States who are concerned with the construction of econometric models of our economy. It is now felt that major progress can be made by coordinated studies of particular sectors of the economy to establish a common basis for a generally acceptable model. Under a committee of the Social Science Research Council, the group of economists have met to establish a common framework within which each member can pursue the development of data and concepts to feed into the formation of an overall model. Working seminars will be

held periodically, and it is hoped that an adequate model can be developed by the summer of 1962. The success of such an effort will assist in the advance of econometric methods and increase our ability to explain and predict the behavior of the United States economy.

The Foundation's particular interest in the economic impact of science and technology is reflected in several grants. One is for the study of the effects of technological development on the allocation of economic resources and on productivity. Another is concerned with an empirical investigation of the extent to which research undertaken for national defense purposes has actual or potential nonmilitary applications. Since expenditures for research and development play a major role in the expansion of the American economy, and since much of the Federal Government's expenditure is devoted to national defense purposes, knowledge about the actual processes whereby the results of the military research and development effort are introduced into the civilian economy would be of great importance for stimulating economic growth.

Other grants in economics are focused on the development and refinement of methods for measuring economic phenomena at the level of the individual household, the firm, and the economy at large.

In the area where economics and geography converge there has been interest in problems of metropolitan structure and growth. This is an example of a situation in which social problems of current national concern provide a good setting for the pursuit of basic research. The rapid growth of metropolitan regions, both in size and number, has created immediate and specific problems and has strikingly demonstrated the inadequacy of our theoretical knowledge of the economics of urban structures. The reality of complex metropolitan areas and modern transportation developments have shown the gaps in existing theory. An NSF-supported project is concentrating on the refinement and testing of linear programming models of urban location and transportation to bring them into closer conformity to reality.

Econometric models have been constructed for the purpose of studying the allocation of economic and residential activities in urban areas, allowing for such complex factors as the conflicting importance of accessibility and amenity values of sites, and individual travel behavior. Actual behavior and preferences will be built into theory which has hitherto assumed, of necessity, simple and rational behavior on the part of consumers. This assumption is known to be unrealistic and it is hoped that the models of increased realism which are being developed will be general and powerful tools useful to the study of metropolitan area and land use and transportation problems.

Sociological Sciences

Three significant trends in sociology and social psychology have received special attention: the development of programs for high speed computers that permit the simulation of social or interpersonal processes, the extension of laboratory experimental techniques to more powerful and complex situations, and the construction of mathematical models of social processes and the invention of mathematical techniques for their analyses.

It is perhaps misleading to label the study of social processes on a computer as "simulation," especially if the term suggests an attempt to mirror in detail the actual dynamics of a social system. Rather, "simulation" allows a set of theoretical processes to be tried out with different parametric values to determine what sort of behavior system results. One investigator is developing computer programs that permit the simulation of complex social processes such as interaction in a three-person group; the relationship between rewards and constraints and participation in an organization; and the processes occurring in human networks of communication and inter-personal influence. The next stage of research involves the conducting of "experiments" on the computer by varying elements of the process being simulated and comparing terminal or stable states (if any) reached after a run through the machine.

Laboratory studies on role-specialization in groups and of parameters in risk-taking allow for precise formulation of the experimental situation, theoretically complex designs, and for control of relevant variables. Yet they do not approach in verisimilitude and power the experiments currently being planned under a recent grant. The grantee began the design of his experiments by first studying natural groups of teen-age boys in various socioeconomic strata of two cities. The data on group organization and individual member interaction (obtained by observation of the natural situation) will form the basis for the controlled experiment. The experimental groups will be studied, however, not in a university laboratory but in a boys' summer camp, a situation in which the investigator previously and successfully conducted similar research.

The application of mathematics and statistics to sociological and psychological problems has received support through a number of grants. These include development of a mathematical model of negotiation as a social process, research in the mathematics of psychophysical scales, and further exploration and testing of two kinds of mathematical models for language learning and use (one based on information theory and one on a theory of grammatical structures). One group of investigators is developing applications of the theory of linear graphs to the analysis of

group structures and interpersonal relationships. Their effort is directed toward removing certain current limitations of graph theory that arise from the fact that some of the complex conditions of group behavior cannot be incorporated into the theory because of the present starkness of the mathematical axioms and definitions. Of special importance is the invention of better ways to handle multiple simultaneous relations among individuals, to define opposite relations, and to indicate intensity and probability of bonds between pairs of individuals and substructures.

Finally, in the realm of statistical methods, a grant has been made for the analysis of multiple classification and discrimination problems, which appear in a number of areas of social science (including archaeology, criminology, psychology, and the analysis of content of communication). This general approach also is of interest to natural scientists faced with the necessity of deciding on the sources of signals and has obvious applications to military intelligence. The fundamental problem is to discern, from indirect and related evidence, the source of "authorship" of a series of acts whose individual similarities or differences can only be inferred, initially, from observable characteristics which, in turn, are related to a source in unknown ways. The research has yielded unexpected returns in suggesting some techniques for the statistical analysis of sequences of behavior (e.g. the chain of interaction that one might observe in a decision-making discussion) and has stimulated the formulation of some new problems in nonparametric statistics that will be especially important in the social sciences.

History and Philosophy of Science

The National Science Foundation has taken the lead in the support of research in the history and philosophy of science as separate disciplines although recognizing their essential interrelationships with the various natural sciences. The program is increasing in size, although it remains smallest of the social sciences programs—a reflection of the number of scholars engaged in these studies.

The largest grant in the history of the program was awarded for the collection of data on the quantum revolution. The research will be conducted by a team composed of a historian of science and senior physicists which will interview men who were active in the 1898–1939 period of development of quantum physics. Collection of unpublished notebooks, manuscripts, and other informal materials will be pursued concurrently with the interviewing. An immediate result of the project will be an organized body of written materials and transcribed oral data which future researchers can use for studies of the psychology and sociology of human creative processes, as well as of the history of physics.

Proposals for research in the history of science were, as always, divided between studies of individual scientists and broader studies of the development of fundamental scientific ideas. Examples of the former type are the study of Isaac Newton and the investigation into the relationship between the nineteenth century naturalist, Richard Owen, and the followers of Darwin. Because of the central importance of Sir Charles Lyell's work in the development of uniformitarian geology, palaeontology, and the Darwinian concept of evolution, a grant has been awarded for the collection and editing of the scattered and unpublished correspondence of Lyell and his scientific contemporaries in order to throw new light on the development of his thought. Throughout the 17 years from 1660 that Henry Oldenburg held the office of Secretary of the Royal Society of London, he maintained a voluminous correspondence with the entire European scientific community. His letters are one of the largest sources of material bearing on scientific activity during the 17th century and they are being prepared for publication.

The recovery of the mathematical models of planetary systems devised before the time of Copernicus and the physical observations on which they were based will be a useful contribution to the study of Islamic planetary theory and to the history of medieval science. Other studies of early foundations of later scientific thought deal with 17th century chemistry and its influence on modern medicine and the relationship of pre-Newtonian physics to the development of physical oceanography.

The philosophical basis of physical science offers one of the most fruitful areas of modern philosophical research. The attempt to formulate known areas of physical theory into one deductive theory is intended to give a deeper understanding of what has been accomplished thus far, uncover unjustified assumptions, and suggest new methods for the solution of problems of physics. A grant has been made to investigate completeness in physical science as it has been applied by mathematical logicians to deductive systems. Elucidation of this problem with regard to quantum physics can have the utmost importance for theoretical foundations of other sciences.

ANTARCTIC RESEARCH

PROGRAM OPERATIONS

General

The National Science Foundation administers a national program of scientific research in Antarctica covering investigations in the earth sciences, atmospheric sciences, biological sciences, and related fields of study. By direction of the President, the Bureau of the Budget, in Cir-

cular A-51, instructed the Foundation "to exercise the principal coordinating role in the development and carrying out of an integrated United States scientific program for Antarctica." In keeping with this responsibility, the Foundation looks after the Antarctic research interests of other Government agencies as well as those of private institutions.

The United States Antarctic Research program continues a scientific activity in Antarctica inaugurated for the International Geophysical Year (1957-1958). This international cooperative scientific effort proved so successful in enhancing the knowledge of the geographical and geophysical aspects of this region that the 12 nations cooperating since the IGY signed the Antarctic treaty in June 1961. This treaty provides that the Antarctic shall be used only for peaceful purposes and that freedom of scientific investigation shall continue in this spirit of international cooperation. The treaty calls for the continued exchange of scientific personnel and information between the cooperating nations. In the spirit of this treaty, the United States participates specifically with Argentina, Chile, The United Kingdom, Australia, New Zealand, and the U.S.S.R. in programs of scientific exchange and in mutual scientific assistance. These cooperative activities further United States scientific objectives by providing access to larger areas of the continent and by making available to United States scientists the results and experience of scientific personnel of other countries.

Program Administration

The National Science Foundation established during 1958 the United States Antarctic Research program under the Office of Special International Programs to undertake the detailed problems of coordinating a broad program of Antarctic research. On May 26, 1961, as a result of the increased international importance of the program and enlarged Foundation responsibilities in this area, a separate office, the Office of Antarctic Programs was established.

Serving in an advisory capacity to the Foundation is the Committee on Polar Research of the National Academy of Sciences. This committee considers broad program objectives for the United States in Antarctica and proposes them to the Foundation as representing the opinions of the scientific community and its interests in certain areas of Antarctic research. This committee is also representative to the Special Committee for Antarctic Research (SCAR) of the International Council of Scientific Unions.

The Department of Defense has been designated the agent to provide the logistic support to the scientific program in Antarctica. To carry out these support activities, responsibilities for the detailed logistic planning

were assigned to the Commander, Naval Support Force, Antarctica. Assisting the Commander, Naval Support Force, Antarctica, in discharging these responsibilities are units of the Navy, Coast Guard, Military Sea Transportation Service, and the Air Force.

The scientific program of the Office of Antarctic Programs is responsible for the development of long-range and immediate program plans and for the evaluation of research proposals. In carrying out these responsibilities the program calls upon the advice and services of the members of the Committee on Polar Research and its panels, specialists in the field at universities and in other Government agencies, and NSF program directors knowledgeable in the particular fields of research. Since each grant awarded by the Foundation for field research in Antarctica must include the assurance that facilities required to support each research activity will be available, each proposal is reviewed by the Field Requirements and Coordination Program of the Office of Antarctic Programs. This program, in close consultation with representatives of the U.S. Navy, draws upon its experience in coordinating scientific field activities in Antarctica to review research proposals for feasibility in terms of available logistic support.

The United States Antarctic Research program includes research activities of interested Government agencies, educational institutions, and other private organizations. Dollar support has been divided about equally between Government and non-Government groups; by number of grants—20 percent to Government agencies, 80 percent to non-Government groups.

The United States Antarctic Research program utilizes in the field a basic network of four stations in Antarctica: Byrd, Hallett, Pole, and McMurdo Stations. In addition to these stations, the National Science Foundation, through agreement with the Military Sea Transportation Service will begin in 1962 to maintain a research vessel in Antarctic waters. These stations serve primarily as locations from which to make observations of geophysical phenomena, while at the same time they serve as staging points for scientific field parties active in the austral summer months. Since the conclusion of the IGY, greater emphasis has been placed in this program on new areas of study such as biology, geology, and mapping which are best carried out in the field in summer months.

International Activities

The United States continues to work with Australia and Argentina in the maintenance of two cooperative scientific stations—Wilkes and Ellsworth—originally built by the United States for the IGY. The

custody of these stations has been transferred to Australia and Argentina, respectively.

The practice of exchanging scientists, carried on during the IGY, has been continued. The United States and the Soviet Union maintain an exchange of scientific personnel annually. One American scientist joins the Soviet expedition to winter at their Mirnyy Station, while one Soviet scientist takes part in the American scientific program at a United States station.

During the past year, several cooperative oceanographic and glaciological programs were undertaken with Argentina and Chile in the region of the Drake Passage between the tip of South America and the Antarctic Peninsula. The United States also provided a geomagnetic technician for the Chilean scientific base to assist scientists of that country in installing a magnetic apparatus and in training Chilean observers to use this apparatus.

Through the U.S. Weather Bureau, the United States is participating in the International Antarctic Analysis Center in Melbourne, Australia. This center replaces the IGY Weather Central originally located at the Little America Station, and carries out daily weather analysis of Antarctic data, as well as some research activities.

CURRENT RESEARCH SUPPORT

Investigations are being carried out under the United States Antarctic Research program in the fields of the biological and medical sciences, cartography, geology, glaciology, gravity, meteorology, oceanography, seismology, and upper atmospheric physics.

Among the many biological studies undertaken in Antarctica as part of the last year's program were the continued collection of airborne insects, limnological investigations of fresh-water lakes, studies of the ecology and physiology of McMurdo Sound marine life, research on the water metabolism of the Adelie penguin, and an investigation of the effects of the earth's rotation on the "biological clocks" of plants and insects.

Of particular significance was the discovery of the remains of fish, some estimated to have been at least two meters long, on the surface of the Ross Ice Shelf in the vicinity of the Dailey Island. It is believed these had been trapped below the ice and subsequently brought to the surface through a continual process of melting from the top and freezing from the bottom. In the collections of airborne organisms, free-living insects and mites were found at elevations of 6,000 feet above sea level, perhaps the highest altitude at which insect life has so far been encountered in Antarctica. In the course of biological studies

on two fresh water lakes in the Taylor Dry Valley, it was found that the water became progressively warmer with depth and in one case approached 72° F at the bottom despite some 10 feet of permanent ice cover over the lake. The stability of the water at the bottom is due to high salinity (several times that of normal sea water), but the high temperatures are as yet unexplained.

Cartographic studies continued, with aerial photography accomplished over about 118,000 square miles from Cape Adare south to the Queen Maud Mountains. The surface control required for the utilization of the photographs in the preparation of maps was accomplished by topographic engineers using new electronic measuring devices.

Geology in the interior of the Antarctic was investigated by three separate parties. One group investigated the central Horlick Mountains, part of the great mountain chain extending across the continent. Here, post-Silurian sedimentary rocks of the Beacon group were found to unconformably overlay the crystalline basement complex. A thick sequence of tillite, a rock formed by the compression and cementing of glacial morainal material, was found in the Beacon group resting on glacially striated pavement showing that an extensive glaciation took place in the Antarctic during the Late Paleozoic or Early Mesozoic eras and further indicates the connection between the Beacon sediments of Antarctica and the Gondwana sediments of Australia, South Africa, and South America.

Four United States Antarctic seismological stations continued to operate as part of the international seismology network in the Antarctic. These have proven very effective in locating earthquake epicenters throughout the Southern Hemisphere, though the Antarctic Continent itself is not an active seismic region.

Two major over-snow traverses continued the exploration of inland areas that started in 1957 and now total 12,000 miles of surface travel over the Antarctic ice cover. One unit traveled from Byrd Station to the Eights Coast of the Bellingshausen Sea while the second traveled from McMurdo to the Victoria Plateau by way of the Skeleton Glacier, then southwest and south to the Pole Station. The Marie Byrd Land party obtained further information on the large subice channel extending from the Ross Sea towards the Amundsen and Bellingshausen Sea. The McMurdo-Pole traverse found the subice rock to be generally near sea level, checking well the results of the U.S.S.R. traverse from Vostock to the Pole in 1959-60. The thinnest ice located on the traverse was about 6,000 feet.

Meteorological observations, including upper atmosphere soundings by balloon-borne equipment, surface observations, and special studies

such as the determination of ozone, carbon dioxide, solar radiation amounts and radioactive fallout continued. At McMurdo in the summer season, special humidity measurements were taken at high altitudes by balloon-borne instruments.

Routine oceanographic data were collected aboard U.S. Navy vessels during the summer supply operations, and a small oceanographic program included observations of ocean currents and water properties throughout the year at McMurdo Station.

Research on the upper atmosphere continued to be one of the major efforts in Antarctica and primarily centered around investigations in geomagnetism, the ionosphere, very-low frequency and extra-low frequency radio propagation, aurora and airglow, and cosmic radiation.

A relatively rare phenomenon, the sudden arrival of solar-produced cosmic radiation of sufficient energy to be detected at ground stations, was observed on November 12, 1960, and again on November 15 by the neutron monitor at McMurdo Station and simultaneously by a similar unit located at Thule, Greenland.

Facilities

SPECIALIZED BIOLOGICAL AND MEDICAL SCIENCES RESEARCH FACILITIES

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

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

Twenty-four grants totaling \$3 million were awarded during 1961 in this program. The following examples will provide some notion of the range of grants made. A second *Drosophila* stock center was established at the Institute for Cancer Research in Philadelphia to complement the

only other one existing in this country at the California Institute of Technology. The second center will not only duplicate the entire mutant collections of the first stock center, as a precaution against loss, but will also acquire and maintain many new mutant strains. Support for a barley stock center was also initiated this year. A sizable grant was made to the American Type Culture Collection for new quarters in which to house valuable collections of microorganisms. These materials are distributed to research laboratories throughout the country and abroad for use in a wide spectrum of biological and medical research.

Two grants were made to museums of note, the Museum of Comparative Zoology at Harvard and the Los Angeles County Museum, for renovations and additions to their research quarters. Various facilities requirements of field stations accounted for six more grants. These ranged in size and purpose from a token contribution toward the establishment of an international field station in the Galapagos Islands to a substantial grant for construction of laboratory and living quarters at the Rocky Mountain Biological Laboratory. Other stations aided were the Bear Lake Laboratory of Utah State University, the Vermillion Sea Station of the San Diego Society of Natural History, a small station for animal behavior studies at Duke University, and one associated with Emory University.

In addition to several grants to marine stations for additions and modifications of their shore research facilities, two were made for the acquisition of major oceanographic vessels, one for the Stanford University Hopkins Marine Station, and the other for the Duke University Beaufort Station. (See Oceanographic Research Vessels.)

UNIVERSITY COMPUTING FACILITIES

The Foundation in 1961 continued its program of partial support for the acquisition or rental of high-speed computers of advanced design by universities for use of basic research. Six grants totaling \$1,685,000 were made. There were also twenty grants for \$796,000 for support of initial operations of computing centers; for procurement of small computers, improvements in existing centers, etc.

OCEANOGRAPHIC RESEARCH VESSELS

Considerable progress was made on the design of the oceanographic vessel for the Woods Hole Oceanographic Institution, and, in September 1961, award of a contract for construction of the 210-foot vessel was announced by the Institution. The new ship, to be named ATLANTIS II after Woods Hole's famous ketch ATLANTIS, will be one of the very few ships ever designed in the United States specifically for

oceanographic research. She will be built of steel and will have twin propellers, powered by uniflow reciprocating steam engines for quiet operation, freedom from vibration, and flexibility in maneuvering—all valuable characteristics in a research ship. She will have a waterline length of 195 feet, beam of 44 feet, and displacement of 2,100 tons. Accommodations will be provided for a crew of 28 and scientific party of 25. The Foundation has granted a total of \$4.75 million for design and construction of the vessel (\$3 million in 1960 and \$1.75 million in 1961).

Duke University will construct a biological oceanographic vessel with NSF assistance, one of the first major research vessels to be built with biological oceanography as its prime function. It will permit Duke and other interested universities to cooperate in extending the scope of their research to include the deep ocean as well as the coast line and shallow water areas. Foundation support amounted to approximately \$618,000.

Stanford University was awarded a grant to enable the Hopkins Marine Station to convert a two-masted schooner to a modern sea-going marine biological vessel that will be one of the largest sailing ships in the world used for scientific purposes. The grant was for \$463,000.

HAWAII INSTITUTE OF GEOPHYSICS

An institute of geophysics is being established in the Hawaiian Islands to take full advantage of the unusual opportunities which the islands offer for geophysical studies in the fields of meteorology, volcanology, seismology, geology, hydrology, astrophysics and cosmic radiation, tropical weathering and erosion, and oceanography.

The general plan is to establish a central laboratory staffed and operated by the University of Hawaii. The main buildings will be constructed on a site presently owned by the University. Smaller buildings will be erected at several outlying sites in order to achieve maximum scientific advantage. The Institute of Geophysics will be administered and supported as an integral part of the University of Hawaii.

An amount of \$300,000 was granted by the Foundation during the fiscal year for site development and detailed architectural and engineering studies.

NATIONAL RESEARCH CENTERS

1. National Radio Astronomy Observatory

Construction of all major buildings has been completed; all instruments have been built for which funds have been provided, with the exception of the 140-foot and 300-foot telescopes.

A contract was executed for the construction of a 300-foot parabolic dish to be used initially for studies of neutral hydrogen distribution and motion in the Milky Way. Plans call for completion of this dish during the next year. It will be of the transit type capable of operating between 22° south and 90° north.

A total of \$5,404,000 was allocated in 1961 to the contract under which Associated Universities, Inc. operates the observatory at Green Bank, W. Va.

2. Kitt Peak National Observatory

The past year was a fruitful one at the Kitt Peak Observatory with construction moving along rapidly. The dome for the 84-inch reflecting telescope was completed; the mounting is now being constructed; and the grinding and polishing of the mirror is proceeding.

The solar telescope, the largest in the world, is progressing at a satisfactory pace. The 100-foot heliostat tower is in place, and the 300-foot shaft and tunnel have been excavated. Operation of this telescope should begin early in 1963. A solar wing is being added to the headquarters building in Tucson to house offices and laboratories.

The satellite telescope has been actively pushed. A remote-controlled 36-inch telescope has been designed and is out for bids. It will first be mounted in Tucson for evaluation and then moved to Kitt Peak for operation from the city by a microwave link. A cooperative program has been initiated with personnel of NASA's Goddard Space Flight Center who wish to use the remote-controlled facility to test their 36-inch Orbiting Astronautical Laboratory.

On October 1, 1960, Dr. N. U. Mayall officially assumed the position of Director of the Observatory. He succeeded Dr. C. D. Shane, president of AURA, who had served on a temporary basis until Dr. Mayall could assume his new position.

3. National Center for Atmospheric Research

This center, as are the National Observatories, is managed and operated for the Foundation by an association of universities—in this case, the University Corporation for Atmospheric Research. The 1961 allocation was \$500,000.

The National Center for Atmospheric Research was established to meet the need for a national center devoted to basic research in the atmospheric sciences. Its purpose is to serve as a focus for intellectual activity bringing together scientists from meteorology and related disciplines and providing research facilities on an appropriate scale to deal with the global nature of meteorological problems. The director, Dr. Walter Orr Roberts; the associate director, Dr. Philip D. Thompson;

and other top staff people have already been appointed and the early outlines of the NCAR program are beginning to emerge.

Table Mountain, near Boulder, Colo., was selected as the site of the new laboratory because of its central location with respect to research establishments and departments throughout the country, its excellent and growing research environment, and its advantages for the study of particular atmospheric phenomena. Land at the site has been made available by the State of Colorado without cost to the Federal Government.

GRADUATE RESEARCH LABORATORIES

Graduate research laboratories are used principally by faculty members and their research associates in carrying out their research programs. However, they are also of paramount importance in serving the needs of graduate and post-doctoral students pursuing thesis or independent research problems. In fact, graduate-level research cannot proceed without adequate research laboratories.

Existing laboratories are to a great extent outmoded and scarcely able to provide for the increased load being imposed by the continually rising number of graduate students and faculty members needing to use them.

Financial resources of many of these institutions are comprised mainly of the traditional endowments and are already being strained to the utmost to provide for the constantly rising costs associated with the usual educational responsibilities for instruction, particularly at the undergraduate level.

The Foundation, therefore, initiated in the 1960 fiscal year a program of support to help alleviate the critical need for graduate research laboratories with primary emphasis, of necessity, on renovation and equipping of existing laboratories with fixed equipment. This was done in order to provide a maximum number of grants to accomplish immediate improvement in the largest possible number of graduate research laboratories.

Grants awarded under this program require the recipient institution to provide from non-Federal sources at least 50 percent of the cost of the project being supported. This requirement assures that the requesting institution will be prudent and will carefully evaluate the project in terms of its own overall research programs prior to submitting a request for funds.

Only university departments having on-going graduate training programs leading to the doctoral degree in science or engineering were eligible to apply for support during the past fiscal year. Support was further restricted to laboratories used for basic research.

A total of 87 grants were awarded in fiscal year 1961 at a cost of \$8.5 million—43 in the life sciences for \$3.1 million, 44 in the physical sciences for \$5.4 million.

During 1961, responsibility for the operation of this program was transferred from the research divisions to the Office of Institutional Programs.

Research-Related Activities

SCIENTIFIC CONFERENCES AND SYMPOSIA

The Foundation during 1961, sponsored and provided partial support for 47 conferences and symposia (listed below). These meetings provided a forum for the exchange of information and ideas among scientists who are pioneering in new or incompletely explored fields. They also furnished opportunity in many cases for younger scientists to learn and obtain advice from some of the world's outstanding senior scientists. Frequently the subject matter was interdisciplinary, of interest to scientists in several fields. In most cases, sponsorship was shared with one or more private or public agencies, including universities and scientific societies.

RESPONSE OF MATERIALS TO HIGH VELOCITY DEFORMATION—Estes Park, Colo., July 11–12, 1960; Chairman: Dr. H. W. Paxton, Carnegie Institute of Technology, Pittsburgh, Pa.; Cosponsor: Metallurgical Society of the American Institute of Mechanical Engineers.

SECOND INTERNATIONAL SYMPOSIUM ON RARIFIED GAS DYNAMICS—University of California, Berkeley, Calif., Aug. 3–6, 1960; Chairman: Dr. Immanuel Estermann, Office of Naval Research, Washington, D.C.; Cosponsors: Office of Naval Research, Air Force Office of Scientific Research, National Aeronautics and Space Administration, and University of California.

INTERNATIONAL CONFERENCE ON ORGANIC SCINTILLATION DETECTORS—University of New Mexico, Albuquerque, N. Mex., Aug. 15–17, 1960; Chairman: Dr. Guido H. Daub, Department of Chemistry, University of New Mexico; Cosponsors: Atomic Energy Commission, University of New Mexico.

VII INTERNATIONAL SOIL SCIENCE CONGRESS—University of Wisconsin, Madison, Wis., Aug. 15–23, 1960; Director: Emil Truog, Chairman, Finance Committee, Soil Society of America; Cosponsors: Rockefeller Foundation, Atomic Energy Commission and Soil Science Society of America.

CONFERENCE ON FUNCTION ALGEBRAS—Dartmouth College, Hanover, N.H., Aug. 15–31, 1960; Chairman: Dr. Hazelton Mirkil, Department of Mathematics and Astronomy, Dartmouth College; Cosponsors: U.S. Air Force and Dartmouth College.

INTERNATIONAL SYMPOSIUM ON IMMUNOCHEMICAL APPROACHES TO PROBLEMS IN MICROBIOLOGY—New Brunswick, N.J., Sept. 1–3, 1960; Chairmen: Michael Heidelberger and Ottor J. Plescia, Institute of Microbiology, Rutgers University, New Brunswick, N.J.; Cosponsor: Rutgers University.

SURVEY OF THE TRANSPORTATION PROBLEM—Woods Hole, Mass., Aug. 1–Sept. 3, 1960; Director: John S. Coleman, Executive Secretary, National Academy of

Sciences-National Research Council, Division of Physical Sciences, Washington, D.C.; Cosponsor: National Academy of Sciences-National Research Council.

INTERNATIONAL CONFERENCE ON ATOMIC MASSES—McMaster University, Hamilton, Ontario, Canada, Sept. 12–16, 1960; President: Professor J. Mattauch, Max Planck Institute for Chemistry, Mainz, Germany; Cosponsors: International Union of Pure and Applied Physics, National Research Council of Canada, Province of Ontario, Canadian Association of Physicists, National Academy of Sciences-National Research Council, and private industry.

NUMERICAL TREATMENT OF ORDINARY DIFFERENTIAL INTEGRAL AND INTEGRO-DIFFERENTIAL EQUATIONS—Rome, Italy, Sept. 20–24, 1960; Coordinator: Professor Aldo Ghizzetti, Deputy Director, Istituto Nazionale per le Applicazioni del Calcolo, Rome, Italy; Cosponsors: Provisional International Computation Center, Rome, Italy, Italian Ministry of Education, and private industry.

INTERNATIONAL CONFERENCE ON THE NATURE OF SOLID FRICTION—Midwest Research Institute, Kansas City, Mo., Sept. 26–28, 1960; Director: Dr. Bruce Daniel, Physics Section, Mathematics and Physics Division, Midwest Research Institute; Cosponsors: Army Office of Ordnance Research, Office of Naval Research, and Wright Air Development Division.

NINTH NATIONAL CLAY CONFERENCE—Purdue University, Lafayette, Ind., Oct. 5–8, 1960; Chairman: Dr. Joe L. White, Department of Agronomy, Purdue University; Cosponsor: National Academy of Sciences-National Research Council.

SYMPOSIUM ON HUMAN GENETICS—Cleveland, Ohio, Oct. 10–12, 1960; Chairman: Arthur G. Steinberg, Department of Preventive Medicine, Western Reserve University, Cleveland, Ohio; Cosponsor: Western Reserve University.

MATHEMATICAL OPTIMIZATION TECHNIQUES—Santa Monica, Calif., Oct. 18–20, 1960; Directors: Dr. Robert M. Oliver and Dr. Raymond C. Crassi, Engineering and Sciences Extension, University of California; Cosponsors: Office of Naval Research, National Space and Aeronautics Administration, University of California, and the Rand Corporation.

SYMPOSIUM ON DECOMPOSITION OF AUSTENITE—Philadelphia, Pa., Oct. 19, 1960; Director: Victor F. Zackay, Chairman, Ferrous Metallurgy Committee, AIME; Cosponsor: The Metallurgy Society of the American Institute of Mechanical Engineers.

IMPACT OF FEEDBACK CONTROL CONCEPTS IN THE STUDY OF ECONOMIC AND BUSINESS SYSTEMS—New York, N.Y., Oct. 28, 1960; Moderator: Dr. Cuthbert C. Hurd, Program Manager, Advanced Systems Development Division, International Business Machines, Inc.; Cosponsors: Foundation for Instrumentation Education and Research and the Institute of Management Sciences.

GAS CHROMATOGRAPHY—University of California, Los Angeles, Calif., Jan. 26–28, 1961; Chairman: Dr. Robert L. Pecsok, Department of Chemistry, University of California; Cosponsor: University of California, Los Angeles.

GEODESY IN SPACE AGE—Ohio State University, Columbus, Ohio, Feb. 6–8, 1961; Chairman: Dr. W. A. Heiskanen, Director, Institute of Geodesy, Photogrammetry and Cartography, Ohio State University; Cosponsor: Ohio State University.

CONFERENCE ON BRAIN AND BEHAVIOR—Los Angeles, Calif., Feb. 19–22, 1961; Chairmen: H. W. Magoun, School of Medicine, University of California, Los Angeles, Calif. and Frank Fremont-Smith, AIBS; Cosponsor: University of California, Los Angeles.

SIXTH ANNUAL SYMPOSIUM ON MINING RESEARCH—University of Missouri, Rolla, Mo., Feb. 22–25, 1961; Chairman: Dr. G. B. Clark, Chairman, Department of Mining, University of Missouri School of Mines and Metallurgy; Cosponsors: University of Missouri and Department of Interior, Bureau of Mines.

SYMPOSIUM ON STRUCTURE, CONFORMATION, AND FUNCTION OF NUCLEIC ACIDS AND PROTEINS—M. D. Anderson Hospital and Tumor Institute, Houston, Tex.,

Feb. 23-25, 1961; Chairman: Saul Kit, University of Texas, M. D. Anderson Hospital and Tumor Institute, Houston, Tex.; Cosponsor: University of Texas.

DIRECT OBSERVATION OF DEFECTS IN CRYSTALS—St. Louis, Mo., Feb. 26-Mar. 2, 1961; Directors: J. B. Newkirk, Research Metallurgist, General Electric Research Laboratory, Schenectady, N.Y. and J. H. Wernick, Bell Telephone Laboratories, Murray Hill, N.J.; Cosponsor: The Metallurgical Society of the American Institute of Mechanical Engineers.

CONFERENCE ON NEUROSPORA—La Jolla, Calif., Mar. 2-4, 1961; Chairman: Frank L. Campbell, NAS-NRC, Division of Biology and Agriculture, Washington, D.C.; Cosponsors: University of California, Atomic Energy Commission and National Academy of Sciences-National Research Council.

FIVE REGIONAL DEVELOPMENTAL BIOLOGY CONFERENCES—Gambier, Ohio, Mar. 16-17, 1961; Wakulla, Fla., May 18-19, 1961; Ames, Iowa, May 1-2, 1961; Lake Arrowhead, Calif., May 25-27, 1961; Chairman: Emil Witschi, Department of Zoology, State University of Iowa, Iowa City, Iowa; Cosponsors: Kenyon College, Florida State University, State University of Iowa and Division of Developmental Biology of the American Society of Zoologists.

SYMPOSIUM ON STATISTICAL GENETICS AND PLANT BREEDING—Raleigh, N.C., Mar. 20-29, 1961; Chairman: Frank L. Campbell, NAS-NRC, Division of Biology and Agriculture, Washington 25, D.C.; Cosponsors: Atomic Energy Commission, National Institutes of Health, North Carolina State College and National Academy of Sciences-National Research Council.

SYMPOSIUM ON ELECTRONIC REARRANGEMENTS AND ENERGY TRANSFER IN BIOLOGICAL SYSTEMS—St. Louis, Mo., Mar. 29, 1961; Chairman: Leroy Augenstein, Biology Department, Brookhaven National Laboratory, Upton, N.Y.; Cosponsor: American Chemical Society.

FOURTH SYMPOSIUM ON ROCK MECHANICS—Pennsylvania State University, University Park, Pa., Mar. 30-Apr. 1, 1961; Chairman: Howard L. Hartman, Head, Department of Mining, Pennsylvania State University; Cosponsors: University of Minnesota, Colorado School of Mines and Pennsylvania State University.

SURFACE CHEMISTRY OF ICE NUCLEATION—University of Arizona, Tucson, Ariz., Apr. 6-8, 1961; Chairmen: James E. McDonald and Myron L. Corrin, University of Arizona; Director: Dr. A. Richard Kassander, Director, Institute of Atmospheric Physics, University of Arizona; Cosponsor: University of Arizona.

SYMPOSIUM ON MATHEMATICAL PROBLEMS IN BIOLOGICAL SCIENCES—New York, N.Y., Apr. 6-8, 1961; Chairman: Dr. S. M. Ulman, Los Alamos Scientific Laboratory, University of California; Cosponsors: American Mathematical Society and the Army Office of Ordnance Research.

INTERNATIONAL SYMPOSIUM ON AGGLOMERATION—Philadelphia, Pa., Apr. 12-14, 1961; Chairman: Dr. W. B. Stephenson, President, Allen-Sherman-Hoff Pump Co.; Cosponsor: American Institute of Mechanical Engineers.

SYMPOSIUM ON CHEMICAL REACTIONS IN THE LOWER AND UPPER ATMOSPHERE—San Francisco, Calif., Apr. 18-20, 1961; Chairman: Dr. Richard D. Cadle, Manager, Atmospheric Chemical Physics, Stanford Research Institute, Menlo Park, Calif.; Cosponsors: Department of Defense Advanced Research Projects Agency, National Institutes of Health, Atomic Energy Commission, Air Force Office of Scientific Research, and private industry.

SYMPOSIUM ON INVERTEBRATE CONTROL MECHANISMS—Lexington, Ky., Apr. 20, 1961; Chairman: D. G. Humm, Department of Zoology, University of North Carolina, Chapel Hill, N.C.; Cosponsors: Society of General Physiologists and the University of North Carolina.

SYMPOSIUM ON MATRIX COMPUTATION—Gatlinburg, Tenn., Apr. 23-30, 1961; Chairman: Dr. A. S. Householder, Chief, Mathematics Panel, Oak Ridge National Laboratory, Oak Ridge, Tenn.; Cosponsors: Society for Industrial and Applied Mathematics, Atomic Energy Commission, and Oak Ridge National Laboratory.

RECORD OF PATTERNS OF WATER MOVEMENT IN RECENT AND ANCIENT SEDIMENTS—Denver, Colo., Apr. 24–26, 1961; Chairman: R. N. Ginsberg, SEPM; Cosponsor: The Society of Economic Paleontologists and Mineralogists.

FLUID DYNAMICS AND APPLIED MATHEMATICS—University of Maryland, College Park, Md., Apr. 28–29, 1961; Director: Dr. J. M. Burgers, Acting Director, Institute for Fluid Dynamics and Applied Mathematics, University of Maryland. Cosponsor: Institute for Fluid Dynamics and Applied Mathematics, University of Maryland.

SYMPOSIUM ON MODERN ELECTROCHEMICAL INSTRUMENTATION—Indianapolis, Ind., Apr. 30–May 3, 1961; Chairman: C. W. Tobias, Department of Chemistry and Chemical Engineering, University of California; Cosponsor: The Theoretical Division of the Electrochemical Society, Inc.

SYMPOSIUM ON MATHEMATICAL THEORIES OF BIOLOGICAL PHENOMENA—Chicago, Ill., May 8–10, 1961; Chairman: N. Rashevsky, Committee on Mathematical Biology, University of Chicago, Chicago, Ill.; Cosponsor: University of Chicago.

MIDWEST CONFERENCE ON THEORETICAL PHYSICS—University of Minnesota, Minneapolis, Minn., May 12–13, 1961; Chairman: Dr. Warren B. Cheston, School of Physics, University of Minnesota; Cosponsor: University of Minnesota.

SYMPOSIUM ON OCEANOGRAPHY IN THE MIDWEST—University of Wisconsin, Madison, Wis.; May 15–16, 1961; Director: Dr. Lewis M. Cline, Department of Geology, University of Wisconsin; Cosponsors: ONR, Committee on Institutional Cooperation and the University of Wisconsin.

SYMPOSIUM ON CHROMOSOMES AND CONGENITAL MALFORMATIONS—Cincinnati, Ohio, May 26–27, 1961; Chairman: F. Clarke Fraser, McGill University, Montreal, Canada; Cosponsors: Teratology Society and the University of Cincinnati.

SYMPOSIUM ON QUANTITATIVE BIOLOGY—Cold Spring Harbor, N.Y., June 4–6, 1961; Chairman: Arthur Chovnick, Long Island Biological Association, Cold Spring Harbor, N.Y.; Cosponsors: Cold Spring Harbor Biological Association, National Institutes of Health and Rockefeller Foundation.

REGIONAL CONFERENCE OF COMPARATIVE ENDOCRINOLOGY—Oisa, Japan, June 6–10, 1961; Chairman: Emil Witschi, Department of Zoology, State University of Iowa, Iowa City, Iowa; Cosponsors: American Society of Zoologists and the Zoological Society of Japan.

TWENTIETH GROWTH SYMPOSIUM—Williamstown, Mass., June 12–14, 1961; Chairman: Edgar Zwilling, Brandeis University, Waltham, Mass.; Cosponsors: Society for the Study of Development and Growth and Williams College.

CONFERENCE IN ELEMENTARY PARTICLE THEORY—University of California, La Jolla, Calif., June 14–16, 1961; Chairman: Dr. Keith A. Bruecker, Department of Physics, University of California; Cosponsors: Atomic Energy Commission, Office of Naval Research, International Union of Pure and Applied Physics.

SYMPOSIUM ON BIOLOGICAL INNOVATIONS AND GEOLOGIC RECORD—Washington, D.C., June 14–16, 1961; Chairman: Philip Abelson, Carnegie Institution of Washington; Cosponsor: Carnegie Institution of Washington.

SYMPOSIUM ON COMETS—Maria Mitchell Observatory, Nantucket, Mass., June 18–21, 1961; Chairman: Dr. Dorrit Hoffleit, Director, Maria Mitchell Observatory; Moderator: Dr. Gerhard Herzberg, National Research Council of Canada; Cosponsors: Maria Mitchell Observatory and American Astronomical Society.

CYTOLOGY OF BACTERIA AND OTHER MICROORGANISMS—Meriden, N.H., June 19–25, 1961; Chairman: Richard B. Roberts, Department of Terrestrial Magnetism, Carnegie Institution of Washington; Cosponsors: Gordon Research Conferences and Kimball Union Academy.

DESALINATION RESEARCH STUDY—Woods Hole, Mass., June 19–July 14, 1961; Chairman: Dr. Dayton E. Carritt, Woods Hole Oceanographic Institute, Woods Hole, Mass.; Cosponsors: National Academy of Sciences-National Research Council.

SUPPORT OF TRAVEL TO INTERNATIONAL MEETINGS

Personal contact between highly competent scientists from all over the world, conducting similar types of research, is one of the most important means by which ideas are exchanged. The cross-fertilization of ideas is vital to the advancement of scientific knowledge. The Foundation, therefore, partially defrays travel costs for a limited number of American scientists to attend selected international meetings and congresses abroad. The grant to the scientist generally provides for a round-trip air-tourist fare between the home institution and the location of the meeting. In fiscal year 1961, 539 scientists received such awards at a cost of approximately \$506,000.

TRAINING ASPECTS OF RESEARCH GRANTS

A significant adjunctive contribution of the research grant programs of the Foundation is the training opportunity it provides for predoctoral and postdoctoral research assistants and associates. During 1961, approximately 6,700 individuals received the highest level of training through participation in research projects under the supervision of many of this country's most able scientists.

When this number is added to the 4,200 awards made under formal fellowship programs of the Foundation, the result represents a total of almost 11,000 persons—all of whom have been given the opportunity to further their scientific education and laboratory training under the most favorable and productive conditions.

PATENTS RESULTING FROM NSF-SUPPORTED RESEARCH

The Foundation, during the 1961 fiscal year, has received notification of the issuance of four patents by the U.S. Patent Office covering inventions arising out of Foundation-supported activities.

1. Patent No. 2,986,563 entitled "Certain Cycl[3.3.2]azines" was issued to Richard J. Windgassen, Jr., holder of a predoctoral fellowship at the University of Rochester, and to Virgil Boekelheide. It is for a new class of heterocyclic compounds containing carbon and nitrogen in the rings. Besides the support given Mr. Windgassen by the Foundation fellowship, the research which resulted in the invention was also supported by the Army Office of Ordnance Research.

2. Three patents were issued to Dr. R. G. Herb, of the Physics Department of the University of Wisconsin, on inventions made during the course of research supported by Foundation grants:

(a) Patent No. 2,888,189, entitled "Vacuum Pump," relates to improvements in vacuum pumps which are capable of producing and maintaining a high vacuum. Patent applications have

also been filed in France, Germany, the Netherlands, Switzerland, and the United Kingdom.

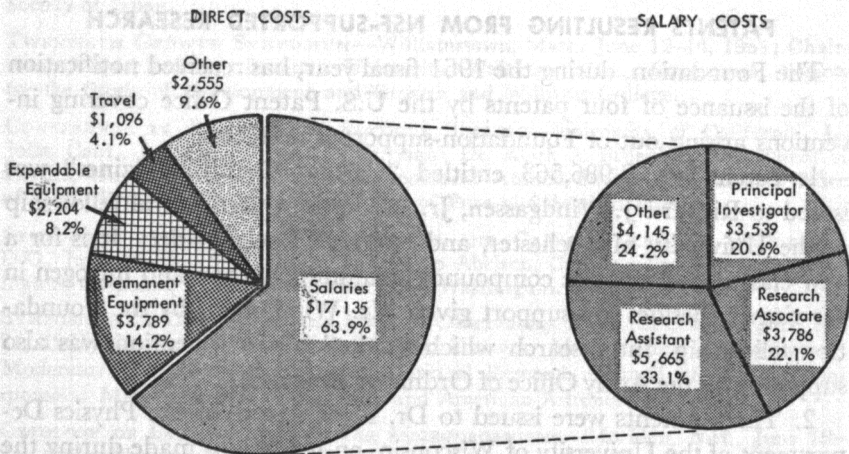
(b) Patent No. 2,913,167, entitled "Vacuum Pump," also relates to improvements in vacuum pumps which are capable of producing and maintaining a high vacuum, and particularly to improvements useful in pumps of small physical size. Patent applications have also been filed in Canada, France, Germany, and Switzerland.

(c) Patent No. 2,967,223, entitled "Feeder Mechanism," relates to apparatus for feeding an elongated member such as a wire to a heated surface on which the wire is to be evaporated.

Pursuant to the provisions of the grants and fellowship involved, the Foundation has secured for the Federal Government royalty-free licenses to utilize these inventions for governmental purposes.

Fiscal Analysis of Research Program

In fiscal year 1961, a total of 2,102 grants were made in support of basic research to 381 institutions throughout the United States and its possessions, also in Argentina, Belgium, Bermuda, Canada, England, France, Israel, Italy, Lebanon, The Netherlands, and New Zealand. Research expenditures totaled \$93 million—\$69 million for research grants, \$16 million for facilities, and \$8 million for research centers.



Indirect Costs of \$4,715 = 17.6% of Total Direct Cost

Note: Based on Average grant of \$31,494.

Figure 1. Distribution of Research Grant Funds, by Type of Expenditure, Fiscal Year 1961

The average 1961 research grant was for \$31,494 for a period of slightly more than 2 years. Grants in the mathematical, physical, and engineering sciences averaged \$37,714; in the biological and medical sciences, \$27,000; and in the social sciences, \$20,557.

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

Table 1. National Science Foundation Grants, by Fields of Science, Fiscal Year 1961

Field	Number	Amount
Biological and medical sciences:		
Developmental biology	94	\$2, 395, 300
Environmental biology	133	3, 039, 100
Genetic biology	86	2, 338, 300
Metabolic biology	100	3, 007, 200
Molecular biology	117	4, 587, 600
Psychobiology	78	2, 284, 540
Regulatory biology	118	3, 474, 060
Systematic biology	178	2, 680, 825
General biology	51	2, 745, 980
Total	955	26, 552, 905
Mathematical, physical, and engineering sciences:		
Astronomy	54	2, 150, 770
Atmospheric sciences (includes weather modification)	60	3, 910, 840
Chemistry	213	6, 317, 730
Earth sciences	137	4, 653, 795
Engineering sciences	164	7, 403, 796
Mathematical sciences	140	4, 566, 531
Physics	141	6, 184, 200
Total	909	35, 187, 662
Social sciences:		
Anthropology	84	1, 397, 300
Economics	16	600, 500
History and philosophy of science	20	210, 000
Sociology	40	1, 245, 700
Total	160	3, 453, 500
Antarctic research (life and physical sciences)	78	3, 841, 770
Grand total	2, 102	69, 035, 837

INSTITUTIONAL GRANTS

The Federal Government provides each year a substantial amount of funds to our universities and colleges for the direct support of scientific research projects, facilities, and science training. However, the full cost of these scientific activities is not provided through the grants and contracts awarded to provide this support, and the institutions have provided, from their own limited resources, the additional funds necessary to fulfill the total support needs.

In addition, the Foundation recognizes that the scientific strength of our Nation rests in part upon the diversity and autonomy of the institutions that contribute to this strength. It also recognizes that imbalances in the financial structure of scientific activities at educational institutions have been created by the large amount of Federal money that they utilize for their scientific research.

In view of these factors, therefore, NSF created, in July 1960, an institutional grants program, conducted through Office of Institutional Grants, to assist institutions to strengthen their general research and training functions without specifying the precise research or related scientific activity to be undertaken. Its purpose is to provide optimum flexibility and simplicity of administration for the colleges and universities concerned, to enable them better to fulfill their diverse and autonomous roles.

Funds from this program may be used to employ additional scientific staff, to purchase research supplies, to satisfy emergency needs for equipment—for anything required by the institution to help maintain or improve the general quality and environment of the institution in its conduct of scientific activities.

The following formula was used for computing grants made during 1961:

Five percent of NSF basic research grant payments made to the institution during the period July 1, 1960—March 31, 1961, with no grant to exceed \$50,000 in any one year. (Because the base period covered only nine months, the maximum grant during this first year was for \$37,500.)

Grants totaling \$1,496,604 were made to 248 institutions in 1961. More than half the awards (to 141 institutions) amounted to \$2,000 or less; 10 institutions received the maximum grant.

EDUCATION IN THE SCIENCES

The programs of the Division of Scientific Personnel and Education have, since the establishment of the Foundation, sought to improve science education throughout the Nation as rapidly and effectively as possible. Specifically, they are directed toward the following goals:

1. Furthering the scientific training of advanced scholars in highly specialized areas of science, so that they may enhance their ability to apply their special talents and skills to problems emerging at the ever-changing frontiers of knowledge; also, furthering the training of graduate students and teachers of science, mathematics, and engineering, who represent an important contribution to the future scientific manpower resources of the Nation.

2. Improving the quality and effectiveness of teachers of science, mathematics, and engineering by making available to them training opportunities at all educational levels.

3. Enhancing undergraduate science education through special courses for the high-ability undergraduate student and through other educational opportunities that permit him to proceed with his scientific education at the speed and the level of which he is intellectually capable.

4. Strengthening science education for secondary school students by providing special courses and other educational opportunities for the academically talented students who are not fully challenged by the scientific courses and experiences normally available to them in high school.

5. Upgrading course content in science, mathematics, and engineering by securing the active participation and cooperation of expert scientists, engineers, mathematicians, and teachers in designing courses, curricula, and textbooks which meet today's needs in these fields.

6. Collecting and analyzing information on American scientific manpower and education in order to determine national needs and provide information that is vital for planning purposes.

7. Improving the scientific literacy of the American public.

Support for the programs to achieve these goals totaled \$70 million in fiscal year 1961—slightly more than in the previous year.

Fellowship Programs

The Foundation's fellowship programs are intended to strengthen the Nation's scientific potential by enabling graduate students, teachers, and advanced scholars of unusually high ability to increase their competence in science, mathematics, and engineering through the pursuit of advanced study or scientific work. Since the inception of NSF fellowship programs in fiscal year 1952, approximately \$57 million has been obligated for the support of some 17,000 fellows in the various fellowship programs. The fellows were selected solely on the basis of their ability from among 64,000 applicants.

Table 2.—NSF Fellowship Programs, 1961

Program	Number of applicants	Number of awards offered
Graduate fellowships	4, 875	1, 536
Cooperative graduate fellowships	3, 241	1, 100
Summer fellowships for graduate teaching assistants	1, 366	625
Postdoctoral fellowships	656	235
Senior postdoctoral fellowships	275	91
Science faculty fellowships	754	285
Summer fellowships for secondary school teachers	1, 866	324
Totals	13, 033	4, 196

The 4,196 awards offered in fiscal year 1961 at a cost of \$14.1 million represent an increase of 187 over the number offered in the previous year.

In addition to the NSF fellowship programs, the Foundation administered two extramural fellowship programs—the North Atlantic Treaty Organization (NATO) Postdoctoral Fellowships in Science and the Organization for European Economic Cooperation (OEEC) Senior Visiting Fellowships.

Program	Number of applicants	Number of awards offered	Number of awards accepted
NATO fellowships	151	67	43
OEEC fellowships	45	20	19

GRADUATE FELLOWSHIPS

Graduate Fellowships, the first type established by the Foundation, provide support to unusually able students to enable them to complete their graduate studies with the least possible delay.

For the fifth consecutive year the number of applicants for these prized fellowships increased with a concomitant increase in the number of awards offered (1,537).

Teaching experience provides a valuable part of the academic training of many graduate students. To encourage graduate fellows to take advantage of teaching opportunities as they arise—indeed, at some institutions, to make such opportunities possible—the National Science Board approved a “teaching for pay” policy in fiscal year 1961. Graduate fellows will be permitted to undertake at their fellowship institutions a limited amount of teaching in any field which the Foundation supports. They may receive for their services up to \$600 during a 9- or 12-month tenure.

COOPERATIVE GRADUATE FELLOWSHIPS

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

The number of awards offered under this program in fiscal year 1961 totaled 1,100, distributed among 129 (of the 161) participating institutions.

SUMMER FELLOWSHIPS FOR GRADUATE TEACHING ASSISTANTS

These awards make it possible for graduate teaching assistants in science, mathematics, and engineering to devote full summer periods to their own academic pursuits. In fiscal year 1961, 625 awards were offered.

POSTDOCTORAL FELLOWSHIPS (REGULAR)

During fiscal year 1961 this program continued to enable persons who have recently obtained their doctorates to undertake additional advanced training as investigators in their specialized fields. A total of 235 were offered awards.

This year an allowance to the fellowship institution was introduced. For each postdoctoral fellow with a tenure of 9 or 12 months, the host institution receives \$200, expendable at its discretion, to assist in meeting the costs of providing the fellow with space, supplies, and equipment.

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.

The number of applicants in fiscal year 1961 increased slightly over that of the previous year, and the 91 awards offered represented a new high.

In fiscal year 1961 a renewal policy became effective. It is now specified that any person who has held a Senior Postdoctoral Fellowship for 2 years is ineligible for a period of 5 years to hold another such fellowship.

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 advance training in their own or related fields.

The procedure established in fiscal year 1960 of having separate evaluations for applicants possessing the Ph.D. degree and those not possessing that degree was continued. A total of 215 awards went to non-Ph.D.'s and the balance of 70 to persons holding the Ph.D. degree. In proportion, the distribution of awards approximated the corresponding division of the applicant population.

SUMMER FELLOWSHIPS FOR SECONDARY SCHOOL TEACHERS OF SCIENCE AND MATHEMATICS

In fiscal year 1960 this fellowship program was reoriented to emphasize work by the fellows at a level acceptable by their fellowship institutions toward the traditional advanced degrees in science and mathematics. Additional progress toward accomplishing this objective was made in fiscal year 1961. Awards totaled 324.

EXTRAMURAL FELLOWSHIP PROGRAMS

1. North Atlantic Treaty Organization (NATO) Postdoctoral Fellowships in Science

For the third consecutive year the Foundation administered, in behalf of the Department of State, the program of NATO Postdoctoral Fellowships in Science. These awards enable United States citizens and

nationals to study abroad primarily in the NATO countries. Other NATO member nations select fellows from among their own nationals. Of the 43 awards accepted this year, 10 were for study and research in the life sciences, and 33 in the physical sciences, including 12 in chemistry.

2. Organization for European Economic Cooperation (OEEC) Senior Visiting Fellowships

These fellowships permit institutions in the United States, its Territories and Possessions to nominate senior scientists, mathematicians, and engineers on their staffs to study new techniques and developments at advanced educational and research institutions primarily in the OEEC member countries or in countries cooperating with that organization. The program is intended to strengthen the scientific work of the nominating institutions. Of the 19 awards accepted in fiscal year 1961, 9 were in the life sciences and 10 in the physical sciences, including 5 in engineering.

SPECIAL REPORT ON THE COOPERATIVE GRADUATE FELLOWSHIP PROGRAM

The Foundation, in planning for its fiscal year 1959 fellowship programs, determined that it should substantially increase its graduate-level fellowship support in science, mathematics, and engineering. The possibility of doubling the number of awards in the existing Graduate Fellowship program was considered. An alternative, however, was the introduction of a new program, one which would involve the fellowship institutions more intimately in the evaluation and nomination of applicants and at the same time accomplish a broader distribution of National Science Foundation fellows at the many excellent institutions of higher education in the United States. This alternative was adopted and resulted in establishment of the Cooperative Graduate Fellowship Program, a program which has met with wide approval.

Under this program the Foundation invites the participation of all United States institutions of higher education that confer the doctoral degree in at least one of the fields supported by the Foundation. Emphasis is placed upon cooperation with participating institutions in identifying and supporting graduate students of high ability. Applicants apply through the participating institution which they expect to attend as fellows. They are screened and evaluated initially by the faculty of that institution solely on the basis of their ability. Each institution is authorized to recommend a specified number of awards, this number being determined by a formula which takes into account the institution's

recent productivity in awarding advanced degrees in science, mathematics, and engineering. All applications are forwarded to the Foundation for final evaluation; the institutions are subsequently notified of those persons selected for awards by the Foundation. Funds are provided to the schools to cover stipends for fellows and a standardized \$1,800 cost-of-education allowance for each fellow, in lieu of tuition and fees.

Since the inauguration of the Cooperative Graduate Fellowship Program the Foundation's position has been that the ability levels to be supported, insofar as human judgments permit, will be comparable to those supported in the Graduate Fellowship Program. In the fall of 1960 a statistical comparison was made of Cooperative Graduate Fellowship applicants and awardees with their counterparts in the Graduate Fellowship program for fiscal year 1960 which produced some very interesting and significant data. The study revealed that, although the *applicants'* mean scores on various objective criteria were remarkably similar for the two programs, Graduate Fellowship *awardees* had consistently higher mean scores than Cooperative Graduate Fellowship winners. Without question, the Cooperative Graduate Fellowship awardees were individuals of high ability, but a comparison with the Graduate Fellowship awardees, by level of study, indicated statistically significant differences. Partial explanations of these differences lie in the greater variability in the ability levels of the Graduate Fellowship applicants and in the lower percentage of applicants offered awards in that competition. Consequently, prior to the fiscal year 1961 evaluation of Cooperative Graduate Fellowship applicants by the central panels, the NSF re-emphasized its position concerning the maintenance of comparable standards for its two predoctoral-level programs. It is hoped that the resulting evaluations have achieved, more closely than previously, the Foundation's objective of comparable ability levels between corresponding quality groups of the two programs.

The steps which the Foundation will undertake toward encouraging more high-ability individuals to apply for Cooperative Graduate Fellowships in fiscal year 1962 are: (a) the number of fellowship recommendations assigned to each participating institution will be increased—even institutions with low doctoral and master's degrees production records will be permitted to recommend 20 individuals applying through their schools, and (b) in a series of regional conferences scheduled for the fall of 1961, the Fellowships Section's professional staff plans to review this program with coordinating officials from all participating institutions and to explore ways in which the quality of applicants may be im-

proved. Funds available for predoctoral-level fellowships, will be apportioned between the two programs in such a manner that individuals of comparable ability will be supported in each program.

Institute Programs

The primary objective of the Foundation's institute programs is to improve the effectiveness of the teaching of science, mathematics, and engineering in the Nation's schools by increasing the subject-matter competence of teachers through training in specially designed group programs. These programs are not only aimed at helping teachers obtain information concerning new developments in their fields—increasingly difficult because of the rapid growth in scientific knowledge—but are also aimed at those teachers who have had inadequate basic training. Institutes provide supplemental training for high school, college, and elementary school personnel, as well as for faculty of technical institutes.

There are three major types of institutes, each especially designed to conform to the time patterns available to teachers for work and study: (1) Summer Institutes, which provide 4 to 12 weeks of full-time study during the summer period when schools usually are not in session; (2) Academic Year Institutes, which provide full-time study during the regular school session for a relatively small number of teachers who take a leave of absence for 1 year; (3) In-Service Institutes, which provide part-time study opportunities for teachers holding full-time positions in the schools.

The basic time-patterns are repeated from year to year, but there is continual experimentation with the subject-matter training offered in individual institutes. Conferences of shorter duration are also used for special purposes.

Since teachers have somewhat different objectives—and usually quite different backgrounds—from those of professional students in scientific fields, institutes are commonly based upon specially planned classes and group activities. A secondary objective of the program is, therefore, to encourage colleges and universities to establish courses or curricula that more effectively meet the subject-matter needs of teachers in areas of science, mathematics, and engineering. These are usually subject matter courses with emphasis on fundamental principles and recent scientific advances.

Experience gained over the years since the beginning of the institute programs has shown that many institute programs could be materially improved and financial savings achieved if plans could be made for

more than one session at a time. This practice would permit more realistic planning for a reasonable staff workload and more efficient use of institutional facilities. In addition, a study of the academic background of applicants indicates that more recent programs have been changing toward the acceptance of less well-prepared teachers to participate in institutes. It has been found, for example, that a significantly larger percentage of the 1960 applicants than of the 1957 applicants had no bachelor's degree. Thus, for many teachers a longer period of training is now needed than earlier experience suggested.

A significant development in the evolution of the Foundation's institute program is the pilot step toward providing multiterm support—that is, continuing support from year to year—for some institutes, a procedure highly favored by the colleges and universities. On this basis, the Foundation will now accept proposals for programs planned for 2 or 3 years, as well as a single year; the multiterm type may consist of a series of summer or in-service programs or some combination of both.

Since this program's inception in 1953 the Foundation has made grants for the support of 2,436 institutes, which have provided over 116,000 opportunities for study in science, mathematics, and engineering. Funds obligated in fiscal year 1961 provided support for 771 institutes, an increase of 122 over the number supported in fiscal year 1960. Of this number, 56 percent were held during the summer; 38 percent were for part-time study during the school year; and 6 percent were for full-time study during the regular school year. These institutes made provision for some 34,985 opportunities for study.

SUMMER INSTITUTES

Summer Institutes for High School and College Teachers

The Summer Institute program continues to be of great interest to both the colleges and teacher participants. Of a total of approximately 706 proposals received in this program, available funds permitted the awarding of grants for 396 institutes in 1961, the result being that many worthy proposals had to be denied. The number of high school and college teachers who apply to these institutes continues to increase and it is estimated that more than 60,000 individual teachers filed applications for the institutes conducted in the summer of 1961.

Of the 396 institutes, 333 were for high school teachers, 42 for college teachers, and 21 for both high school and college teachers. The distribution by fields of study was as follows:

Fields	High school teachers	College teachers	High school and college teachers
Anthropology.....	1	1	.....
Biology.....	28	5	2
Radiation biology.....	13	6	2
Chemistry.....	23	3	4
Earth sciences.....	16	2	.....
General science.....	16	.....	.....
Mathematics.....	90	4	7
Physics.....	16	2	1
Engineering.....	.....	11	.....
Isotope technology.....	.....	5	.....
Psychology.....	1	.....	.....
History and philosophy of science.....	.....	2	.....
Multiple fields.....	129	1	5
Totals.....	333	42	21

About 21,000 high school and college teachers received stipend support in the summer institutes conducted during 1961.

The geographical distribution of the institutes covers all 50 States, the District of Columbia, and Puerto Rico. As in the past, a wide variety of types of institutions are represented among host colleges and universities.

Summer Institutes for Elementary School Supervisors and Teachers

The pilot-study program of institutes for elementary school supervisors and teachers continued with a very small but gradually increasing number of institutes. Proposals received totaled 121, but available funds permitted only 19 grants to be made, providing stipends for 644 teachers. The number of applicants for this type of institute is enormous. Individual institutes received as many as 1,400 applications.

Summer Institutes for Technical Institute Personnel

Two institutes for teachers who are on technical institute faculties were supported in fiscal year 1961. One of these was conducted at the University of Illinois and the other at the University of Houston. Approximately 80 teachers participated.

Summer Conferences for College Teachers

There were 23 short conferences for college teachers supported in the summer of 1961 with places for 687 participants. These confer-

ences included 4 in biological sciences, 10 in physical sciences and engineering, 6 in mathematics, and 3 in computer science. Of the programs in mathematics, 4 were specifically designed for college teachers involved in training secondary school mathematics teachers. Essentially like summer institutes but of shorter duration, conferences are designed to offer science instruction to college faculty members whose duties in the summer permit them to undertake such training for only 1 to 4 weeks.

ACADEMIC YEAR INSTITUTES

The Academic Year Institute program provides opportunities for full-time study for the academic year to a relatively small number of experienced teachers of science and mathematics who can take a year's leave from their regular duties.

Thirty-three institutes were supported during the 1960-61 academic year, providing training opportunities for 1,534 participants. During 1961-62, about 1,570 teachers will participate in 43 NSF-supported institutes. The increased number of institutes in 1961-62 was principally the result of a decrease in the number of participants per program (47 to 37, on the average) in order to get such programs underway in more institutions.

A recent innovation in institute programs, conducted at one institution on an experimental basis, included the training of 12 pre-service certificated secondary school teachers along with 24 experienced in-service secondary school teachers.

At another institution a small number of participants were offered an advanced program—beyond the master's level—designed to prepare experienced teachers as secondary school supervising teachers. The number of science and mathematics supervising teachers is increasing sharply as a result of the National Defense Education Act, and it is essential that such persons be competent in their subjects.

The Foundation made 9 grants in 1961-62 to support institutes for 75 college teachers, as compared with 5 grants made in 1960-61 which provided training for 43 college teachers. In eight of these institutes the emphasis was on upgrading "teachers of teachers," whereas the last of this group offered training at the master's level in chemistry for teachers in junior colleges. Three institutes planned exclusively for college teachers represented an additional innovation in the 1961-62 program. Among these three, one is an institute in radiation biology for college teachers conducted as a cooperative project of the National Science Foundation and the Atomic Energy Commission.

IN-SERVICE INSTITUTES

In-Service Institutes for Secondary School Teachers

In-Service Institutes offer instruction for teachers of science and mathematics during the academic year at times so chosen that the participants may attend while still teaching full time—e.g., late afternoons, evenings, or Saturdays. These institutes provide an excellent opportunity for the sponsoring colleges and universities to help secondary school teachers who live within commuting distance.

During academic year 1960–61 a total of 191 In-Service Institutes for Secondary School Teachers, offering instruction for approximately 8,900 participants, received support from the Foundation. In the 1961–62 school year, approximately 11,500 secondary school teachers will participate in 253 In-Service Institutes. This expanded program provides support for promising new projects as well as substantial support for the continuation of institutes which have already established working relationships with the teachers and schools in their areas. The program reaches many teachers who are not able, for various reasons, to attend summer or academic year institutes.

Approximately half of the course work offered in these institutes during the past year was in the field of mathematics, while the remainder covered the range of the biological, physical, and earth sciences.

In the 1961–62 In-Service Institutes program, about one-fourth of the grants are for sequential-type programs. Noteworthy among these sequential institutes are four located in large metropolitan areas which offer teachers the opportunity to complete, on a part-time basis, master's degree programs essentially equivalent to those developed in academic year and summer institutes.

About two-fifths of the institutes are directed toward subject matter which closely relates to new course content developments in the fields of mathematics, biology, chemistry, and physics. Three institutes in radiation biology will receive joint support from the Atomic Energy Commission and the National Science Foundation.

In-Service Institutes for Elementary School Personnel

In-Service Institutes for Elementary School Supervisors and Teachers provide part-time study in the sciences and mathematics during the academic year. Courses offered have been especially designed by colleges and universities to meet the need for informed instruction and supervision in the sciences and mathematics at the elementary school level.

In academic year 1960–61 the Foundation supported 13 institutes of this type, with approximately 400 teachers, supervisors, and principals

participating. The 1961-62 program has been increased to 35 institutes, with training opportunities for approximately 1,030 elementary school personnel. Need for expanding this program was more than adequately demonstrated by the many local studies cited in the proposals received and by the lack of formal science instruction in the training of the majority of elementary school teachers.

Because of the very small number of participants who receive training as compared with the number of elementary teachers who need it, the institutes usually emphasize work with "key" teachers, specialists, or supervisors who may in turn help other teachers. Many institutes also serve as active centers for developing new materials and lesson plans for elementary schools. Several institute programs correlate their instruction with newly developed curriculum materials in mathematics.

Special Projects in Science Education

Special Projects in Science Education activities are concerned principally with experimental testing and development of promising new ideas for improving science instruction, and with new and more effective methods of increasing the understanding of science on the part of our young people. In a sense, many of these activities are research studies designed to answer the question, "How can we improve science education?" and are therefore somewhat analogous to the Foundation's activities in support of basic research. To meet these objectives, programs have been developed for secondary school students, college undergraduates, high school and college teachers, as well as for the public to increase its understanding of science.

PROGRAMS FOR SECONDARY SCHOOL STUDENTS

Programs directed toward the secondary school level are planned by universities, colleges, scientific societies, research organizations, and other groups. Some attempt to interest secondary school students broadly in science; others, to provide additional educational opportunities to students who show special talent for science.

Visiting Scientists (Secondary Schools)

Outstanding scientists and engineers are enabled to visit secondary schools to make personal contacts with students and teachers, to acquaint them with the sciences as vital activities, and to offer such counsel concerning careers and educational matters as may be appropriate. These visits stimulate an interest in science on the part of students and, at the same time, offer professional assistance to the secondary school teacher.

Scientific societies in various disciplines plan, establish, and administer the associated projects.

In fiscal year 1961, two grants were made. These grants, along with one grant made in 1960 and continuing in 1961, will provide for 1,060 days of visits.

Traveling Science Libraries

The Traveling Science Library has been organized and circulated by the American Association for the Advancement of Science (AAAS) for the primary purpose of making available to secondary and elementary school students, on a loan basis, carefully selected books on science and mathematics.

In conjunction with the operation of the libraries, the AAAS has prepared and annually revised various lists of books on science, mathematics, and engineering suitable for elementary school and high school students. For a number of States, these lists currently influence the standards and serve as official guides for the purchase of science books.

In fiscal year 1961, a grant was made to the American Association for the Advancement of Science to provide for the following activities:

1. The Traveling Science High School Library to serve a maximum of 1,600 secondary schools with a total of 480,000 students.
2. The Traveling Science Elementary School Library to serve 800 schools with a total of 240,000 students.
3. The preparation and distribution of various booklets to be of assistance to students, teachers, and librarians.

AAAS Science Book List for High School Students—60,000

Inexpensive Science Library—50,000

Elementary School Book List—65,000

Annotated Catalogs of the two Traveling Science Libraries—
30,000

Career Guidance Publication—10,000

Summer Science Training for Secondary School Students

The Summer Science Training Program for High-Ability Secondary School Students is designed to provide academically talented secondary school students with educational experiences in science and mathematics beyond those normally available in high school courses. The objectives are to help:

- a. Identify high-ability secondary school students who have excellent potential for becoming creative scientists—and to help these students identify their own interests, abilities, and limitations.

- b. Accelerate their scholarly development by providing opportunity for instruction in scientific content and methods by scientists of recognized stature.
- c. Develop cooperation between colleges and high schools in increasing the quality of education in the sciences.

Programs offered are of two main types. The type most frequently encountered stresses lectures, quizzes, supervised study periods, laboratory work, and field trips centered around one or more areas of science, though there is some variation with the discipline being studied. The other program type gives the student real research experience by enabling him to work on a project of appropriate scope under the guidance of experienced scientists. Some programs combine elements of both types.

The 168 grants made in fiscal year 1961 to colleges, universities, and nonprofit research organizations provided summer science training experience for about 6,400 high-ability secondary school students in various disciplines in the mathematical, biological, physical, and engineering sciences.

Cooperative College-School Science Program

The Cooperative College-School program is designed to help develop cooperation between colleges and secondary schools in increasing the quality of education in the sciences; to provide scientifically talented secondary school students with experiences in advanced course work or research participation; and to include selected high school teachers of a high degree of competence in programs specifically planned and coordinated for dual participation of student and teacher. Formal cooperation of the public school system in the development and support of the programs is encouraged.

The 23 grants made in fiscal year 1961 will involve approximately 3,000 participants.

This new summer science training program differs from previous programs for secondary school students in that it involves both teachers and high-ability students and thus is designed to have greater effect upon participating schools than is possible when only an occasional student participates on an unplanned basis.

State Academies of Science

State Academies of Science have diversified organizational structures and resources, and present a wide variety of programs for support, depending upon the scientific requirements of the various States and the facilities of the Academies. Three major areas are currently supported: (1) Visiting Scientists program—similar to that sponsored by the

national scientific societies but more local in scope. It operates primarily at the State level through the professional scientific body of the State; (2) Junior Academies of Science—these operate in close liaison with senior scientists of the State in executing science projects and research with an opportunity to meet annually with the senior Academy to present the results of their research studies and to hear the presentation of scientific papers of the Senior Academy; (3) Collegiate Sections of the Academy—these afford undergraduate college students opportunities to execute research studies and present their results at State Academy meetings, and in some cases, publish findings in the Proceedings of the Academy.

Short-term conferences for college undergraduates, seminars and workshops for teachers, and science curriculum studies are among other activities conducted by the various State Academies of Science with National Science Foundation support.

The 52 grants made in fiscal year 1961 to 30 State Academies of Science, 1 large museum with strong scientific and science education staffs, 2 municipal Academies of Science, and 3 other organizations provides support for 23 Visiting Scientists programs, 10 Junior Academies, and 18 miscellaneous, one-of-a-kind projects.

Supplementary Science Projects for Students

This program complements and supplements the regular summer science program for secondary school students. It provides, primarily through grants to colleges and universities, for special extracurricular science activities. Some are for science programs conducted during evenings or weekends, or for unique experimental projects which do not fit clearly into the defined programs. Support is provided for the preparation and publication of career guidance booklets, national science journals to permit the publication of research papers by college undergraduates and high school students, the educational science activities of museums and planetaria, a program in basic science orientation and research by the 4-H Foundation, and for conferences where selected high school teachers and students sponsored by appropriate scientific agencies can present current research results and training opportunities.

Under this program a wide variety of diverse and highly individual projects were considered. Only those of unusual merit, eight in number, amounting to about 20 percent of the total number requested, were supported in 1961.

UNDERGRADUATE SCIENCE EDUCATION PROGRAMS

Undergraduate Science Education programs make possible, at colleges, universities, and nonprofit research institutions, a number of

activities designed to provide special opportunities for the scholarly development of outstanding undergraduates. The programs are aimed at developing new and broader means for able undergraduates to advance, through research participation or independent study, in their understanding of science and in their ability to employ effective investigative procedures.

The wholehearted acceptance of these programs by the academic community is evidenced by the continual increase in the number of proposals received each year, of grants awarded, and of participants supported. One indication of the success of the programs is the growing list of scientific publications with one or more undergraduate "alumni" as principal author(s).

During 1961 grants were made under two separate programs, Undergraduate Research Participation and Undergraduate Independent Study, each designed to meet particular needs of outstanding undergraduates.

Undergraduate Research Participation

The Undergraduate Research Participation program recognizes the value of bringing able undergraduates into direct contact with research and research scientists. It makes it possible for educational institutions to provide research training to high-ability undergraduates who have potential for scientific research and college teaching. This research experience is also intended to encourage the participant to pursue graduate work in science.

The 364 grants made in the Undergraduate Research Participation program in fiscal year 1961, together with the 173 extensions of grants made in fiscal year 1960, provide approximately 4,500 undergraduates with a research experience in a variety of scientific disciplines, including certain of the social sciences and experimental psychology.

Undergraduate Independent Study

The Foundation established the Undergraduate Independent Study program in 1961 by awarding 11 grants to institutions proposing novel approaches to fostering independent study by individuals or small groups of undergraduates. The grants enable 147 high-ability undergraduates to participate in independent study programs.

This program recognizes that the undergraduate of high ability may, by working independently or with a small group of peers, find his way to fuller accomplishment and understanding than are attained through more formal academic course work. The student may be ready for studies of a level and variety not offered routinely in regular undergraduate courses. He may well learn rapidly with a minimum of

guidance if given time, freedom to explore, and access to reference materials.

ADVANCED SCIENCE EDUCATION PROGRAMS

Programs in this area cover a wide range of activities directed toward the development of projects of special interest to predoctoral and postdoctoral scientists and toward the improvement of the scientific background of science teachers. These goals are accomplished through research experiences, contact with leaders in scientific thought afforded by advanced subject-matter institutes, conferences and campus visits, and through opportunities for study and discussion of problems in science education.

During fiscal year 1961 the Research Participation for Teacher Training program was divided into two programs—Research Participation for College Teachers and Research Participation for High School Teachers—with the result that more appropriate proposals for each group were received.

Research Participation for College Teachers

This program provides opportunities for college teachers (including those of junior college level) to gain research experience during the summer. Teachers with adequate subject-matter knowledge, but limited opportunity for research during the academic year, are afforded the chance to obtain the stimulation and identity with science and the excitement of discovery that only research can provide.

A new feature included in the 1961 program was the opportunity extended to a few teachers to continue their summer research programs into the academic year with some guidance from their research supervisors.

The 54 grants awarded in this program and the 6 extensions into the academic year will help provide 408 college science teachers at both the predoctoral and postdoctoral levels with research experience in many scientific fields.

Research Participation for High School Teachers

This program provides opportunities for high school and junior college teachers of science and mathematics to obtain research experience with outstanding research scientists at colleges, universities, and non-profit research organizations. Teachers participate in research by actually working on an individual basis in the laboratory or in the field. This experience should improve the teacher's understanding of science and of the scientific method and thus contribute to raising the level of his classroom instruction. The closer relationships between colleges and

high schools resulting from this program should lead to better preparation of high school students for college.

In general, a teacher applying for this program is required to have a master's degree in the scientific subject matter, or an academic background including sufficient advanced science courses to qualify him for admission to candidacy for such a degree, although actual candidacy for the degree is not a requirement. "Graduates" of institute programs are a prime target group. As in the college-level program, some participants will continue in the academic year.

The 51 grants made in this program in 1961 provide support for 367 summer participants and 102 academic-year participants in a variety of disciplines in the mathematical, biological, physical, and engineering sciences, and in psychology.

Supplementary Training for Science Teachers

The Supplementary Training for Science Teachers program is aimed at improving the quality of science teaching at all educational levels through a number of individual activities of a nonprogrammatic nature. In fiscal year 1961, 20 grants were made for such unique programs as:

1. A short regional conference on new curriculum developments for high school science teachers in the Midwest.
2. A conference for high school physics teachers on scientific frontiers and their interaction with society.
3. A television course for elementary school teachers.
4. A workshop on advanced course planning for twelfth grade science teachers.
5. A conference on aerospace science for high school physics teachers.
6. A symposium on frontiers in bio-medical engineering for high school science teachers.
7. A summer workshop for science supervisors.

Advanced Subject-Matter Institutes

Advanced Subject-Matter Institutes either focus on fields of science of a highly specialized nature or are based on an advanced treatment of subject matter. They are institutes for specialists and frequently deal with so-called "derived fields," in which the subject matter commonly transcends the limits of the usual academic departmental offerings; for example, programs involving oceanography, space navigation, and materials research.

Such institutes often draw upon the resources of several academic departments, including industrial, governmental and, frequently, foreign

scientists of unique competence. They may convene for periods ranging from one week to an academic year and may be held at field stations, aboard oceanographic research vessels, or even at foreign sites where demonstrations and field studies can be carried out most effectively.

The 28 Advanced Subject-Matter Institutes funded in fiscal year 1961 were devoted to such fields as theoretical astronomy, quantum chemistry, shallow-water oceanography, numerical analysis, kinematics, transport phenomena in chemical engineering, re-entry dynamics, and theoretical physics. Two institutes took American scientists to foreign sites for special study of tropical biology in Costa Rica and classical stratigraphy in the British Isles.

Inter-Institutional Cooperative Associations

The prime objective of the Inter-Institutional Cooperative Associations program is to encourage and aid collegiate institutions to share their strengths in an endeavor to raise the general level of the academic community of science. Though at its inception this program was envisaged as one primarily for fostering relationships between large universities and adjacent small colleges, it has been broadened to include cooperative undertakings between widely separated universities as well as groups of small colleges. Any "association" of collegiate institutions which together present a program that shows promise of increasing the effectiveness of teaching and scholarship in the sciences in their region, may submit a proposal for support. "Association" in this context, however, does not imply the necessity for any corporate or legal entity. Plans to achieve this end may properly include staff visits, conferences, and seminars; exchange of professors and library materials; loans of equipment; and joint use of physical facilities and other related activities.

Four grants were made in fiscal year 1961.

Visiting Scientists Program

The Visiting Scientists program provides a valuable link between graduate schools and research laboratories and the undergraduate institutions and between foreign research centers and our graduate schools. It fosters an exchange of information through the more informal medium permitted by personal contacts, a type of exchange essential to the continued growth and development of advanced science education.

The program consists of groups of projects: (a) the visiting American scientists projects, which provide opportunities for small colleges, junior colleges, and developing universities to obtain the advice and guidance of distinguished scientists in this country in the development of their science programs; and (b) the visiting foreign scientists projects, which

provide opportunities for broadening the perspective of faculties and graduate students in science at our major academic institutions through interchange of scientific knowledge and research concepts with prominent foreign scientists. These objectives are primarily implemented through special lectures, seminars, and conferences with faculty members and students in the fields of their specialties.

In the projects involving American scientists, 15 grants were made to professional societies which will provide for 3,320 days of visits annually. In the foreign scientists group, 6 grants were made to professional societies which will provide for 1,360 days of visits annually.

PUBLIC UNDERSTANDING OF SCIENCE

This experimental program provides support to colleges and universities, professional scientific societies, and other interested groups for selected activities which are designed to increase the quality and quantity of science information that reaches the general public. Experimental projects have been conducted along several approaches, including conferences between scientists and mass-media executives to stimulate interest in science reporting; seminars and workshops to improve the scientific competence of science news writers; support for professional scientific societies in the dissemination of science information to the mass media; preparation of science materials for community discussion groups; adult education in the sciences; development of science exhibits for public exhibition; and support for educational television and radio presentations on science subjects.

A total of 13 grants were made during fiscal year 1961.

Course Content Improvement Program

The long-range objective of the Course Content Improvement program is to help bring about a major modernization of elementary school, high school, and college course-content materials in mathematics, science, and engineering.

Several important generalizations can already be drawn from experience with the program:

First, since education should be a continuum for the learner, balanced and coordinated attention must be given to a sequential science program for all educational levels. Better preparation in elementary schools enable secondary schools to provide a broader and more thorough program. High school improvements make it possible for colleges and universities to devise more stimulating courses taught at a higher level.

Colleges and universities, in turn, can then produce more teachers equipped to do a better job in the schools.

Second, although good teaching is characterized by personal innovation and individual teachers and institutions must bear the ultimate responsibility for deciding what to give students, all teachers at all levels can do a better job if they have first-class model courses and aids to learning and teaching. The better the materials, the more likely will it be that all students receive good educations irrespective of the inevitable variation in knowledge and skill of teachers.

Third, the creation of model courses and materials of high quality demands the best talent the country affords and the collaboration of leading research scholars with outstanding teaching scholars.

Fourth, research and development on school and college instructional programs requires substantial investment; a single cycle of building a better course or series of courses in one discipline for a particular level requires the efforts of several hundred people over 4 or 5 years at a cost of several million dollars. Judged against its potential value for the Nation, however, this investment is small indeed.

Finally, the task is an unending one. Continuing effort is needed to incorporate the fruits of the explosive growth of knowledge into the educational experience of our youth.

COURSE CONTENT IMPROVEMENT STUDIES IN SCIENCE AND ENGINEERING

A review of highlights of projects concerned with science and engineering is followed by a fuller report on mathematics as an example of a profession-wide effort to devise superior, up-to-date instructional materials.

Elementary and Junior High Schools

Under the auspices of the American Association for the Advancement of Science nearly 200 scientists, teachers, and school administrators participated in a feasibility study of science for the kindergarten through ninth grades. The study group concluded that science should be part of the total curriculum in every grade and recommended in strongest terms that a massive effort must be undertaken to develop materials, investigate the psychological bases of learning science, and provide better preparation in science for elementary-school teachers, both prospective and in-service. It is expected that a major program will be initiated in this area during the next year. Highly interesting work is already being done by pilot projects conducted by scientists and teachers at the University of California at Berkeley and the University of Illinois.

Secondary Schools

Large projects concerned with high schools are making important progress. The textbook, laboratory guide and apparatus, teacher's guide, films, monographs and examinations for the physics course prepared by the Physical Science Study Committee became available through commercial distributors in the fall of 1960. Some 50,000 students throughout the country used the materials in 1960-61. Current work includes additional films; supplementary text, experiments, and films for a college version of the course; preparation of longer films designed for use in situations where well-qualified teachers are not available; and continuing collection of feedback to direct future revisions. Overseas, teachers' institutes and studies on the adaptation of this approach to other settings have been carried out in Western Europe, Israel, New Zealand, and South America.

In chemistry, preliminary versions of the high school courses developed by the Chemical Bond Approach Project and the Chemical Education Material Study were tried by several thousand students and work began on substantially revised versions which will receive even more extensive trial during the next year. Definitive editions of texts, laboratory guides, films, and other aids are scheduled for distribution for the 1963-64 school year.

Three different approaches to high school biology, together with the block laboratory projects providing several weeks investigation of a topic in depth, research projects for gifted students, and other materials being developed by the Biological Sciences Curriculum Study were tried by some 13,000 students. This experience enabled the BSCS to prepare substantially improved second versions during the summer of 1961 for experimental use in more than 360 schools the following academic year. This trial will lead to a final revision, and materials will be available to all interested schools by the fall of 1963.

Preparation of a sourcebook on earth sciences for teachers in elementary and secondary schools was completed by the Teaching Resources Development Project of the American Geological Institute. The book will be published early in 1962. Work has gone forward on films and monographs in meteorology sponsored by the American Meteorological Society. Discussions have begun on projects for developing full earth sciences courses and preparing source materials on anthropology.

Colleges and Universities

Support has been granted for a Commission on College Physics to serve as a group to coordinate course content improvement projects,

stimulate additional studies, and help disseminate results. The American Geological Institute has received funds for a comparable group concerned with curricula in the geological sciences. A conference of leaders in engineering held in the summer of 1961 developed a broad program for course improvement and related endeavors in this field. Support has also been awarded for studies of engineering graphics, theoretical and applied mechanics, systems engineering in the electrical engineering curriculum, laboratory programs in mechanical engineering, and technical institute education. Specific course developments in college physics are under way at Washington University and the Massachusetts Institute of Technology, in biology at Harvard, in physiology under the American Physiological Society, and in analytical chemistry at Hollins College and the University of Illinois.

SUPPLEMENTARY TEACHING AIDS

Wide interest has developed in a program for the design and development of prototypes of new science equipment. The 378 proposals submitted in 1961, requesting a total of \$7 million, represented a five-fold increase over the number for the preceding year: 57 grants were awarded for such projects as equipment for measuring the relativistic mass of the electron, for experiments in psychology, for demonstrating kinship relationships, for illustrating aspects of formal, deductive, and symbolic logic, for meteorological experiments, and for studies on automation and process control.

Interest in the production of educational film and television presentations is also burgeoning. Partial support was provided for a course on modern biology to be shown nationally on the Columbia Broadcasting System's College of the Air and on other stations, under sponsorship of the Learning Resources Institute. The University of Wisconsin will prepare a telerecorded course in mathematics for grades 5 and 6, to be used for teacher education, as well as for direct instruction. Films on United States archeological sites will be made by the University of Texas and films on customs, technology, and ceremonies of Amerindians by the University of California. Through the Graduate School of the U.S. Department of Agriculture outstanding biologists produced a series of five lectures on "The Promise of Life Sciences." The American Psychological Society and the National Television and Radio Center will prepare a series of films reporting current research in experimental psychology.

SPECIAL REPORT ON STUDIES IN MATHEMATICS

Every informed person now knows that science is reshaping the world. The explosion in mathematical, scientific, and technological knowledge has brought about an educational dilemma, for science has far outstripped the slow pace of change in school programs. By the end of World War II mathematicians realized that the times urgently demanded new approaches. Mathematics in elementary and secondary schools had not changed, except in details of pedagogy, since 1900; indeed the mathematics itself was virtually all known by 1700. Similarly, most undergraduate programs revealed little of the dramatic mathematical discoveries of the past hundred years. Two things had to be done: to help teachers at all levels attain much greater knowledge of basic mathematics, and to develop model new courses and instructional materials to aid and guide teachers.

Mathematicians then began studies of the problem and a variety of experiments in designing courses, with support from private foundations, universities, professional societies, and other sources. Particularly influential were the University of Illinois Committee on School Mathematics project to invent fundamentally new high school courses, the Committee on the Undergraduate Program of the Mathematical Association of America (MAA) which suggested more modern courses for colleges and prepared sourcebooks on content, and a careful study of content for grades 9–12 carried out by the Commission on Mathematics of the College Entrance Examination Board.

In 1954–58 the National Science Foundation began to support exploratory projects in course content improvement, including, in mathematics, a committee study of educational implications of manpower requirements in mathematics, summer writing projects to prepare source materials for courses for teachers, and production of different kinds of filmed presentations. These exemplify one aspect of the Foundation's program—readiness to consider many kinds of promising ideas offered by competent scientists for upgrading education in the sciences.

By 1958 the imperative need for, and the feasibility of, a major effort to devise modernized courses were clear. Also by this time, in response to a parallel need in high school physics, the Physical Science Study Committee had shown the importance of a "critical mass" of talent, personnel, and financial resources in carrying out such a task. Leading mathematicians meeting in NSF-supported conferences urged, in the strongest terms, a large-scale effort. The result was the organization of the School Mathematics Study Group (SMSG). Dr. E. G. Begle became director of SMSG, with headquarters at Yale University (since

moved to Stanford), and some 25 college and university mathematicians, high school teachers, experts in education, and representatives of science and technology were appointed to an advisory committee. The National Science Foundation awarded its initial grant to SMSG, and a 4-week writing and planning session was held in the summer of 1958.

During the following 3 years, aided by NSF grants totaling \$4 million, the SMSG has undertaken a series of integrated projects to improve course content in elementary and secondary schools, encourage students to study mathematics, and help teachers prepare to give the new courses. Projects are supervised by panels which operate under basic policy set by the advisory committee. This work has involved hundreds of research mathematicians, university and college mathematicians, elementary and secondary school teachers, experts in testing, psychologists, and other specialists. In developing courses the typical procedure is to prepare experimental versions of sample textbooks and associated commentaries for teachers, try them in schools, revise them in light of experience and further reflection on content, conduct additional trials as needed, and, finally, publish definitive editions for use by all interested schools, teacher education programs, and authors of textbooks. In the fall of 1961 definitive editions of textbooks and commentaries for grades 7-12 were published by the Yale University Press. Experimentation is going forward on materials for grades 1-6 and modification of basic courses for less able students.

Another project will produce short expository monographs published as paperbacks which will bring good supplementary mathematics to secondary schools and to the general public. Study guides and special books have been written for teachers. Added to this are materials for talented students, trial of correspondence courses for gifted students, inquiry into effects of the sample textbooks on attitudes toward mathematics, a long-range study of the performance of students using SMSG materials, and investigation of the potentialities of programmed learning.

While mathematicians agree on the broad direction for improving school mathematics, there is ample room for healthy divergence of views on specific content, sequence, and approach. A number of smaller study groups, with support from several agencies, are exploring these. For elementary school mathematics, much experimentation is particularly needed to find out how children learn mathematical concepts and skills, define desirable content, and develop instructional aids for pupils and teachers. Such NSF-supported studies are going on at Stanford University, the University of California, the University of Minnesota, and the University of Illinois.

Mathematics projects illustrate the ground rules for NSF support in course content improvement. For elementary and secondary schools three main types of projects are considered: (1) committee and conference explorations of problems; (2) small-scale, experimental content-development efforts; and (3) projects involving large teams in the design of new courses and materials. In all cases the initiative lies with responsible mathematicians, and the work is led by outstanding mathematicians, who collaborate with teachers and such other specialists as may be required. Support is provided only for research and development; the final products must make their way on their merits.

Progress in school mathematics provides rich opportunities to change college programs, both to build upon school developments and to effect reforms long overdue. Four categories of projects are involved: (1) national committees and conferences which define problems and provide guidelines for course content improvement; (2) planning and coordinating bodies consisting of top-flight scientists drawn from the Nation as a whole, organized to plan course improvement efforts, encourage specific groups to undertake special projects, provide liaison, and aid in disseminating results; (3) projects for preparing actual courses and materials by groups drawn from several institutions, and (4) intra-institutional course development.

In mathematics the first type of project is represented by such groups as the MAA Committee on the Undergraduate program. Late in 1958 this Committee asked some 60 outstanding mathematicians to review the college problem and recommend future activities. As a result, a reconstituted Committee on the Undergraduate Program in Mathematics (CUPM) was established in 1959 and awarded a Foundation grant of \$350,000 in 1960. CUPM exemplifies the second type of project. Its aim is a professionwide effort to improve undergraduate mathematics. Under the chairmanship of R. Creighton Buck (University of Wisconsin), with Robert J. Wisner (Michigan State University Oakland) as executive director, the 12-member committee has established panels—each including committee members, other mathematicians, and leaders in other disciplines—to make studies and recommend mathematics programs in four areas: (1) for students planning to teach mathematics in elementary and secondary schools, junior colleges, and colleges and universities; (2) for students in physical sciences and engineering; (3) for students in the biological and social sciences; and (4) for students planning graduate study in mathematics. Committee recommendations will be distributed to all interested persons and institutions; CUPM also hopes to stimulate qualified groups to develop courses which take account

of its findings and suggestions. The Foundation expects to support several such projects which represent the third and fourth types of college study.

Support is also granted for the development of learning and teaching aids; examples are the MAA films mentioned previously, film courses for in-service preparation of teachers produced by the Minnesota National Laboratory in cooperation with the Minnesota Academy of Science and the University of Minnesota, and equipment being developed at the University of Michigan for teaching mathematics in elementary schools.

As the organization of CUPM shows, mathematics course improvement cannot be divorced from needs and developments in other disciplines. Liaison and cooperation among study groups in different fields are encouraged; thus, SMSG has asked groups in biology, chemistry, and physics to supply problems and examples illustrating applications of mathematics.

Nor is the United States alone in the need for better instruction in mathematics. We can learn from other countries and they from us. Expert expositions by Polish and Russian mathematicians are being translated by a University of Chicago project, the Survey of East European Mathematics. U.S. mathematicians have participated in several conferences arranged by the Organization for Economic Cooperation and Development to consider such problems as secondary school mathematics, design of new syllabi, and mathematics for engineering and technology. Materials produced by such teams as SMSG have elicited lively interests in all parts of the Free World. A recent conference in England strongly recommended that a similar project be launched in the United Kingdom, and in 1961 some 200 Latin American teachers of mathematics in secondary schools attended an institute in Peru to learn about new developments in mathematics itself and efforts to utilize these developments in improving school programs.

Scientific Personnel and Education Studies

The general objectives of the Scientific Personnel and Education Studies programs are to meet the needs of the Foundation, other Government agencies, and the public generally for information on scientific and technical personnel as required for the management, operation, and evaluation of substantive programs in this area. These objectives are described in the National Science Foundation Act of 1950 as the maintenance of "a register of scientific and technical personnel and in other ways provide a central clearinghouse for information covering all scientific and technical personnel . . ."

THE NATIONAL REGISTER OF SCIENTIFIC AND TECHNICAL PERSONNEL

The National Register, operated by the Foundation since 1953, is a comprehensive program designed to provide detailed information about the characteristics of the Nation's scientists and to insure the prompt location of science-trained persons on whom the Government might call in time of national emergency. Scientists are currently circularized at 2-year intervals by cooperating national professional societies, and registration records are centrally maintained at the National Register Records Center at Raleigh, N.C.

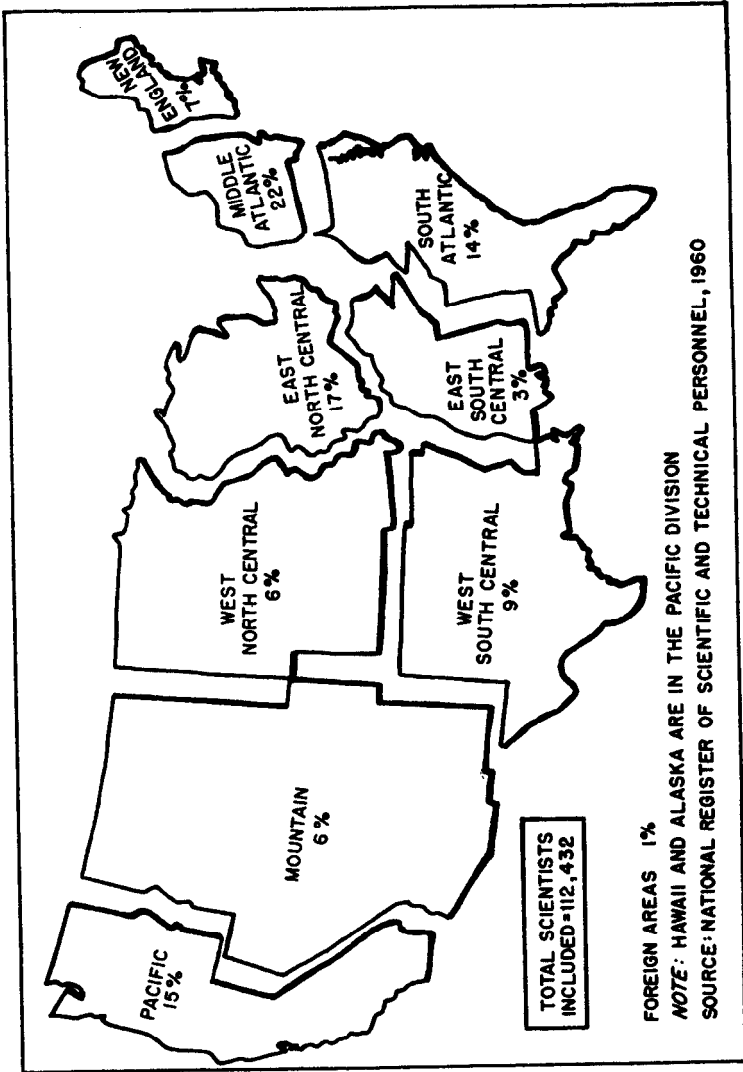
Fiscal year 1961 was principally a period of recircularization in order to establish registration data on a current basis and to increase coverage ratios. The cooperating scientific societies¹ mailed out over 350,000 questionnaires shortly before the beginning of the fiscal year and by the end of June 1960 about 120,000 returns had been processed at the Records Center. These returns served as the basis of a preliminary analysis of the characteristics of scientific manpower. This analysis, published as *Scientific Manpower Bulletin No. 12*, was first released at the American Association for the Advancement of Science annual meeting in December 1960. For the first time in the Register's history, data on the income and professional characteristics of scientists were released during the same year in which they were collected. (See table 3 and figure 2.) Other analyses from these preliminary returns, including geographic distribution and foreign language proficiency of registrants, are being prepared for publication.

The recircularization continued throughout the year with the societies conducting follow-up mailings to nonrespondents. As the fiscal year drew to a close, 237,000 returns had been received by the societies, with an anticipation that more than 200,000 individual registrants would be included eventually in the 1960-61 National Register.

The volume of requests for information from the National Register continued to increase throughout the fiscal year. These requests may be categorized in the following areas:

1. Statistical information related to salaries, educational level, work activities, age distribution, employers of scientific and technical personnel, etc.

¹ Cooperating societies include the: American Chemical Society, American Geological Institute, American Institute of Biological Sciences, American Institute of Physics, American Mathematical Society, American Meteorological Society, American Psychological Association, and Federation of American Societies for Experimental Biology, and through these organizations about 200 specialized societies. The U.S. Public Health Service cooperates in the registration of sanitary engineers.



Note: Hawaii and Alaska are in the Pacific division.
 Source: National Register of Scientific and Technical Personnel, 1960.

Figure 2. Distribution of Scientists in the National Register, by U.S. Geographic Division, 1960

2. Numbers of registrants located in specific geographical areas, i.e., State, county, or metropolitan area.
3. Information on the techniques of establishing rosters for use by industrial establishments, educational institutions, and foreign countries.
4. Identification of individual scientists for foreign translation activities, international teaching assignments, and special studies to be conducted by scientific societies and others.

Table 3.—Median 1960 Salary Rates and Median 1959 Gross Professional Income Reported by Scientists

	1959 median gross income	1960 median salary
Total, all scientists	\$10, 000	\$9, 000
Men	10, 000	9, 000
Women	7, 000	7, 000
Highest Degree		
No degree	9, 000	8, 000
Bachelor's	9, 000	9, 000
Master's	9, 000	8, 000
Medical degree	14, 000	12, 000
Ph. D. or equivalent	10, 000	10, 000
Age Groups		
20-29	6, 000	7, 000
30-39	9, 000	9, 000
40-49	11, 000	10, 000
50-59	12, 000	11, 000
60 and over	12, 000	11, 000
Professional Experience		
1 year or less	5, 000	6, 000
2-4 years	7, 000	7, 000
5-9 years	8, 000	8, 000
10-14 years	10, 000	10, 000
15-19 years	11, 000	10, 000
20 or more years	12, 000	12, 000
Type of Employer		
Educational institutions	9, 000	8, 000
Federal Government	9, 000	9, 000
State and local government	8, 000	8, 000
Nonprofit organizations	10, 000	10, 000
Business, industry, and self-employed	10, 000	10, 000
Commissioned Corps, PHS	10, 000	9, 000
Military service	8, 000	7, 000
Other employers	10, 000	9, 000

Table 3.—Median 1960 Salary Rates and Median 1959 Gross Professional Income Reported by Scientists—Continued

Work Activity	1959 median gross income	1960 median salary
Management or administration	\$12, 000	\$12, 000
Research, development or design	9, 000	9, 000
Teaching	9, 000	8, 000
Production and inspection	8, 000	8, 000
Other activities	9, 000	8, 000

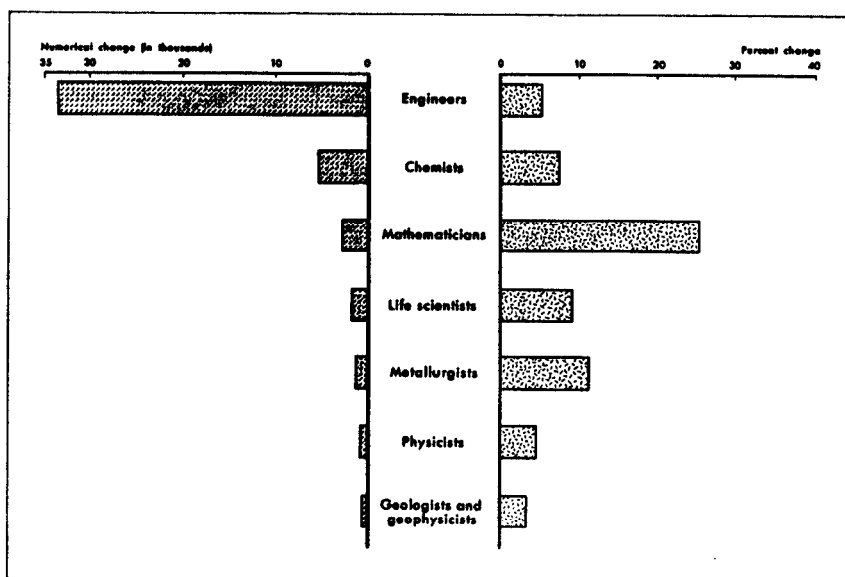
Source: National Register of Scientific and Technical Personnel, 1960.

Discussions with other Government agencies concerned with the recruitment and utilization of manpower under emergency conditions have led to a better understanding of National Register functions under such conditions. In view of the manpower mobilization functions assigned to the National Science Foundation, the National Register can be expected to assume an increasing importance as serious manpower shortages develop in scientific and technical occupations.

SCIENTIFIC MANPOWER STUDIES

The Scientific Manpower Studies program relates to the Foundation's function of providing ". . . a clearinghouse of information covering all scientific and technical personnel . . ." This program is directed toward meeting the scientific manpower information needs of the Foundation, other Government agencies, private organizations, and the public in general. Information on the supply, demand, utilization, education, and other characteristics of the Nation's scientific and technical personnel resources are provided through published materials and through special studies, memoranda, etc.

The Scientific Manpower Studies activity during fiscal year 1961 encompassed a wide range of studies: some initiated this year; others continued as a part of an annual series, and still others underway from previous years. Among the more important studies in progress were: studies of scientific, engineering, and technician employment in private industry (see accompanying table for some of the results of the 1960 survey), colleges and universities, and the Federal Government; studies of students enrolled for advanced degrees; the registry of high school teachers of science and mathematics; a study of career plans of college seniors (in cooperation with the National Institutes of Health and the U.S. Office of Education); research studies of high-ability youth; studies



Source: National Science Foundation.

Figure 3. Growth in Scientific and Engineering Employment in Industry, for Selected Occupational Groups, January 1959 to January 1960

of equipment requirements to improve undergraduate science instruction in selected fields; analysis of information on high school backgrounds of science doctorates; a study of Federal funds for science education; studies on the identification of creative scientific talent; the development of a plan for a series of studies of professional personnel and college graduates based on the 1960 Census of Population; and a study of needs for, and supply of, science manpower for high energy physics programs.

These projects conform to the general series of studies recommended in "A Study of Scientific and Technical Manpower" (a report on the collection, tabulation, and analysis of scientific manpower data submitted by the Foundation to the House Committee on Science and Astronautics) and in the Foundation's report, "A Program for National Information on Scientific and Technical Personnel." One of the recommendations of the latter report resulted in the designation of the Foundation to act as a "focal agency" for the coordination of studies of scientific manpower within the Federal Government. The Foundation has been fulfilling this responsibility in connection with studies of several Federal agencies.

In November 1960 the Foundation convened a conference of university, industry, and Government representatives to consider alternative

methods of measuring demand for scientific and technical personnel. A Foundation-supported study carried out by the Bureau of Labor Statistics provided a basis of discussion for the conference, which was composed of a panel of experts in science and economics. The Bureau of Labor Statistics report, "A Long Range Study of Demand for Scientific and Technical Personnel," will be published in the near future. On the basis of recommendations by conferees and consultations with other personnel knowledgeable in the field, the Foundation will undertake further studies of the demand for scientific and technical personnel.

The Foundation was responsible for coordinating and preparing the U.S. Government's response to two surveys of the Organization for European Economic Cooperation (OEEC): "The Supply, Recruitment, and Training of Science Teachers" and "The Third International Survey of Demand for, and Supply of, Scientific and Technical Personnel." Both assignments required the cooperation of several other Government agencies.

During fiscal year 1961 the manpower studies publications issued by the Foundation included:

Scientific and Technical Personnel in American Industry, Report on a 1959 Survey, NSF 60-62—First in a series on the employment of scientific and technical personnel in industry. It presents information on the number of industrial concerns employing such personnel; the number of engineers and scientists (by major field of science) and technicians employed by industry; and the number of such persons engaged in research and development and other functions.

The Science Doctorates of 1958 and 1959—Presents information on the employment plans and characteristics of persons who earned doctorates in science and engineering fields in 1958 and 1959. It is based on data obtained from these doctorate holders through the Doctorate Records Study of the National Academy of Sciences—National Research Council, under Foundation support. The report concludes that roughly half of all new doctorates planned to work for colleges and universities, more than one-quarter for industrial concerns, less than one-tenth for Government organizations, and about one-eighth for other employers. The report also includes information on the geographical origins of new doctorate holders, the regional location of the bachelor degree institutions and high schools attended, lapse of time between bachelor's degree and doctorate, and data on personal characteristics such as age, sex, citizenship, and marital status.

Scientific Manpower, 1960—Includes papers presented at the Ninth Conference on Scientific Manpower, held in conjunction with the annual meeting of the American Association for the Advancement of Science in

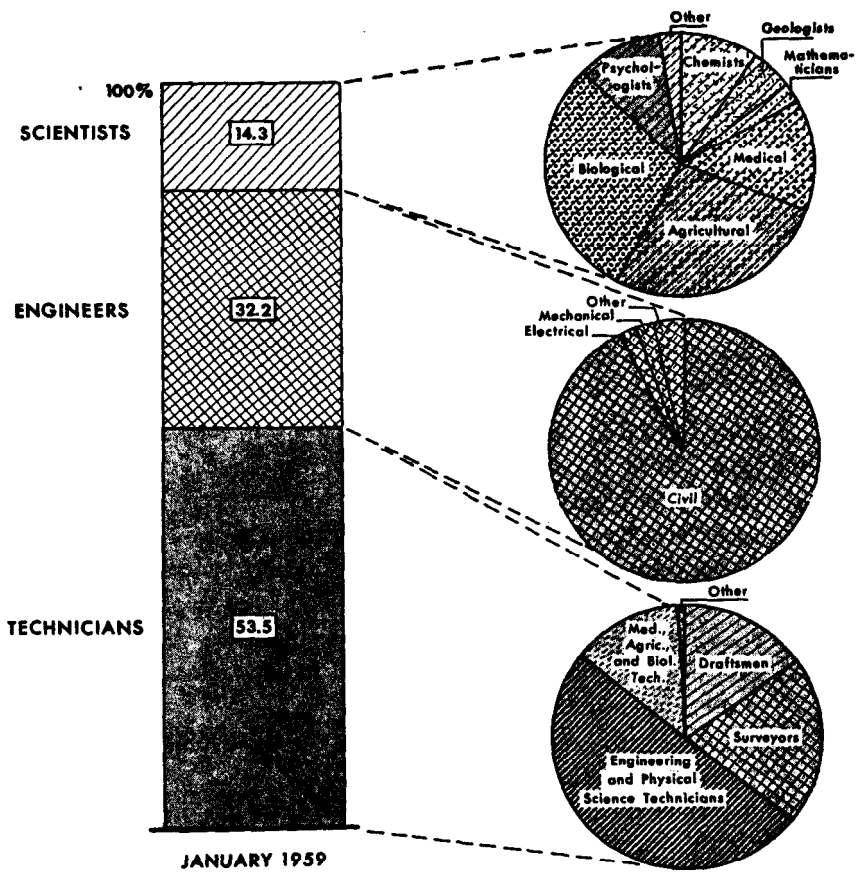
New York, December 1960. The conference theme was "Developing Student Interest in Science and Engineering."

Table 4.—Baccalaureate to Doctorate Time Lapse and Years of Professional Experience, by Fields of Science, 1958 and 1959 Doctorates Combined

Field of doctorate	Mean time lapse in years	Median years of predoctoral professional experience	Time lapse minus years of experience
All sciences.....	8.1	3.2	4.9
Physical sciences.....	7.5	2.7	4.8
Geology.....	8.6	4.0	4.6
Mathematics.....	8.1	3.8	4.3
Physics.....	7.5	2.6	4.9
Chemistry.....	6.5	1.5	5.0
Engineering.....	8.3	4.4	3.9
Behavioral sciences.....	9.4	4.0	5.4
Psychology.....	9.3	4.1	5.2
Anthropology.....	10.7	3.3	7.4
Life sciences.....	8.6	3.6	5.0
Physiology and related.....	8.6	3.4	5.2
Microbiology.....	8.5	3.6	4.9
Genetics.....	8.5	3.2	5.3
Zoology.....	9.0	3.5	5.5
Botany and phytopathology.....	8.2	3.6	4.6
Agriculture and related.....	8.4	4.1	4.3
Biochemistry.....	7.7	2.7	5.0
Medical sciences.....	9.3	5.4	3.9
Miscellaneous life sciences.....	9.0	3.9	5.1

Scientific and Technical Personnel Employed by State Governments, 1959—Reports the first comprehensive survey of employment of scientists, engineers, and technicians by State government agencies. The survey, which covered more than 3,000 separate State agencies, revealed a total of almost 41,000 employed scientists and engineers and 47,000 technicians. Nearly 97 percent of the scientists, engineers, and technicians covered by the survey were employed in three broad agency groupings—public works and highways, health and welfare, and agriculture and conservation. Nearly 70 percent of the scientists and engineers were in engineering specialties.

Professional Manpower and Education in Communist China—This publication reports that the number of highly qualified personnel capable of advanced scientific research in China is small, with major research emphasis on immediate application. Rather than conducting high-level



Source: National Science Foundation

Figure 4. Scientists, Engineers, and Technicians Employed by State Governments, January 1959

research, the Chinese scientist finds it far more expedient "to borrow existing knowledge from the more advanced nations and convert it to the special needs and the present level of Chinese technology."

A serious qualitative lag exists in education on all levels in China. The report foresees only a gradual rise in the current standards. "As the numbers at the various educational levels become stabilized, additional emphasis will be placed on quality; this will coincide with an increase in the number of more qualified teachers. At all levels, but especially in higher education, the quality of the graduate will be closely related to the degree of emphasis on labor and the time that students will be expected to contribute to actual production work."

DISSEMINATION OF SCIENTIFIC INFORMATION

The ultimate goal of the Foundation's program in the scientific information field has been, and continues to be, the development of integrated systems, national in scope, designed to give every U.S. scientist and engineer effective access to the significant results of the research conducted by all other scientists and engineers. NSF, through its Office of Science Information Service, has followed two fundamental approaches in carrying out its responsibilities in this area.

1. Promoting development of new and better techniques for handling scientific information.
2. Improving the existing methods for the dissemination of scientific information.

The total 1961 fiscal-year effort along these lines has been conducted primarily within the administrative framework of four specific programs. There are, however, certain major problem areas which are of overall concern and are, therefore, discussed separately.

Major Problem Areas

GRANTS AND PROPOSALS

In the 1961 fiscal year, the Foundation made 166 grants totaling \$5,379,940 for improving the dissemination of scientific information. Prior to this year, funds were available to support almost all worthwhile scientific information proposals that came in. Now the point has been reached where requests that, under present NSF criteria, would be considered worthy of support, require funds substantially greater than those that are available. In the area of scientific publication support, for example, acceptable proposals actually on hand at the end of the fiscal year involved funds in excess of the total 1961 allotment for that purpose. Little evidence is in sight of any levelling off in the receipt of scientific information proposals.

This situation poses a serious problem. Continually expanding direct Federal subsidy of the dissemination of scientific information would seem bound eventually to transfer a major fraction of the control of the Nation's information system out of the hands of the scientific community into those of Government. The only feasible alternative seems to be realistic recognition and implementation by those who administer research funds of the principle that dissemination of the results of experimentation is an integral element of the total research sequence and, as such, should receive an appropriate fraction of the research dollar. The Foundation has increasingly emphasized the wisdom of this method as the proper approach to supporting the normal media through which scientific information is exchanged. During 1961, this emphasis has been particularly strong in, but not limited to, the publication field. The use of page charges by primary journals, as one means to this end, was increasingly urged.

COORDINATION OF SCIENTIFIC INFORMATION ACTIVITIES

A major—perhaps the principal—responsibility of OSIS is to provide leadership in coordinating existing scientific information activities, whether they be wholly within Government, totally outside of Government, or of mixed public and private origin. The Foundation's conduct of its coordinating role takes two basic forms—one of which has received insufficient emphasis in past reports on the program. This aspect is the coordinating effect inherent in almost everything it does. For example, before the Foundation awards a grant for documentation research or publication, its action typically is preceded by a series of discussions with the proposing group to make the request compatible with an effective, integrated overall system. Similarly, in the case of proposals for the conduct of studies and experiments, NSF tries during pregrant discussions to insure that the proposed project fits into a unified total program and promises to produce results applicable beyond its immediate objective.

The Foundation's other approach in this area is explicit. In this phase, NSF calls together representatives of operating organizations to work out mutually beneficial, cooperative solutions to common problems; it supports studies and experiments to develop information essential to intelligent cooperation; it sponsors conferences intended to achieve improved integration of the efforts of the numerous U.S. private and public groups concerned with scientific information; and it participates in pertinent conferences called by other organizations.

The principal national problems in this area undoubtedly stem from the enormous complexity of the existing scientific information system

and the natural reluctance of any organization to give up some of the known benefits of autonomy for the hoped-for advantages of a cooperative effort. NSF has basic responsibility for developing a well-coordinated national scientific information system, but has no administrative authority over any groups whose activities are to be coordinated. Therefore, it must work by persuading agencies and organizations involved that cooperation and coordination of effort will benefit them individually and will advance science as a whole. Although this limitation undoubtedly reduces the speed with which at least superficial coordination might be achieved, it has the very great advantage that cooperative efforts that do result are supported wholeheartedly by those involved and, therefore, are likely to be lasting.

One important Foundation approach to coordination has been to counsel with scientific societies, providing temporary financial assistance where necessary, to work out ways for them to take increasing responsibility for developing a unified, overall, U.S. scientific information system. It is NSF's firm conviction that such expansion of the role of these societies is necessary if the basic control of the dissemination of the results of research is to remain with the scientific community where it belongs.

Among the most significant 1961 advances in the promotion of coordination have been those involving the availability of information stemming from Government-supported research. These and other examples are described later.

In the area of international coordination, the Foundation participated actively in the overall planning of the International Federation of Documentation; it worked closely with, and partially supported, the Abstracting Board of the International Council of Scientific Unions; and it was intimately associated with various scientific information activities of UNESCO. To insure continuing, effective coordination of U.S. and foreign planning in this field, NSF is providing support for the Office of Documentation of the National Academy of Sciences-National Research Council. In addition, NSF has participated in various international conferences concerned with the worldwide dissemination of the results of research.

OVERALL FEDERAL SCIENTIFIC INFORMATION PATTERN

Closely related to the coordination problem within Government is the lack of a consistent total Federal pattern in the scientific information field. The fact that over 60 percent of all U.S. scientific research is directly or indirectly funded by Government indicates that the total

Federal stake in scientific information is very large. For the most part, the concern of Government agencies in this field has taken the same form as that of any large-scale producer and user of the results of research. Consequently, over the years, each agency's scientific information program quite naturally has evolved in response to its own particular needs, largely without regard to whether any kind of consistent national pattern was being developed. With the accelerating flood of scientific information in recent years, resulting from the many-fold expansion of research, has come an increasingly imperative need for such a national plan.

During 1961, the Foundation has focused increasing attention on this problem and, particularly, on certain prerequisites to the development of an effective overall Government system of which the separate agency programs will be logical components. One extremely important prerequisite is that each agency's own scientific information activities be well and effectively organized. Working through interdepartmental committees and informal discussion groups, NSF, aided by the Federal Council on Science and Technology, has been vigorously promoting action toward this objective.

EDUCATION AND TRAINING

Three factors that obviously affect the influence of scientific information upon the advancement of research are: (1) the skill with which the information is presented, (2) the appreciation that scientists and engineers have of its potential value, and (3) the competence of those involved in making it available to research people. Greatly increased educational and training emphasis is needed in all of these areas.

Scientific curricula in U.S. colleges and universities are seriously lacking in emphasis on good writing and the effective presentation of research results in reports and papers. Similarly, undergraduate and graduate training in many sciences largely ignores instruction in the use of scientific literature and bibliographic tools in general; in no technical subject field are these powerful scientific assets sufficiently emphasized. Also, almost no universities or other institutions in the U.S. are equipped to give librarians and information specialists adequate training in modern methods of processing, storing, and retrieving scientific data, and in new approaches to the complex problems resulting from the explosive growth in technical literature in recent years.

More immediate problems prevented NSF from embarking upon a vigorous program in this area prior to 1961. During the past year, however, study of these problems was begun with educational groups, scientific organizations, research librarians, and the Foundation's Division of Scientific Personnel and Education. These exploratory conver-

sations have been directed toward defining the problem and determining what should be the role of OSIS in working for improvement in the presentation of scientific material, in training scientists and engineers in its more effective use, and in developing well-trained scientific information specialists. Although, by its nature, such a program necessarily is somewhat long range, significantly increased emphasis is planned for 1962.

Documentation Research

The Documentation Research program stimulates and supports studies, research, and experiments directed toward (1) new and more effective systems—mechanized where possible—for processing, storing, and searching large volumes of scientific information, and (2) mechanized production of accurate and readable translations of foreign language materials into English. The program is also concerned with the extent to which the information needs of the scientific community are being met by existing publications and information services, or could be met by proposed new methods.

Every indication points to the fact that scientific and technical information is growing in total volume and diversity of form and subject matter at a rate faster than it can be effectively collected, organized, and disseminated. There is, in addition, a large and growing body of important research reported in languages not commonly used by American scientists and engineers. The program was established to support research seeking at least partial resolution of these scientific information problems by the development of systems using high-speed electronic and mechanical equipment for organizing and searching information and for translating scientific texts from one language into another.

STUDIES OF INFORMATION NEEDS OF SCIENTISTS

Continued emphasis was placed in 1961 on analyses of the present patterns of scientific communication, the ways in which scientists and engineers use existing publications and information services, and their needs for new and improved services.

Exploratory studies on the possibilities of developing measures of the value of recorded scientific information and on a proposed theory of human communication were carried out by Case Institute of Technology.

A grant was made to the American Psychological Association for an analysis of the total system of scientific communication in psychology, including studies of psychologists' use of information, the functions and

effectiveness of journal and abstracting/indexing publications, and the role of nonwritten scientific communication and meetings. The study will provide for experimentation with a searching service to be operated with the assistance of experts in psychology.

INFORMATION ORGANIZATION AND SEARCHING

Continuing projects supported by the Foundation are concerned with methods for the analysis, ordered arrangement, encoding and searching of scientific subject matter, theoretical studies of information storage and searching, and evaluation of procedures and systems.

The Itek Corp., under a 2-year Foundation contract, has made considerable progress on the development of a normalized language for information searching systems and the development of procedures for selecting indexable information from documents and for converting the information from the language of the documents into the normalized language, which is more amenable to coding for mechanized storage and retrieval. The work is covered in a series of reports.

A pioneering effort in controlled comparison of four indexing and classification systems has been carried out by the Cranfield Project of the Association of Special Libraries and Information Bureaux of Great Britain. Two reports on the project were issued during the year.

A large-scale test program to determine the effectiveness of procedures for analyzing, coding, and searching the subject content of scientific literature has been supported at Western Reserve University. A comprehensive experimental searching service for metallurgists is being operated there with the joint support of the American Society for Metals and the Foundation. Responsibility for planning tests of the procedures and for evaluating the results is in the hands of an ad hoc committee of metallurgists and information specialists established by the National Academy of Sciences-National Research Council at the Foundation's request. Upon the recommendation of this committee, the Foundation has let two contracts to the Stanford Research Institute and Arthur Andersen & Co. for exploratory work on the development of objective criteria for the evaluation of information searching systems.

A thorough analysis of the characteristic use of notation systems for structures of chemical compounds has been launched by the NAS-NRC. The study will consider similarities and differences among various chemical notation systems, the uses now being made of them, criteria which led to their adoption and development, and the purposes that might be served by agreement among chemists on the use of one or more standardized systems.

MECHANICAL TRANSLATION AND LINGUISTIC ANALYSIS

Before machines can process texts of documents for either mechanized information searching systems or mechanical translation systems, more precise knowledge of syntax, semantics, and other aspects of language is needed. Consequently, a considerable portion of current research supported by this program is directed toward extending knowledge of language.

In this field as a whole, the efforts of groups working on Russian-to-English mechanical translation, including a number supported by the Foundation, have resulted in several sizable automatic dictionary programs for such scientific fields as electronics, mathematics, physics, chemistry, and biochemistry. Several approaches to the automatic parsing of Russian texts have met with partial success.

Efforts directed toward methods which may ultimately contribute to complete and accurate translation by machine are being continued at Massachusetts Institute of Technology. In this research program, detailed knowledge of the grammars of several languages is gradually being built up. In addition, the theoretical work has produced certain important insights into the nature of language, the most recent being the "depth hypothesis," which offers a possible explanation of several characteristics of language, based on a limitation of the degree of complexity in sentence structure.

Support was continued for the Harvard University project for research on automatic translation and mathematical linguistics. The project is largely devoted to a program for research on automatic translation of Russian into English.

A project at the University of California, Berkeley, which has been primarily devoted to Russian-English mechanical translation research, has undertaken a smaller but parallel study of Chinese. Two small projects devoted exclusively to the study of Chinese, aimed at Chinese-English translation, have begun; one at the University of Washington, and the other at the Ohio State University.

LINGUISTIC ANALYSIS FOR OTHER PURPOSES

Although approximately 10 groups have been working on the analysis of Russian and other foreign languages in connection with mechanical translation research, only 1, at the University of Pennsylvania, has tackled English. Under Foundation support, a computer program for grammatical analysis of English sentences has been devised, and work is well along on a more complex program for "transformational analysis," the reduction of sentences and their component clauses and phrases into simpler, more uniform constructions.

This work has proved so successful that it has served as the basis of a related research effort at the Radio Corporation of America. The ultimate aim of the University of Pennsylvania effort is the development of procedures for automatic indexing, abstracting, and searching of the analyzed texts.

STATE-OF-THE-ART SURVEYS

During the fiscal year, *A Survey of Computer Programs for Chemical Information Searching* was published by the Research Information Center and Advisory Service on Information Processing at the Bureau of Standards. An extensive report on automatic character recognition also was prepared; a preliminary version has been distributed for comment. The Center, supported jointly by the Foundation, the National Bureau of Standards, and the Council of Library Resources, Inc., assembles and studies publications and reports on information processing research, prepares state-of-the-art papers on various aspects of the research, and furnishes advice on research problems to Federal agencies and other cooperating organizations.

During the past year also, under an NSF contract, Documentation, Inc., has conducted a state-of-the-art survey of coordinate indexing techniques; a report is being prepared.

COORDINATION AND EXCHANGE OF INFORMATION

The seventh and eighth reports in the series *Current Research and Development in Scientific Documentation* were released by the Foundation during fiscal year 1961 to provide a means for coordination and exchange of information among working groups. These reports are international in coverage and contain descriptive statements contributed by investigators conducting research on various aspects of information handling and on potentially related problems. Issue No. 8 covers current activities in the United States and 16 foreign countries; it contains descriptions of 195 projects in 122 organizations, an increase of 36 projects and 23 organizations over Issue No. 7 published 6 months previously.

Members of the Interagency Committee on Mechanical Translation Research, under Foundation chairmanship, met several times during the fiscal year to seek coordination of Federal programs in the field. Agreement was reached on guidelines for the conduct of meetings and for the reporting of research results. During the year, two meetings on mechanical translation research were held, the first being a technical conference sponsored jointly by the Foundation and the Office of Naval Research. The second meeting, sponsored by the Foundation, was held to seek agreement on grammar codes and format for Russian-to-English automatic dictionaries. Two participating organizations are already using an exchange format; further exchanges are anticipated. Use of

the Chinese telegraphic code by groups working with Chinese texts has been recommended by the Foundation and adopted by several groups in order to avoid the multiplicity of transliteration systems which has been a difficulty in processing of Russian for mechanical translation research.

Support of Scientific Publications

The Scientific Publication program provides leadership and support for (1) a publication system that will permit scientists to publish promptly, in adequate detail and format, the results of their research and (2) a reference system that will facilitate scientists' access to the great and growing volume of published information produced in the course of striving towards the first objective. Adequate abstracting and indexing is the keystone of this second objective.

Program activities in 1961 were focused upon a number of the problems that must be solved before these two objectives can be achieved. Projects supported may be grouped into two general classes: those assisting present scientific publishing services; and those investigating new or improved systems, providing faster, more comprehensive services at lowest possible cost. Some highlights of the year's activities follow.

CONTINUATION OF CONVENTIONAL PUBLICATION SUPPORT

Foundation activity in this area of scientific communication involved support of several different types of publications. Uses to which these funds were put include: launching new primary journals; eliminating manuscript backlogs; assisting research journals to publish cumulative indexes; enabling abstracting and indexing services to expand their coverage; and publishing a number of significant single items which could not have been published without subsidy, including monographs, symposium proceedings, reviews, data compilations, and bibliographies. As in previous years, emphasis was placed on the temporary nature of publication support. This operating policy is based on two beliefs: that the Federal Government's activities in long-term support of information dissemination should be part of its normal support of research, and that adoption by NSF of research journals as semipermanent wards is both impractical and extremely undesirable.

STRENGTHENING ABSTRACTING AND INDEXING SERVICES

The Foundation continued its program of strengthening existing abstracting and indexing services, while attempting to identify gaps in U.S. coverage of scientific literature.

During the year a grant was made to Biological Abstracts, Inc., to institute a new semimonthly permuted title index and to increase by twenty percent the number of abstracts published annually in *Biological Abstracts*. Publication of the *BASIC* (*Biological Abstracts* Subjects in Context) is the result of efforts to provide a current subject approach to the journal's contents. Indications are that a permuted title index might alleviate the present 18-month index lag. It is hoped that this system will provide a satisfactory interim index for the users of *Biological Abstracts* pending preparation of more exhaustive regular subject indexes.

Appearing during this reporting period was the first issue of another experimental type publication supported initially by the Foundation—*Chemical Titles*. This is also a permuted title index, published semimonthly by Chemical Abstracts, Inc.

With NSF support, the institute of the Aerospace Sciences began publication of a new monthly abstracting journal entitled *International Aerospace Abstracts*. The new periodical replaces several previously available aerospace information services, no longer adequate to meet the needs of workers in this field.

The Foundation continued its support of the National Federation of Science Abstracting and Indexing Services, established in 1959 to coordinate the work of the various services, seek ways to improve them, and provide more complete coverage of scientific literature. During the year the Federation issued a directory, prepared by the Library of Congress, of 492 abstracting and indexing services in the United States, a valuable guide to the literature of science and technology. Compilation of a companion list of foreign services is underway. At its annual meeting in March, the Federation adopted a resolution calling for preparation of a study of a coordinated national program for abstracting and indexing.

SCIENTIFIC COMMUNICATION STUDIES AND EXPERIMENTS

The New York Botanical Garden pilot project for the study of a machine-oriented coding system for plant taxonomy was continued under a new Foundation grant. Included in the expanded study will be the preparation and publication of an International Plant Index by the use of punched cards and data processing machines.

This project is considered as an experiment in methodology and the resulting indices will be evaluated by a group of competent taxonomists. With this in mind, the researchers will provide a report during the study on the possibilities of including additional data on the index cards; they will also investigate the potential use of the indices by other than plant

taxonomists. Within the next 18 months it is expected that 10 volumes of 250 pages each will be ready for print out.

For the past several years there have been numerous published and unpublished expressions of the need for a system of organizing citations in scientific literature. As a result of this interest and related staff work dating back to 1957, funds were made available this year for joint support with the National Institutes of Health of an experimental study of citation index methods and the preparation of a Genetics Citation Index. The study, being conducted by the Institute for Scientific Information, Inc., Philadelphia, is designed to ascertain the best methods for preparing such indices and to evaluate the usefulness of a citation index to scientists, using the field of genetics as an example.

A number of the major national scientific societies have been encouraged by the Foundation to conduct comprehensive disciplinewide studies of their own communication "networks," to uncover weaknesses, and to take steps to correct them. With NSF support, the American Institute of Physics has been studying physics communication problems; this project continues.

During this year a grant was made to the American Institute of Biological Sciences for another such study, the first of its kind to be attempted by biologists themselves. This investigation, organized as the Biological Sciences Communication Project, is seeking ways to improve overall effectiveness of the control and dissemination of biological information. First step in the program is an examination of methods for acquiring, indexing, storing, and retrieving scientific literature. Studies will follow of biologists' needs for and use of information. The effectiveness of visiting biologists' programs, conferences, and symposia will also be appraised. At the international level, consideration is to be given to methods for obtaining and disseminating valuable foreign research information gathered by U.S. biologists visiting other countries.

Foreign Science Information

As scientific research carried on abroad continues to increase in both volume and quality, it takes on greater significance to the U.S. scientific community. But this heightened awareness is accompanied by hindrances to ready access because much of the published information on this research is in languages familiar to only a few American scientists. In addition, many foreign-language journals and other publications are not readily available in American research libraries and other reference centers. The extent and sources of foreign scientific information, especially in the Soviet Union, Communist China, southeast Asia, and Latin America, are not widely known.

The Foreign Science Information program promotes the effective availability in the United States of worthwhile scientific research results published in foreign countries and encourages the interchange of scientific information. In striving to meet the growing demand for improved access to foreign research findings, the program staff gives leadership to, and encourages the participation of, some 20 U.S. professional scientific and technical societies, a similar number of U.S. universities, and officials of a dozen or so Federal agencies. This program also administers, on behalf of several Federal agencies, the translation of foreign scientific literature financed by funds accruing to the credit of the United States from the sale of surplus agricultural goods abroad under the provisions of Public Law 480 of the 83d Congress.

TRANSLATION OF SOVIET SCIENTIFIC LITERATURE

The translation of key Soviet journals, selected articles, and books and monographs was continued during the 1961 fiscal year. To inform the scientific community of the availability of translated journals, a revised edition of a list of 48 journals receiving Foundation support was prepared and issued. Journals produced by other agencies are also listed.

Cover-to-cover translation of 40 Soviet scientific journals totaled more than 61,000 pages during 1961, as compared with 31,000 during 1958.

As U.S. scientists become better informed about Russian research, there is an increasing demand for translation of selected articles from Soviet journals, aside from those being translated on a cover-to-cover basis. The number of pages translated on a selective basis has grown from 6,490 in 1960 to 9,660 pages in 1961. The Foundation has also launched a project for the abstracting of Soviet biological literature by *Biological Abstracts*.

Grants were given for the translation of 10 Russian books and monographs totaling 4,064 pages to give another avenue of access to significant scientific research conducted abroad.

TRANSLATION OF OTHER LANGUAGES

Concern has been expressed by American scientists that research published in oriental languages is gaining in significance while still being unavailable in English translation. The Foundation has stimulated the selective translation of scientific papers published in Communist China and the translation and publication of significant scientific journals and monographs published in Japanese. Also, the Foundation is supporting the translation and publication of a monthly list of the tables of contents of all scientific and technical publications originating

in Japan which are received by the Japanese Diet Library (the Japanese "Library of Congress").

PUBLIC LAW 480 TRANSLATION ACTIVITIES

Additional foreign currencies credited to the United States under Public Law 480 were obligated by the Foundation during the year for expanding cooperative programs with Israel, Poland, and Yugoslavia for the translation of significant scientific literature published in Russian, Polish, and Serbo-Croatian. During fiscal 1959 and 1961, foreign currencies equivalent to \$1,783,000 were obligated; no such funds were obligated during 1960.

The continuing contract with the Israel Program for Scientific Translations, which calls for the translation, editing, and printing of approximately 46,700 pages of scientific and technical literature published in Russian and other European languages, has produced 49 books and 126 individual articles. A printing schedule of approximately 2,000 pages per month has been established for the publication of 30,500 pages of translated material which has already been reviewed by U.S. scientists. Another 16,200 pages are in the process of translation. At the end of the fiscal year, translations of selected Swiss patents were being made available.

In Poland, the contract with the Central Institute for Scientific and Technical Documentation contemplates the translation, editing, and printing of about 19,000 pages of Polish scientific and technical literature. In addition, the abstracting and simultaneous publication in English of Polish scientific and technical periodicals has been started. About 11,500 pages are presently in the process of translation and about 7,500 pages of translated material have been received for editing. Sixty-eight selected articles have been printed.

The translation, editing, and printing of approximately 20,000 pages of Serbo-Croatian scientific and technical literature has been contracted for with the Directorate for Scientific Research of the Yugoslav Federal Executive Council. The printing phase of the program has been initiated, 6,500 pages have been reviewed by American specialists, and another 7,000 pages are in the process of translation.

EXCHANGES AND CLEARINGHOUSES

Establishment and encouragement of working exchange agreements and clearinghouse operations are essential to ensure that information on worthwhile scientific research results occurring in foreign countries is made available to the U.S. scientific community. Examples of such activities are given in the following paragraphs.

Two representatives of the Foundation were assigned in October 1960 to the staff of the American Embassy in Tokyo and are assisting in promoting the exchange of scientific knowledge between scientists and institutions in Japan and the United States. As part of their duties, they encourage the publication in English of reports by Japanese scientists and arrange for the translation and abstracting into English of Japanese scientific documents.

Member countries of the European Productivity Agency have established a European Translation Center in Delft, the Netherlands, to promote broader distribution of translations of Russian and other eastern European scientific literature in the western world. Formation of the center was achieved with the advice, encouragement, and manpower support of the Foundation.

A five-man team representing the National Federation of Science Abstracting and Indexing Services, supported by a Foundation grant, toured Japan late in the fiscal year to investigate Japanese progress and activities in all phases of documentation and information retrieval work with the hope of developing practical means of broadening the exchange of abstracts and publications. This tour corresponded to a similar visit made last year by the Japanese Technical Information Processing Study Team to information centers in the United States.

Support was continued for the Special Libraries Association Translation Center at the John Crerar Library in Chicago, which concentrates on the acquisition of translations from all non-Government sources. This work is closely coordinated with a complementary effort covering Government-produced scientific translations conducted by the Office of Technical Services, U.S. Department of Commerce.

CONFERENCES, AREA STUDIES, AND REFERENCE AIDS

As mentioned in an earlier section of this report, the Foundation stimulates and supports international cooperation in scientific information activities to provide adequate knowledge to U.S. scientists of foreign publications and their acquisition, foreign and international information services, and the availability and coverage of foreign scientific information in the United States.

Publication by the American Association for the Advancement of Science, in June 1961, of the proceedings of the Symposium on Sciences in Communist China was the culmination of months of planning and organization by Foundation staff members of the 2-day symposium conducted as part of the December meeting of the AAAS. The symposium was sponsored by the Foundation and 10 cooperating professional societies. As a direct result of the symposium, as least five major pro-

professional societies (American Institute of Physics, American Institute of Biological Sciences, American Geological Institute, American Institute of Chemical Engineers, and American Mathematical Society) are developing programs to examine, monitor, or translate Chinese scientific materials.

During the fiscal year work was virtually completed on organizing the program and arranging for speakers for the Section of Scientific Information as part of the 10th Pacific Science Congress in Hawaii from August 21 to September 2, 1961. The section, organized by the Office of Science Information Service, will deal with communication of scientific research, organization of scientific information and training for information work, resources of research information and exchange of publications, and information activities of international organizations.

A series of conferences was held to develop improved means of disseminating Soviet and Eastern European linguistic literature in the United States.

To provide insight into the extent and nature of the Soviet technical information system, the Massachusetts Institute of Technology undertook a 2-year study, with Foundation support, of the organization, methods, and development of the dissemination of scientific and technical information in the U.S.S.R. A significant first step in the study was the translation and publication of a Russian-authored review of Soviet technical information under the title *Technological Information in the U.S.S.R.*

The resources of scientific information in Czechoslovakia and East Germany, particularly in the natural sciences and engineering, are the subject of critical examination by a Foundation-supported study team from Columbia University.

The results of a survey of the resources, services, and potential for expansion of documentation centers in Latin America were published during the fiscal year in a report entitled *Science Information in Latin America*. The study was cosponsored by the Foundation and the Division of Science Development of the Pan American Union.

Two studies are being supported through the Association of Asian Studies (University of Michigan) and the American Mathematical Society to survey publishing in the natural, social, and applied sciences in Mainland China and to survey contemporary Communist Chinese mathematical research.

Preparation of a guide to Soviet science, intended to fill the needs of U.S. scientists traveling to the Soviet Union or wishing to establish contact with Soviet scientists, was undertaken by Princeton University.

The first in a series of bibliographies of social science periodicals and serial monographs published in Communist bloc and other countries using so-called "difficult" languages was issued during the year by the Foreign Research Office of the Bureau of the Census. The project is being supported by a grant from the Foundation.

In recognition of the need for improved handling of Oriental agricultural publications, the U.S. Department of Agriculture Library published, with Foundation aid, a bibliography of current publications from Japan, Taiwan, Mainland China, North Korea, and South Korea in agriculture and allied sciences.

Research Data and Information Services

The Research Data and Information Services program is primarily concerned with two particularly acute problem areas in scientific information, both of which were given increased attention and financial support during 1961. The first, which is on the whole unsatisfactory, involves dissemination of research results generated under Federal grants and contracts, as well as in Federal laboratories. Scientists and others who can use such information either do not know of its existence or are unable to obtain much of that which is available. The second problem concerns specialized scientific data and reference services, which are rapidly increasing in number and, with few exceptions, independently of one another. There is a real need to improve the compatibility of these services and to coordinate their coverage and activities on a national scale so that no serious gaps or duplications exist.

A number of specific actions, parts of a coordinated program, were taken during the year to attack various phases of these two problems, with particular emphasis on that of Government research information. In the coming months, special attention will also be given to the concept of developing a formal, uniform, Government-wide policy that will facilitate maximum dissemination of Federal scientific information. In essence, recognition must be given scientific information activity as a distinct, definable function of the Government and its various agencies in conducting their research and development programs.

DISSEMINATION OF GOVERNMENT RESEARCH RESULTS

The Foundation has devoted considerable attention to ways of improving the technical report literature of the Federal Government to increase its usefulness and availability to the scientific community. For example, one of its general goals is to achieve more uniformity in the types of technical reports issued by Government agencies and their contractors. At the same time there should be established a uniform

system of coding and numbering such reports that would reduce multiple identifying numbers to a minimum. As a first step, a contract has been let for a study to identify, define, and analyze various categories of Government technical reports and their code designations. Also to be determined is the practicability of developing and adopting a coordinated Government-wide system of report categories and code designations. This short-term study will help to solve one of the major problems associated with effective use of this material, i.e., adequate identification and organization of the thousands of such reports issued each year.

NSF encouraged the further expansion of the report announcement services of the Office of Technical Services (OTS), Department of Commerce. Beginning in 1962 the OTS announcement journal *U.S. Government Research Reports* will include all unclassified, available reports from the Department of Defense rather than a selected number as was done previously. (This journal also announces AEC and NASA unclassified reports; information is given on how to obtain copies of all documents listed.)

During 1961, as part of a general effort to improve dissemination of research results, the Foundation promoted the establishment of a national network of regional reference centers for U.S. Government technical reports. In cooperation with the Office of Technical Services, efforts were initiated to establish working arrangements and an overall agreement with each of 12 selected institutional libraries strongly oriented to science and technology. This network, when fully operative, will provide access for all regions of the United States to cumulative organized collections of unclassified Government technical reports. It will also provide a means for obtaining loan or purchase copies of such material. The Department of Defense, National Aeronautics and Space Administration, and Atomic Energy Commission, producers of an estimated 90 percent of Government technical reports, are cooperating fully in the project; OTS is coordinating and managing the entire activity. Steps are being taken to induce all other report-producing agencies to participate.

With NSF support and guidance, the Science Information Exchange, a national clearinghouse for information and administrative data on current U.S.-sponsored projects, was formally established in the 1961 fiscal year. In the planning stage for a number of months, the new Exchange, covering physical and biological sciences, is an organizational expansion of the Bio-Sciences Information Exchange (BSIE) established in 1950; it is to be operated by the Smithsonian Institution.

During the year, the Foundation extended its series of surveys of Government agencies with scientific information activities. The pur-

pose of these studies is to describe for each agency the types and subject coverage of the scientific reports it issues, the availability of this material, and the scientific information policies and procedures under which it operates. The data obtained from these surveys are published in a series of bulletins entitled "Scientific Information Activities of Federal Agencies." Included in each bulletin is information on agency research and development activities, names and types of information services provided, documents generated, how they are announced, and how copies may be obtained. In 1961 six new bulletins were published, covering the Tennessee Valley Authority; National Science Foundation; Department of Commerce, Parts II and III; Federal Communications Commission; and Veterans' Administration. Ten of an expected total of 40 have now been published. Others in the series are being prepared and will be issued during the coming year.

SPECIALIZED INFORMATION AND DATA CENTERS

Rising interest in regional scientific information centers has resulted in a number of requests for support of such activities. In an attempt to develop guidelines with which to evaluate these requests, a grant has been awarded to Southern Methodist University for a basic study of the centers. Models of regional centers will be formulated and modes of operation for each will be detailed. Thus, a generalized analysis of such centers will be made, without reference to any particular area or region.

Among other things, the study will determine typical geographical areas which reasonably can be served by information centers. Factors affecting scientific information needs, such as types of industry, extent of research, and growth trends in various technical fields, will be noted and defined. In addition, basic data will be sought on present and future services an information center could provide, and a catalog of potential user needs will be attempted. Possible ways of cooperating with libraries and other information facilities to obtain improved services, will also be investigated.

SPECIAL INTERNATIONAL PROGRAMS

The Office of Special International Programs has been assigned responsibility, within the Foundation, for initiating and developing cooperative and experimental programs in international science and science education, for liaison with other Government agencies involved in such activities, and for providing backstopping service in support of United States participation in selected international organizations.

International Science Program

DEVELOPMENT OF INTERNATIONAL SCIENCE POLICY

The rapidly expanding role of science in international affairs has pointed up the need for a thorough study by the Federal Government of the proper role it should play in world science relationships. The Foundation, because of its responsibilities and experience, has been called upon to assist in: (a) developing national policy for the stimulation and conduct of scientific and technological activities abroad, (b) arranging for cooperation with international scientific and technological activities of the various Government agencies to help evolve a program in science and science education for assisting developing nations.

During the past year, this program participated in studies of engineering aid to Latin America, in examination by an interagency group of the image of U.S. science abroad, and in consideration of appropriate content for U.S. science exhibits to be mounted abroad.

ESTABLISHMENT AND OPERATIONS OF THE NSF-TOKYO OFFICE

Two representatives of the National Science Foundation have been placed within the American Embassy in Tokyo.

This office was established in September 1961 and has a staff of three Americans and three Japanese. It functions as part of the American Embassy and reports to the Foundation through the Office of Special

International Programs. The Office has been active in these principal areas: (1) science liaison and analysis and (2) science information and improvement of science communications generally.

Science Liaison and Analysis

The staff has devoted itself to establishing contact with officials of the Japanese Government responsible for administering and promoting science and technology, with officers of professional scientific organizations, with university and other research organizations, and with individual Japanese scientists, and with such groups as the Science Council of Japan, the Ministry of Education, and the Science and Technics agency.

NSF-Tokyo has served as the liaison office with the Japanese committees planning the Conference on Cosmic Rays and Earth Storms and the Conference on Crystallography and Magnetism held in Kyoto in September 1960.

This office has instituted a program of study of various aspects of Japanese science and technology. A number of varied studies have been completed.

Science Information

NSF-Tokyo has developed close relationships with the Japan Information Center for Science and Technology, the Science Information Office of the Science Council of Japan, the National Diet Library, the Science Information Section of the Ministry of Education, and the Japan Documentation Society. Exploratory discussions have been held with several Japanese scientific societies to see where translations of scientific journals into English are necessary and feasible to improve communication between Japanese and American scientists. Discussions have been held with representatives of the Physical Society of Japan, the Chemical Society of Japan, and the Oceanographic Society of Japan. NSF-Tokyo has also provided assistance to the staff of the National Diet Library responsible for producing the English version of the *Japanese Periodicals Index* under an NSF grant.

Appropriate backstopping has been provided in the Washington headquarters of NSF to assure the effectiveness of its Tokyo operations.

INTERNATIONAL SCIENCE SUPPORT PROJECTS

Foreign Science Evaluation

During the past year, NSF has continued its experimental program of support for surveys in particular fields of science in foreign countries. The purpose of this program is to provide to the Foundation and to the scientific community evaluative reports on the status of research in

specific fields of science in foreign countries. A small number of grants have been made to permit outstanding U.S. scientists to spend 2 or 3 months visiting scientific activities in foreign countries for the purpose of preparing research reviews in their special fields. During the past year, grants were made to Dr. Ralph Gerard of the University of Michigan for a survey of some aspects of bio-medical research in India; to Dr. Harlow Shapley, professor emeritus, Harvard College Observatory, for a survey of progress in the field of astronomy in India; and to Dr. A. D. Wallace of Tulane University for a study of mathematical activity in Poland, Hungary, and Yugoslavia.

Cooperative Activities

Under this program, the Foundation is exploring experimental approaches to cooperating in international support of scientific centers in developing areas. During the past year a grant of this type was made to the Comision Nacional de Energia Atomica in Buenos Aires for short-term support of two research projects. The grant was made for Dr. Jorge A. Sabato to study the fabrication of perfect single crystals of alpha-uranium and the relationship between physical and mechanical properties and substances in uranium crystals. The metallurgy group of the Comision Nacional was selected for support because in addition to scientific competence it has shown high potential for leadership as a key scientific group in Latin America. The funds are being used to strengthen the scientific potential of a developing research team which is concerning itself with cooperative interchange of ideas in the Americas.

Another cooperative project is the grant made to Dr. Wallace O. Fenn on behalf of the International Union of Physiological Sciences for an international traveling lecture team in physiology. This grant provides partial support for an international team of scientists in the field of physiology on a tour of India. This project is an experiment in person-to-person scientific communication which should aid in international programs of research in physiology. The team which includes one American is headed by Professor W. D. Patton of Oxford. The project is being supported cooperatively by the Executive Board of the IUPS, the Royal Society of Great Britain, and the National Science Foundation.

U.S.-U.S.S.R. EXCHANGES

In September 1959, the sum of \$235,000 was granted to the National Academy of Sciences for the support of an exchange of scientists between the U.S. and the U.S.S.R. This amount was to implement the Bronk-Nesmeyanov Agreement which had been signed in July 1959, by the Academies of Sciences of the two countries, to implement in the scien-

tific area the Lacy-Zaroubin agreement. During the past year the exchanges have been continuing at an accelerated rate.

Of the 44 visits to which each side is entitled under Articles 1, 2, and 3 of the current Exchange Agreement, approximately 52 percent of the American visits and 64 percent of the Soviet visits have been either completed or formally proposed.

International Science Education Program

Within the objective of the National Science Foundation to promote education in the sciences, it is the aim of the International Science Education Program to encourage and support fruitful contacts between U.S. and foreign science educators and scholars. This program has the twofold purpose of (a) making available to U.S. scientists and educators the knowledge and experience of their foreign counterparts and (b) of assisting U.S. science educators to study science training in foreign educational systems and to work in close cooperation with foreign and international groups on current problems of science education improvement. A further program objective is to assure representative U.S. participation in and contribution to deliberations of international bodies concerned with either general or specific questions of science education.

In fiscal year 1961 support was provided to program areas covering course content improvement and science teacher and student training activities.

COURSE CONTENT IMPROVEMENT PROGRAM

In 1961, partial support was given for conferences dealing with current problems and goals of education in the sciences. International conferences were held at the Massachusetts Institute of Technology on Scientific and Engineering Education, at Syracuse University on Electrical Engineering Education, and at the University of Southampton on Mathematical Education. In addition, grants have been made to the International Commission on Mathematical Instruction for an Inter-American Conference on Mathematics Education to be held in Colombia and to the Organization of American States for a Regional Seminar on Educational Problems of Nuclear Energy to be held in Argentina. As in the last fiscal year, grants also were made to enable U.S. educators to participate in the 60th Annual Meeting of the British Science Masters Association and to engage in related activities in Great Britain.

U.S. course content improvement groups were encouraged to establish and maintain communications abroad with analogous groups or with individual foreign science educators with whom the U.S. groups have mutual interests. For this purpose grants were made to the Chemical

Bond Approach project and to Educational Services Inc. In addition, a heightened interchange of ideas and experience in this activity was promoted by awards to Educational Services Inc. for cooperative work in symposia on physics education in three countries abroad and to the Biological Sciences Curriculum Study for foreign cooperation in that group's 1961 Writing Conference.

SCIENCE TEACHER AND STUDENT TRAINING PROGRAMS

One hundred and seven foreign science teachers and educators from 33 countries were placed in 91 NSF Summer Institutes, and 1 in an Academic Year Institute. Nine organizations or agencies with interest in foreign science education cooperated in the nomination and support of these participants who provide a stimulating influence at the institutes they attended. Support was continued for U.S. participation in the Scandinavian Growing Point Program, the NATO Advanced Study Institutes, and a number of other programs for student training.

Liaison and Backstopping Activities

For several years the Foundation has been providing backstopping on behalf of the United States to the science programs of the Organization for European Economic Cooperation, an 18-nation organization of Western European countries, plus the United States and Canada as associate members. Since ICA (International Cooperation Administration) has been the official U.S. respondent to all affairs of this Organization, this backstopping has been provided under an agreement between ICA and NSF. During fiscal year 1961, the Foundation has supplied position papers and staff work on various science matters and has, with funds transferred to it by ICA, recruited 26 representatives to attend meetings of the Committee for Scientific and Technical Personnel and the Committee for Applied Research, the two science committees of OEEC, and to various meetings of specialists arranged within the programs of these two Committees. ICA responsibility for U.S. participation in science matters of the OEEC came to an end on June 30, 1961, and the agreement between ICA and NSF has been terminated.

For the last year preparatory groups from interested nations have been busy in creating a successor organization to the OEEC. This organization is known as the Organization for Economic Cooperation and Development (OECD). Canada and the United States have become members of the new organization, thus making a total of 20 nations. U.S. participation in the new organization is now the responsibility of the Department of State. On June 27, 1961, the Department of State

officially requested the National Science Foundation to continue to perform the various specialized functions necessary to backstop the science activities of the new OECD. In the new organization there are again two science committees, the Committee for Scientific and Technical Personnel and the Committee for Scientific Research. The new Committee for Scientific Research will be active in both basic and applied research matters.

In order to provide adequate local backstopping to the science activities of OECD, NSF has arranged for the support of two U.S. persons beginning in fiscal year 1962 in the U.S. Regional Organizations' Office in Paris to provide continuing contact with the two science committees and with the OECD Secretariat serving these committees.

During fiscal year 1961, as in previous years, NSF has continued liaison responsibilities with the State Department's Secretariat for the U.S. National Commission for UNESCO and the NATO Backstopping Committee. It has continued to work closely with the Office of the Science Adviser to the Secretary of State and with the Assistant Secretary of State for Educational and Cultural Affairs, the Soviet and Eastern European Exchanges staff of the State Department, the International Cooperation Administration, the Organization of American States, and the several committees of the National Academy of Sciences that deal with foreign science matters.

MEASURING AND APPRAISING THE NATIONAL INVESTMENT IN SCIENCE

Science and Technology in Relation to Economic Growth

One of the issues of our time is the rate of this Nation's economic growth. Among the major influences that have come under recent intensive study is the role of science and technology as a growth stimulant in the economy.

During World War II and the years immediately following, science and technology were directed mainly toward national defense. However, there were considerable carryover benefits of these military projects to the peace-time economy. Since then there has been an expanding program of research, which has served the civilian as well as the military needs of the Nation. Today, the total research and development effort of the country is at an annual rate of about \$14 billion. This amount is estimated as over 2.5 times the R&D expenditures of 1953.

The implications of a research and development effort of this magnitude on the economy are of two kinds: the direct effects in terms of sales and employment generated by these expenditures, and the "feedback" to the economy of the results of research and development in the form of new products and processes. Since much development and subsequent technology have their genesis in basic research, support of this activity is a potential stimulant of economic growth.

During the past year three major policy reports indicated public concern with the effect of research and development on the economy. The report of the President's Committee on National Goals¹ recognized the economic contributions of "increase of knowledge" by calling for "corrective increase in the fraction of our GNP (gross national product) which we devote to basic research" (See fig. 5).

¹ *Goals for Americans*, The American Assembly, Columbia University (1960), Prentice-Hall, Inc.

The President's Science Advisory Committee in a later report stated: ²

Ordinary capital investment puts savings to work on labor-saving machinery that is already known and understood; the increased wealth produced is what separates the developed modern society from helpless poverty. But scientific and technological investments are still more powerful tools, since they invest in the discovery of what we do not yet understand. We are only just at the beginning of the use of scientific investment in this large sense, and the returns it can bring in are literally incalculable. Simply in terms of economic self-interest our proper course is to increase our investment in science just as fast as we can, to a limit not yet in sight.

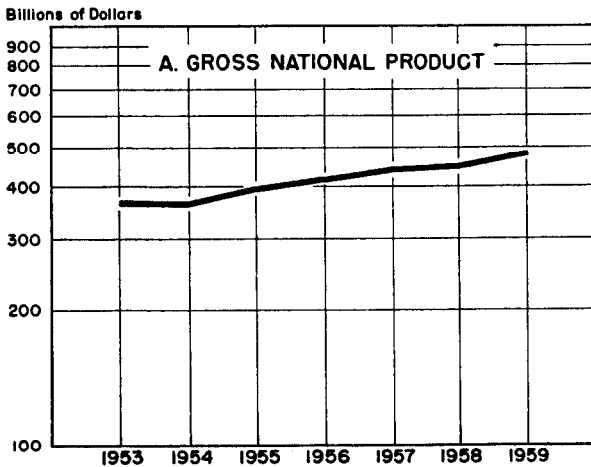
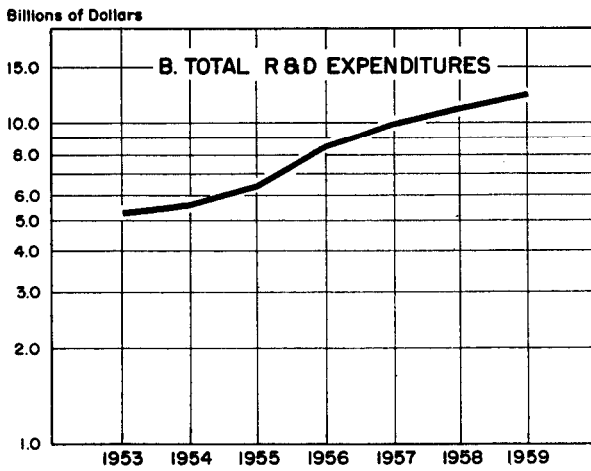
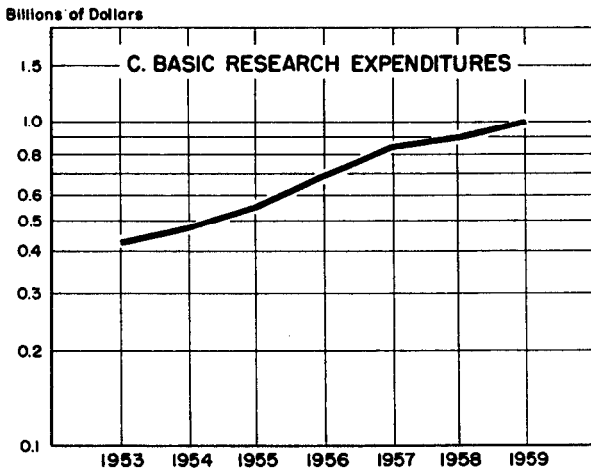
These reports either explicitly or by implication acknowledged that a sound means of achieving scientific progress was to insure that "every young person who shows a desire and capacity to become a scientist should have the opportunity to do so." From this policy position, the Foundation issued in July 1961 a report, *Investing in Scientific Progress*.³ It attempted to spell out what the needs would be to implement this policy (table 5). The report incorporated a series of projections drawing upon a variety of data from surveys of research and development and other inquiries. It estimated at \$3 billion the total 1961 investment, from all sources, for science and engineering education and for basic research in colleges and universities.

The combined investment for education and basic research at academic institutions, the report concluded, on the basis of population and education trends, must grow to more than \$8.2 billion in 1970 to meet national needs. Of this sum, about \$2.7 billion would be for university basic research.

The current estimates and projections for 1970 contained in the report were based upon the work of the Foundation's Office of Special Studies. This office is engaged in collecting, analyzing, and publishing facts regarding the Nation's scientific resources. (See appendix F for list of reports published during the year.) These activities fulfill the statutory responsibilities of the Foundation to make "comprehensive studies regarding the Nation's scientific effort" and to appraise "the impact of research upon industrial development and upon the general welfare."

² *Scientific Progress, the Universities, and the Federal Government*, The White House (1960), Washington 25, D.C.; Supt. of Documents, U.S. Government Printing Office.

³ See also part I of this report for other discussions of this publication.



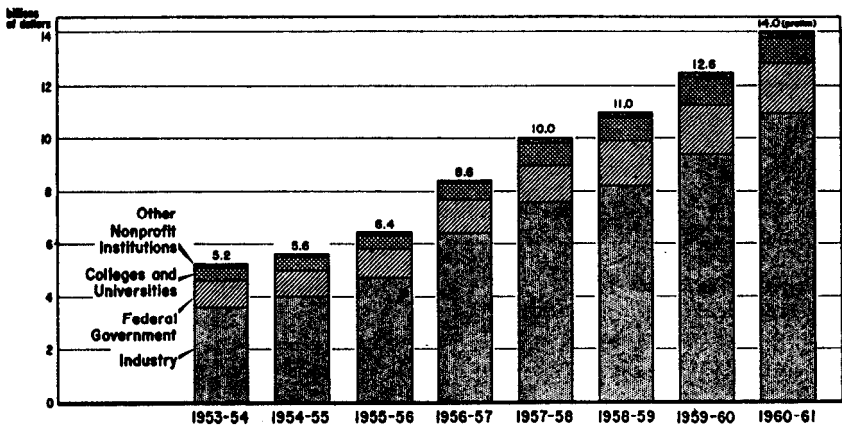
Note: R&D expenditure data refer to hyphenated years beginning with 1953, e.g., 1953-54. The gross national product data refer to calendar years.
 Source: National Science Foundation and the U.S. Department of Commerce.

Figure 5. Research and Development and the Gross National Product, 1953-59

Table 5.—Investment in Basic Research and Education in Science and Engineering, 1961 and 1970

	Education in science and engineering		Basic research	
	1961	1970	1961	1970
Colleges and universities:		(Required)		(Required)
Professional staff:				
<i>Full-time equivalent number of personnel</i>	100,000	175,000	45,000	85,000
	<i>Millions</i>	<i>Millions</i>	<i>Millions</i>	<i>Millions</i>
Salaries.....	\$800	\$2,100	\$345	\$970
Assisting staff:				
<i>Full-time equivalent number of personnel</i>	100,000	175,000	35,000	65,000
Salaries.....	\$425	\$1,100	\$158	\$450
Operating and overhead expenses..	\$648	\$1,700	\$227	\$665
Information.....	\$36	\$90	\$33	\$95
Equipment.....	\$80	\$200	\$30	\$180
Facilities.....	\$150	\$350	\$85	\$360
Actual total.....	\$2,139	\$5,540	\$878	\$2,720
	<i>Billions</i>	<i>Billions</i>	<i>Billions</i>	<i>Billions</i>
Rounded total.....	\$2.1	\$5.5	\$0.9	\$2.7
Secondary schools.....	\$2.2			
Elementary schools.....	\$0.4			
Other nonprofit institutions.....			\$0.1	
Industry.....			\$0.5	
Federal Government.....			\$0.3	
Totals for 1961 (in billions).....	\$4.7		\$1.8	

The studies emphasize the total national scientific effort in terms of input—funds and manpower. They offer trend data beginning with 1954 and extending to the current fiscal year. The series shows a rise in current dollars expended for scientific research and development to an estimated \$14 billion in 1960–61 from \$5.2 billion in 1953–54.



Note: A hyphenated year is employed to take account of the varying fiscal and business years of the many respondents.

Each nongovernmental sector includes funds for Federal contract research centers administered by organizations under contract with Federal agencies.

Source: National Science Foundation.

Figure 6. Funds Used for Performance of Research and Development in the U.S., by Sector, 1953-61

Financing and Performance of Research and Development

These national totals are obtained by adding the totals for each sector of the economy, i.e., the Federal agencies, industrial firms, colleges and universities, and other nonprofit institutions such as private foundations. Thus, the trend data show the financial role which each sector contributes in money or expends in the performance of the effort.

Industrial performers of research and development showed an increase in expenditures over this period of about 190 percent, the largest increase of any of the survey sectors (fig. 6). The sector whose funds for performance increased least was the Federal Government, a rise of over 100 percent, although it was the major financer of research and development in the economy. By comparison, national economic activity as measured by the gross national product increased by 38 percent during the same period.

Information on the role of each sector as performer and as a source of funds for research and development for the year 1959-60 is presented in a transfer table (fig. 7). It portrays the financing underlying the \$12.5 billion which was spent in the performance of research and development for that year. On the basis of these reports from performers and similar data from previous years, one can generalize that the relative roles of the sectors as performers and as sources have remained about the same for the past 5 years.

(Millions of Dollars)

SECTORS Funds Provided by	Funds for Performance of R&D by	FEDERAL GOVERNMENT	INDUSTRY	COLLEGES AND UNIVERSITIES	OTHER NONPROFIT INSTITUTIONS	TOTAL	PERCENT DISTRIBUTION, R & D SOURCES
FEDERAL GOVERNMENT		\$1,840	\$5,420 ^{a/}	\$700 ^{a/}	\$140 ^{a/}	\$8,100	64
INDUSTRY			\$4,020	\$50	\$50	\$4,120	33
COLLEGES AND UNIVERSITIES ^{b/}				\$210		\$210	2
OTHER NONPROFIT INSTITUTIONS ^{b/}				\$40	\$60	\$100	1
TOTAL		\$1,840	\$9,440 ^{a/}	\$1,000 ^{a/}	\$250 ^{a/}	\$12,530	100
PERCENT DISTRIBUTION, R & D PERFORMANCE		15	75	8	2	100	

a. Each nongovernmental sector includes funds for Federal contract research centers administered by organizations under contract with Federal agencies.

b. Data include State and local funds received by these institutions and used for research and development.

Note: All data are based on reports by performers.

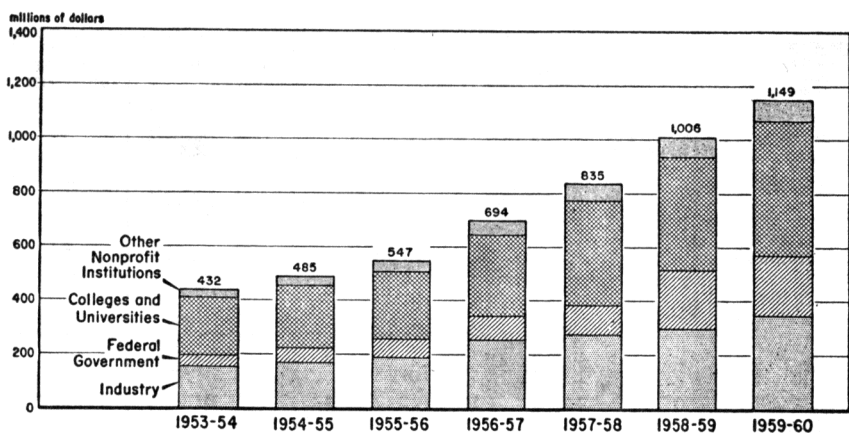
Source: National Science Foundation.

Figure 7. Intersectoral Transfers of Funds Used for Performance of Research and Development, 1959-60

In terms of total funds spent on performance of research and development, the nongovernmental sectors accounted for about 85 percent for the year 1959-60—the industry sector spending 75 percent and the two nonprofit sectors together, colleges and universities and other nonprofit organizations, reporting 10 percent of the total. This distribution obviously reflects the great R&D strength and potential of private industry.

Almost two-thirds of the total R&D financing was reported as Federal in origin, with industry supplying almost one-third. Not surprising is the fact that the two nonprofit sectors supplied only 3 percent of the total. These institutions have few means of accumulating funds of their own. Funds from the Federal Government as a source were pervasive, constituting more than one-half of the R&D funds for performance in each of the nongovernmental sectors.

The predominant role of the government or public sector in R&D financing stems not only from the inherent responsibility of the Federal Government for defense research and development but also from the growing importance of its responsibility for the general welfare such as agriculture, health, and the conservation of natural resources. The picture for R&D funds contrasts with that for the economy as a whole in which the decisions and financing generated in the private sectors determine to a greater extent the levels of activity.



Note: A hyphenated year is employed to take account of the varying fiscal and business years of the many respondents.

Each nongovernmental sector includes funds for Federal contract research centers administered by organizations under contract with Federal agencies.

Source: National Science Foundation.

Figure 8. Funds Used for Performance of Basic Research in the U.S., by Sector, 1953-60

Basic Research

Funds used in the performance of basic research have, like those for total research and development, increased in recent years. From 1953-54 to 1959-60, the latest year for which basic research estimates are available, funds rose by more than 165 percent, as indicated in figure 8. Federal agencies as performers showed the largest relative increase and industry, the smallest. Basic research funds were from 8 to 9 percent of total funds for research and development during this period.

The intersectoral flow of funds for basic research is different from that for all research and development. Here, the preeminent role played by the colleges and universities as the home of basic research is reflected in their use of almost one-half of the reported funds. Again, however, the Federal Government is the major source of basic research funds.

Study of All Scientific Activities

This statistical and analytical work, useful not only in the deliberations on science policy but also to the operational program of the Foundation, is being broadened to meet the greater need to view the totality of all scientific activities in relation to the economy. These studies are expanding to consider the relation of the various components of science and technology to each other, such as research and development, the education of scientists and engineers, the utilization of pro-

fessional and supporting personnel, development of facilities, the dissemination of scientific information, and the organizational aspects of the scientific community.

Data are being developed on expenditures for the dissemination of scientific information within the Government and in other sectors of the economy. Similarly, data are sought in connection with facilities used in research and development and in educational activities. Special studies are underway to relate the educational and manpower aspects of science to other components of science and technology.

As noted, the surveys and analyses of research and development have been oriented toward inputs in terms of dollars and manpower. Preliminary studies are in progress on the measuring of scientific output in terms of patent issuance, scientific publication, and individual and group productivity.

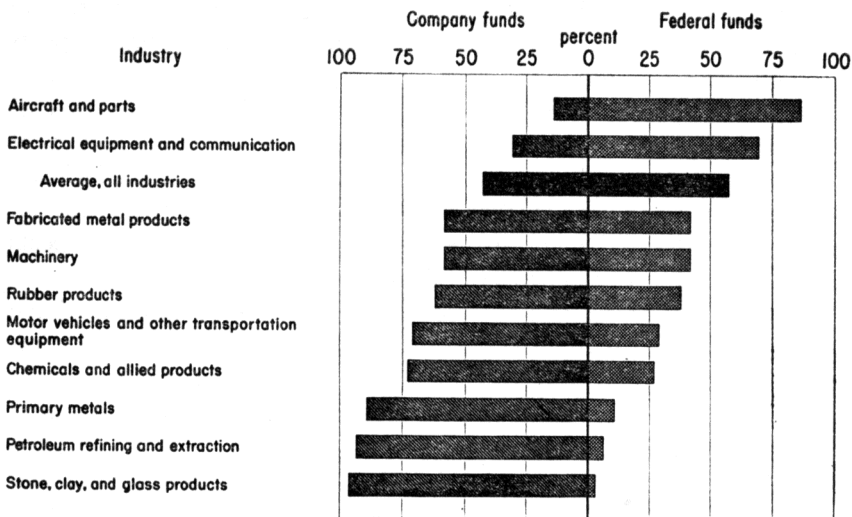
The Foundation is also undertaking the study of science organization and management and their relation to the broad organizational structures of our social and economic institutions. The program includes a study of working conditions favorable to creative scientific activity and the influence of changing technology in the advancement of scientific research.

Policy Implications

The statistics do not indicate the direction in which policy should go but they do reflect, in quantitative terms, some of the intersectoral relationships about which a great deal of public discussion and inquiry have taken place.

For instance, the fact that the single largest transfer of R&D dollars flows to industry from the Federal Government, mostly from the Department of Defense, not only attests to industry's ability to perform research and development but also indicates the fact that, in terms of dollars, almost one-half the industrial research and development facilities are engrossed in work of a military character.

Industry itself, as figure 7 indicates, contributes a substantial amount to the national pool of funds for total research and development. Data from our more detailed industry studies indicate a great variation among industries in the extent to which they finance research and development themselves (fig. 9). Obviously, some industries, such as chemicals, are more research-minded than others, and in any industry some firms are more research-oriented than others. The complex question on which we need greater understanding is what types of economic and technological conditions and managerial motivation lead some industries as a whole or certain firms within an industry to make the risk decisions to invest in research and development while others do not take this step.



Source: National Science Foundation.

Figure 9. Company Funds and Federal Funds as Percents of Total R&D Funds, by Industry, 1959

One relatively small transfer of funds in both the total research and development and basic research analyses is the flow from industry to the colleges and universities sector, reflecting the fact that industry performs most of its own research and development including basic research. Industry has been contributing generously, however, to the support of education in colleges and universities. For industry, as well as the rest of the community, is indebted to the colleges and universities for the education of scientists and engineers. In this area, we need to supplement the data on transfers of funds for research and development with information on industry's support of higher education. This is a part of understanding the entire task of replenishing and expanding the research resources in colleges and universities, a job in which each segment of society must play a part.

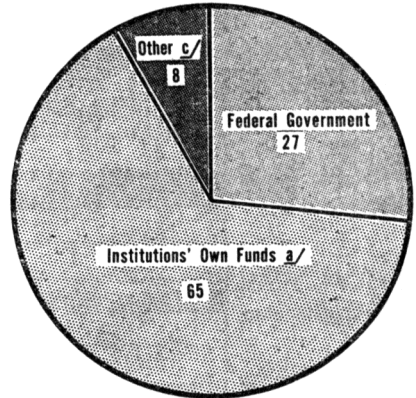
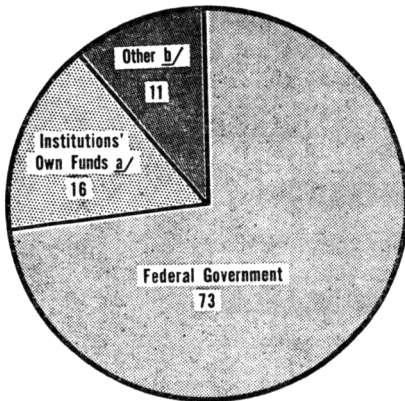
Also, of particular interest in the support of colleges and universities is the magnitude of research funds going from the Federal Government to academic institutions. As the statistics indicate, these funds (which include money going to Federal contract research centers administered by the universities) now make up more than 70 percent of the universities' total expenditures for research and development (fig. 10). Although the Federal agencies which provide this support and the schools which perform the research both operate in the public interest, they do not have identical responsibilities. The objectives of the universities are education, research, and community service. Those of the Federal agencies range

A. OPERATING EXPENDITURES FOR SEPARATELY BUDGETED RESEARCH AND DEVELOPMENT

Total, \$740.7 million

B. CAPITAL EXPENDITURES FOR RESEARCH AND DEVELOPMENT

Total, \$153.5 million



- a. Institutions' own funds include State and local government funds.
 - b. Other sources include foundations (5 percent) and industry (5 percent).
 - c. Other sources include foundations (2 percent) and industry (1 percent).
- Source: National Science Foundation.

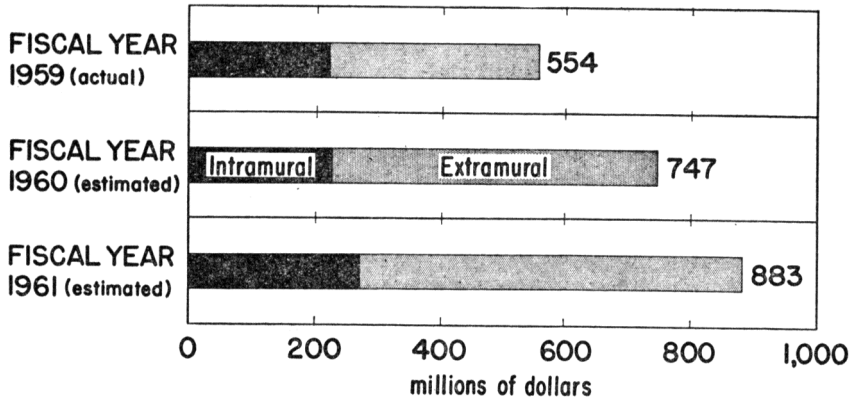
Figure 10. Percent Distribution of R&D Expenditures in Colleges and Universities, by Source of Support, Fiscal Year 1958

from provision for the national defense to promotion of the general welfare. As these broad purposes have interacted on one another since World War II—particularly in contract research—there has been mounting debate over the government-university research relationship.

A report by the President's Science Advisory Committee, which explored these difficult questions, has been noted. A few of the questions are mentioned here. First, with respect to the university's broad functions, what effect has the large-scale Federal contract research center had on the traditional activities of education, research, and service? For example, has the presence of such a center hampered the ability of graduate laboratories to serve as the training ground for future scientists? Second, in what ways has responsibility for mission-oriented Federal basic research, as well as the presence of large-scale applied research, altered the traditionally unfettered nature of university basic research? Third, in what ways can the federally supported projects in universities enhance the interdependent objectives of basic research and scientific education?

One other major issue, reflected in the NSF statistics, concerns the Federal responsibility for the conduct of basic and applied research and development within the Government's own laboratories (figs. 11a and b). Some of this work is performed by agencies that possess unique facilities, such as the Bureau of Standards and Bureau of Mines. Other Federal R&D programs are carried on intramurally because they

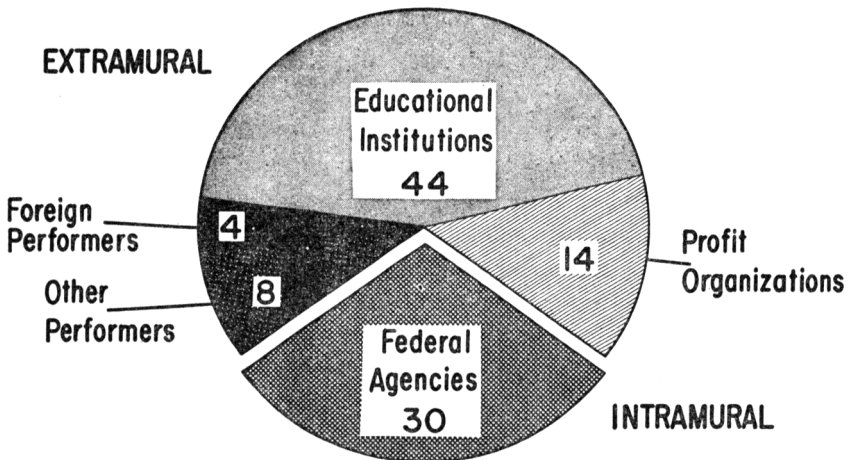
are associated with the larger regulatory and public welfare functions of an agency. In still other cases, research and development are not adaptable to such an administrative arrangement. In the greater emphasis on research in the entire Federal program, what arrangement is best fitted for each type of research is a question which will continue to demand an answer.



Source: National Science Foundation (based on *Federal Funds for Science IX*).

Figure 11a. Federal Obligations for Basic Research, by Performer, Fiscal Year 1959-61

Total Basic Research = \$747 Million



Source: National Science Foundation (based on *Federal Funds for Science IX*).

Figure 11b. Percent Distribution of Federal Obligations for Basic Research, by Performer, Fiscal Year 1960