Program Activities

of the

National Science Foundation

SUPPORT OF BASIC RESEARCH IN THE SCIENCES

Research Programs

Foundation programs in support of basic research are conducted through the Division of Biological and Medical Sciences; the Division of Mathematical, Physical, and Engineering Sciences; and the Social Science Research Program. Research projects described here are to be considered illustrative of the research being supported. Facilities support included under these programs has been limited to specialized research facilities, where the need was urgent, was clearly in the national interest, and the necessary funds were not available from other sources.

DIVISION OF BIOLOGICAL AND MEDICAL SCIENCES

Current Research Support

In the area of *Developmental Biology,* a wide variety of research was supported, covering chemical embryology (metabolism of embryos), plant growth (hormonal control), plant morphogenesis (shoot or root apex activity, floral induction, slime mold development), chloroplast differentiation, physiology of reproduction (ovarian, uterine, and placental physiology), regeneration (wound-healing), skin and tumor grafting, histology, histochemistry, anatomy, embryology (plant and animal), and cytology (mechanisms of mitosis). Specifically, studies are being supported on the sequence of the events which operate in limb formation in mammalian organisms by such techniques as tissue transplantation and interchange of organism parts; nucleic acid metabolism and the changes which occur in it during early development of the mammalian embryo; the mechanisms of cellular interactions, particularly their biochemical and biophysical aspects; the origin and fate of special initiator-cell members of cell populations; and microscopic structure and histochemistry of the fine structure of the skin in primates.

As in previous years, the *Environmental Biology* program supported a wide variety of projects including various aspects of animal and plant ecology, both terrestrial and aquatic life histories, environmental physiology, paleoecology, certain phases of parasitology, and other areas of

biology in which the major immediate emphasis is on the interrelationships between the external physical, biological, or sociological factors and one or more organisms. Although much of American research activity in environmental biology continues to be descriptive and devoted to observations of gross physical habitat and organism survival relationships, the program has emphasized studies analyzing functional aspects of the interaction, exchanges, and adjustments of the members of the plant and/or animal community and of their physical and biological environments. Interest in population dynamics in its many aspects, including cyclic phenomena, continued to be an expanding interest.

Within the *Genetic Biology* program, studies in the area of microbial genetics included work aimed at determining the mechanisms by which enzymes involved in biochemical syntheses are controlled genetically. Studies also were supported on gene-enzyme interrelationships, pointed toward enhancing our understanding of the interactions between gene and enzyme. Research on the genetics of higher plants included work on mutations in maize, as well as work on cotton and tobacco. Significant research relating to the theoretical aspects of quantitative genetics also was supported.

Some of the outstanding research supported during the last fiscal year by the *Metabolic Biology* program covered the following areas: the problem of enzyme-inhibitor relationships responsible for cellular metabolic activity; elucidation of the enzymatic mechanisms occurring in fat metabolism of higher plants; and the investigation of certain aspects of protein biosynthesis. Other exciting projects supported included a study of the function of nucleic acids in growth, differentiation and induced enzyme formation, and an investigation of the basic mechanisms of mammalian carbohydrate metabolism.

With the advent of the program covering metabolic processes, the *Molecular Biology* program was redefined to encompass studies of the physical and chemical properties of substances of biological origin; studies of individual enzymes such as isolation, purification, properties, kinetics, and mechanism of action; and such aspects of physical biology as fine structure, membrane phenomena, and chemical and physical properties of particulates. This year's grants have been concentrated in the areas of protein structure, enzyme kinetics, bioenergetics, membrane phenomena, and photobiology, with somewhat less emphasis on biogenesis, immunochemistry, and biochemical cytology.

With respect to the substance of the *Psychobiology* program, research covering the underlying neurological foundations and neurochemical aspects of behavior continued to be supported. The traditional interest of the program in relating newly developed quantitative techniques to

experimental problems in psychology was also continued through support of work on the development of psychological measurement models, and on the use of multivariate methods in psychological research. In a somewhat related area, the impact of computer techniques on research in the field of psychology is illustrated by a grant aimed at developing computer techniques for handling data from the area of learning research.

The program in *Regulatory Biology* supported outstanding research in such conventional fields as neurophysiology and endocrinology. However, exciting research in less traditional areas is illustrated by projects involved in the study of chemical processes that give rise to biological rhythms. The program also encompassed investigations of the development of regulatory processes in fetal and newborn organisms, in the chemical senses of insects, and other regulatory processes of organisms.

The areas of research in *Systematic Biology* is on essentially three levels of complexity. At the first level, the units of organic diversity are discovered, identified, characterized, and named. At the second level, the major task is classification—the arrangement of the otherwise chaotic mass of species into the so-called higher categories. At the third level, systematic biology is the study of the interrelationships of organisms in space and in time. During fiscal year 1958 grants were made to aid research on each of these levels. An illustration of the type of discovery and inventory-taking that occupies taxonomists in lesser known parts of the world is a study of the flora of the Lesser Antilles. Similar studies of the life of a different geological period cover research on the Triassic vertebrates of Argentina. The application of comparatively new techniques to problems of classification is demonstrated by research on the fine structure of pollen grains, on paper electrophoresis as a method in avian taxonomy, and on serological studies of the grass family. At the third level of complexity in the systematic area, valuable summarizing research is under way on the zoogeography and evolution of Pacific insects, on the speciation of amphibian populations, and on the Drosophilidae of the Caribbean region.

Significant Research Developments

WAX-EATING BIRDS PROVIDE CLUE FOR CONTROL OF TUBERCULOSIS.—The honey guide, a small family of bird found primarily in Africa, presents an interesting problem in animal behavior in its symbiotic (mutually beneficial) relationship with certain mammals, including human beings. Specifically, these birds guide the mammal to the vicinity of wild bees' nests and, following the foraging of such nests by

the mammal, feed avidly on the waxy comb, which constitutes their chief source of food. In the course of investigations on this behavior and on the unique problems of digestion and nutrition involved, a hitherto unidentified wax-splitting bacterium was isolated from the intestinal tract of the bird. Although this organism, *Micrococcus cerolyticus,* cannot by itself degrade wax *in vitro,* rapid breakdown of wax occurs if a mixture of ground liver, intestine, and spleen of chicks is added to the culture. Conversely, chicks, while themselves unable to digest wax, metabolize this substance effectively if it is mixed with a culture of the micrococcus.

Of particular interest is the apparent "interference" effect between the micrococcus and the tubercule bacillus, whose envelope is "waxy" or lipoidal in nature. As a result of recent studies in this connection, a protein fraction isolated from the micrococcus has been found to inhibit the growth of the tubercule bacillus in tissue culture. This apparently is a result of inhibition of the oxygen uptake of resting cells or of cell-free extracts of the bacillus. In preliminary experiments, it has been found that this protein fraction also appears to protect guinea pigs against tubercule bacillus, presumably by inhibiting the development of the infecting organisms.

This investigation may not only provide an explanation of the basic mechanisms of "interference" between two microbial species and of wax digestion but also suggests important implications in the therapy and control of tuberculosis. Moreover, this work vividly illustrates how information in one area of biological sciences may lead directly to important observations in another, superficially quite unrelated area.

BASIC GENETIC AXIOM REGARDING INDIVIDUALITY OF GENES UNDER QUESTION.—A firm belief in the individuality of genes underlies all research in modern genetics. By "individuality" is meant that a given gene will not be modified or changed in any way by external influences, except for the well-known agents, such as X-rays, which cause mutation. Although the *expression* of a gene can readily be affected in all kinds of ways, the basic nature of a gene is presumed to remain constant and unchanged, generation after generation, until such time as, by chance, it suffers a mutation. Then the new mutant form of the gene again persists almost indefinitely until such time as another mutational event may occur to produce still another mutant form of the gene.

The first case on record which clearly violates this basic axiom about the individuality of genes has been discovered. A gene in corn—one that produces color in the kernel—can be permanently modified simply by bringing it into combination with a particular one of its alleles

(partner genes). When the color gene is later removed by outcrossing from the "contaminating" influence of its partner, it is found to be no longer capable of producing normal seed pigment. Further, this loss of potency is permanent; the color gene has been mutationally changed. Thus, it is now possible to modify at will a particular gene merely by making a cross of two different kinds of corn plants.

Should this phenomenon be found to occur generally, an entirely new mechanism will have to be taken into account in explaining the origin of genetic variability, which itself underlies all evolutionary change. This discovery may well turn out to be among the most significant basic discoveries in genetics. In any event, the "individuality of genes" will never be the same again.

PLANTS SHARE ROOT SYSTEMS.—In nature, the roots of plants of many species or of individuals of the same species frequently grow together in a tangled mass. It has also been reported that natural root grafts may form between one plant and another, but the significance of this botanical curiosity is poorly understood. Grafts were revealed by examining roots of trees exposed by windfalls, excavation of roots, or by detection in a tree of substances (isotopes, dyes, poisons, etc.) injected into another tree. Injection of these substances into root systems through stumps of felled trees proved to be the most effective method of determining the transfer of material between trees, and therefore the presence of a true root graft.

It was discovered that more than half of the trees in one test plot were grafted to one or more of the neighboring trees. In another test plot not only were most of the root systems grafted together, but this method revealed that many of the seemingly dead smaller trees had living root systems which had been captured by the large trees.

These findings may bring into question one of the basic assumptions of plant ecology, namely, that most plants operate as individual entities in competition with other individual entities. These results suggest that some plants may operate as a well-knit group or unit having a common physiology. The concept of group operation could be of importance in understanding the dynamics of vegetation development.

NONNERVE TISSUE TUMOR AGENTS SPECIFICALLY INDUCE NERVE GROWTH.—Certain cancerous tissues (sarcomas) of mice contain a diffusible agent which strikingly promotes the outgrowth of nerve fibers from spinal and sympathetic ganglia (groups of nerve cells along the spinal cord) in the chick embryo to which these sarcomas have been grafted. The tumor agent is specific in that it does not stimulate the

growth of any cells other than those in the spinal and sympathetic ganglia. More recently it has been found that nerve growth factors, similar to the tumor factors, are present in the salivary glands of the mouse and rat, in snake venoms, and in the venom of the Gila monster. Both the sarcoma and venom factors are proteins which obtain their effects by stimulating the protein-synthesizing machinery of the nerve cell. As one of several examples of the influence of diffusible protein growth-promoting substances upon cell behavior, these studies advance our understanding of the control of pathological and normal growth in animals, including man.

MECHANISM OF INFORMATION-EXCHANGE BETWEEN CELLS PROBED.—Understanding the process of development of multicellular organisms from the original single cell, the fertilized egg, requires knowledge of the control mechanism by which cells interact (exchange information) to promote orderly growth and differentiation.

A most promising technique for studying this phenomenon has been that of interposing barriers, such as filters and membranes, between interacting cellular groups. Results so far obtained show that direct surface contact between cells is not necessary for the transmission of information from one cell to another (in the form of special information-bearing molecules). There are indications that the chemical transfer of information occurs via cytoplasmic bridges connecting the cells and low macro-molecular bridges of the matrices which surround the cells.

SEX HORMONES CONTROL PLANT GROWTH.—Sex hormones not only control sex organ formation and sexual behavior in animals and the higher plants but have been recently discovered to play a similar role in the more primitive plants (water molds and ferns). In the water molds the sexual process is composed of a number of distinct reactions which occur alternately in the male and in the female, and each reaction is directly dependent both for its initiation and regulation upon a hormone(s) produced by the plant during the last preceding stage. Particularly interesting is the isolation and chemical characterization of a specific male sex organ-inducing agent secreted by the sex cell-producing stage (prothallium) of the common bracken (fern). This agent, at a concentration of one part in 30,000, is able to transform almost half of the cells of the test fern prothallium into male sex organ-producing cells, whereas no male sex organs develop in the untreated controls. The agent which is organ specific, but not species specific, has been identified as an unsaturated aliphatic acid with a molecular weight of about 500.

PROTEIN-LIKE MATERIALS SYNTHESIZED DIRECTLY FROM AMINO ACIDS.—Proteinoids (protein-like material) have been produced by the application of heat (170° C.) to mixtures of amino acids. By the use of two acids—aspartic and glutamic—in excess quantities, it has been possible by adding various mixtures of the 18 amino acids which occur in natural proteins to produce substances with characteristics of proteins. The amino acids polymerize in a specific nonrandom order. By the proper selection of these amino acids, it is possible to synthesize proteinoids which contain desired pharmacological properties, etc.

The sequence of reactions and products formed through thermal action on amino acids to produce proteinoids gives strength to one of the hypotheses of biogenesis—namely, that complex biological molecules originally came into existence in the presence of moderately high temperatures, possibly resulting from the intrusion of hot volcanic magma into marine waters or by the inundation of heated tidal pools.

THE ALTERATION OF PROTEINS AT WILL.—The discovery of a method for introducing sulfur in the form of sulfhydryl (-SH) groups and disulfide (-SS-) groups into proteins and protein-like molecules has made it possible to alter at will the physical, chemical, and physiological characteristics of proteins. This development not only provides an excellent tool for probing the structure of the protein molecule, but also permits tailoring of proteins with desired medical and industrial characteristics.

The reagent used is N-acetylhomocysteine thiolactone with silver as a catalyst. The number of -SH groups introduced is controlled by varying the concentration of silver. These -SH groups are incorporated into the protein molecule through displacement of amino groups ($-NH_2$).

A nonmelting gelatin which has promise as photographic emulsion, and a nonsolidifying gelatin which might be used as a plasma extender have been prepared. Similarly a protein fraction with which antibiotics, mercurial diuretics, etc., may be conjugated to extend the life and potency of these agents has been postulated. The use of this process on aminated cotton has produced a product with a number of wool-like characteristics. (-SS- groups are the chief crosslinks in wool fabrics, but are absent in natural cotton.) This thiolated cotton is highly efficient for removing heavy metals from solution and is an insoluble oxidizing and reducing agent (electron exchanger).

THE TRANSPORT OF PROTEINS ACROSS THE INTESTINAL BARRIER.—During the digestive process enzymes, such as trypsin, break down pro-

teins into their constituent amino acids which are then absorbed into the circulatory system through the intestinal lining.

By feeding a trypsin inhibitor in conjunction with a protein, such as insulin, intact protein molecules can be transported across the intestinal barrier into the blood without previous breakdown.

These experiments may well explain the manner in which antibodies in colostrum (the early milk from mothers) are transmitted to the infant. This research also indicates a strong possibility that, through the use of digestive enzyme inhibitors, essential protein-like molecules may be introduced into the circulatory system by oral administration rather than through commonly used injection techniques.

BASIC HEREDITARY AND VIRUS MATERIAL SYNTHESIZED ENZYMATICALLY.—By adding an enzyme obtained from bacteria (DNAase) to a previously prepared mixture of nucleic acids, it has been possible to synthesize deoxyribonucleic acid (DNA), the basic hereditary and virus material. The mixture required the addition of a small amount of DNA as a primer as well as magnesium ions. (The net synthesis of DNA exceeded that added as a primer by twentyfold.) The enzymatically synthesized product had the same structure as proposed by Watson and Crick for natural DNA (two nucleic acids chains which wind around each other in a double spiral). Chemical understanding of DNA replication increases our knowledge of heredity, and the reproduction of viruses. Since one of the hypotheses held by medical scientists is that the synthesis of DNA differs in cancer cells from that in normal cells, the key to understanding cancer may lie in just such experiments.

VIRULENCE OF BACTERIA DETERMINED BY ADDITION OF CELLULAR COMPONENTS.—As previously mentioned, the biological properties of DNA, a vital constituent of the nucleus of all animal and plant cells, are of paramount importance since this compound is closely associated with the process of reproduction and the transmission of hereditary factors.

In recent studies on the growth of a number of different bacterial species (e. g., *Brucella abortus, Diplococcus pneumoniae*), it has been found that addition of a mixture of bacterial DNA and deoxyribonuclease (DNAase)—the enzyme specific for its hydrolysis—to growing cultures of these organisms produces striking effects upon the selective establishment of virulent cells in an initially nonvirulent population. Two different mechanisms are operative in causing this effect—a selective inhibition of the growth of nonvirulent cells (Brucella) or a selective stimulation of the multiplication of virulent cells (pneumococci), which may be associated with increased DNA synthesis. In addition to this

striking effect on bacterial cells, experimental evidence indicates that these DNA-DNAase digests are capable of stimulating the rate of multiplication of lymphosarcoma cells in mice. Certain antagonists to the DNA-DNAase effect, such as protamines, DNA-protein antisera, and kinetin riboside have been observed. One of these (kinetin riboside) produces increased selective inhibitory effects against virulent pneumococci and lymphosarcoma cells when administered in combination with DNA and DNAase.

Information of this sort concerning the factors and mechanisms which are involved in determination of the relative virulence of microorganisms is of considerable interest because of its relationship to an understanding of the phenomena of resistance and susceptibility to infectious diseases as well as to a possible therapeutic treatment of infections and malignant disease.

Exploration of South American "Lost World".—The Guyana Highland, the principal mountain-mass of South America north of the Amazon and east of the Andes, lies in southern Venezuela, with conspicuous extensions into Brazil, Colombia, and the Guianas. It is a spectacular area of numerous discontinuous and isolated tabular mountains characteristically ringed by high vertical cliffs whose summits are continuously wreathed in clouds of overhanging mists. Threaded by uncharted rivers, and uninhabited except for small groups of often hostile Indians, this is the "Lost World" hinted at by Conan Doyle and W. H. Hudson. Until 1944 only a few fringes of this vast unknown region had been touched by scientists. Since that time a program of exploration has taken place which, even in these modern times when the world's surface is thought to be known, is a classic comparable to the discoveries of a century ago. A totally unsuspected mountain, now named Neblina, 50 miles long and 10,500 feet high, has been discovered by a group of scientists who have made 18 expeditions in the Guyana Highland during the past 14 years.

The flora of this region, now being made known for the first time, is spectacular in the extreme, containing an extraordinary number of unsuspected native plants at the level of genus and species. Furthermore, the region appears to be the center of distribution for many ancient groups of plants. The explorers have now reached the end of a phase of their work and are turning to detailed study and evaluation of the many thousands of collected specimens. A fuller knowledge of this flora will provide biogeographers with data crucial to a knowledge of plant distribution throughout tropical America.

Facilities for Research in the Biological and Medical Sciences

During fiscal year 1958, grants were made for facilities support at a cost of slightly less than $1 million. Among these grants was one for $544,250 to the Marine Biological Laboratory at Woods Hole, Massachusetts, to cover one-fourth the cost of constructing a new research laboratory building and the complete cost of constructing 25 cottages for housing scientists and their families. The new research building will replace 3 antiquated wooden laboratory buildings and will provide additional working space. The Rockefeller Foundation is providing one-half, and the National Institutes of Health one-fourth, of the total laboratory costs. By providing additional housing, this grant will enable scientists, especially younger ones with growing families and limited incomes, to take advantage of the Laboratory's facilities for summertime research. Many have been discouraged by the economics of the situation—in this case, the cost of rental housing in a summer resort area.

A grant of $200,000 was made to the Jackson Memorial Laboratory to permit building an addition to the main building to satisfy immediate and pressing research space. The two other sizable facility grants were those to the Missouri Botanical Garden ($60,000) for herbarium and library facilities for botanical research, and to the Museum of Comparative Zoology, Harvard University ($300,000) for museum facilities for research in systematic zoology and paleontology.

Somewhat related to facility support were a number of equipment-type grants of a size beyond that normally encountered in ordinary research proposals. These varied from a grant for an ultracentrifuge to grants for the purchase and installation of electron microscopes. In all cases, equipment grants were made on a basis of the quality of the research program in which the equipment was to play an integral part. In the case of electron microscopes, it also was the practice of the Division to have assurances from the recipient institution that it would participate in the support of the microscope by providing for a full-time operator whose salary was to come from the institution receiving the equipment.

DIVISION OF MATHEMATICAL, PHYSICAL, AND ENGINEERING SCIENCES

Current Research Support

The *Astronomy* program, perhaps more than any other discipline, has felt the impact of the new interest in space. The excitement and importance of what was sometimes considered mere star-gazing are rapidly

becoming apparent. For example, studies of the minor planets, which number in the tens of thousands, will give their locations to the degree of accuracy required for navigation in interplanetary space. The sun, too, is the object of intensive study to answer such questions as: How does the sun eject cosmic rays? What is the precise nature of the sun's surface? These and many other questions have taken on new importance, and answers for them are being sought.

Grants in the *Chemistry* program have continued to emphasize organic and physical chemistry, with support also for inorganic and analytical chemistry. The special support provided for basic research in high polymers was continued during the year, but plans have been made to incorporate this support within the framework of the existing subdisciplines. Of special interest are grants involving total synthesis and reaction mechanisms.

Fields of special emphasis in the *Earth Sciences* program included geochemistry, which is becoming more and more identifiable with classical geology, and meteorology. The other fields have remained in about the same relative positions from the standpoint of support received, and include geology, oceanography, geophysics, and aeronomy. A new program for *Atmospheric Sciences* will be established in fiscal year 1959, to deal primarily with meteorology and the sciences basic to meteorology, including phenomena of the upper atmosphere.

The research supported by the *Engineering Sciences* program is by its nature more nearly part of a "closed feedback loop" in that the need for further basic study is frequently brought to focus through applications of previous research. Grants were made in the fields of mechanics of solids, transfer and rate mechanisms, thermodynamics, properties of materials, fluid mechanics, and electrical theory.

The *Mathematical Sciences* program, on the other hand, is perhaps the farthest removed from "feedback." It continues to support research in areas of applied mathematics as well as in algebra, analysis, topology, and geometry. Mathematical research, of course, differs from research in the experimental sciences in that it cannot be done by designing and performing an experiment, but must be carried out by the mathematician thinking about the problem.

The *Physics* program placed major emphasis on high energy physics, particularly involving the interactions of elementary particles. The program has found grants to be especially effective when they provide either for scientists in smaller institutions to work with those from larger ones, or for team attacks through which staff members of several small institutions join together on a problem.

CLOUD SEEDING PROVIDES BASIC WEATHER MODIFICATION KNOWLEDGE.—The increasing attention paid to the possibilities of weather modification, such as production of rain to alleviate dry spells, has dramatized the lack of knowledge of the basic processes which cause weather and atmospheric conditions. Interpretation of the much publicized cloud-seeding experiments has largely been speculative, for the basic physics of clouds is as yet largely unexplored. A series of National Science Foundation grants have begun to make up the deficiences in knowledge in this area. In one case, clouds developing day after day in the same place, near Tucson, Arizona, were observed visually with stereographic cameras, and with radar. Areas of cloud development were seeded on certain days selected at random, and the results were compared with those of nonseeded days. Although the number of tests was not sufficient to determine statistically how effective seeding may be, the radar showed that precipitation from larger seeded clouds appeared to be greater than from similar unseeded ones. This represents a real gain in our understanding of how the seeding of cumulus clouds can result in an increase in precipitation.

ULTRASONIC WAVES USED FOR NEUROSURGERY.—Because of interest in what happens as a result of intense uniform concentration of ultrasonic waves (those with frequencies which are far above normal hearing level), a neurological instrument was developed under a Foundation grant which employs ultrasonic waves rather than cutting edges. This device focuses sound waves into extremely small precise regions in the brain, permitting much more detailed study and understanding of various portions of the brain. A most important aspect of the new tool is that it may be employed to cut out tiny regions of the inner brain without disturbing the outer structure. This type of bloodless surgery has been used in abating the tremor of Parkinson's disease.

STREAM MODEL MAY AID IN FLOOD CONTROL.—Basic engineering research on the effects of underwater dunes on the roughness, velocity, and sediment-transporting capacity of a stream may well revolutionize thinking about flood control and care and use of natural waterways. A laboratory model of a stream used in conjunction with a high-speed motion-picture camera has resulted in clarification of the motion of individual sand grains in a flowing stream. The entire pattern of sand dune movement has been speeded up through use of the model. Basic knowledge has been supplied which, when applied to particular conditions in specific streams, can bring about more efficient and soundly based flood-control programs.

PEGMATITE FORMATION GIVES CLUE TO LOCATION OF IMPORTANT MINERALS.—One of the most puzzling rocks found in the earth's crust is called "pegmatite," or "giant granite." The pegmatites contain minerals commonly found in granites, but in much larger crystals. These large crystals are easily mined and separated, so that pegmatites consitute our chief source of certain mineral commodities, such as feldspar (used as an abrasive) and mica (used as electrical insulation). Also, large crystals of rare minerals in pegmatites are our principal source of elements, such as lithium and beryllium. How did such large crystals grow? Most geologists have believed that the giant crystals must have been deposited from hot dilute solutions rich in volatiles. The excess water was presumed to have escaped upward to the earth's surface.

Recent field and laboratory studies have upset the old ideas. The hypothesis has now been evolved that pegmatites are relatively dry melts (magmas) and are closed physico-chemical systems, and that the giant crystals are formed during a "second boiling." Early crystallization releases latent heat and enriches the residual magma in water enough to saturate it. At this point a vapor phase is produced, which is responsible for both the transport of the material and the formation of the giant crystals. Laboratory tests have confirmed these ideas; miniature pegmatites actually have been produced.

This is of great practical interest in guiding the exploitation of known bodies of pegmatite minerals and in searching for undiscovered deposits, for it shows that such deposits wil be shallow and contained within a limited area. In addition, since the phenomenon apparently applies to other types of molten rock, many other investigations are suggested which may lead to information about the origin of various ores and the discovery of additional sources of these ores.

REACTIONS OF FREE RADICALS STUDIED IN SLOW MOTION.—Atoms or groups of atoms bonded together by pairs of electrons can be split to yield positive and negative ions. For example, atoms "A" and "B" bonded by two electrons can be split to yield "A" with a positive charge and "B" with a negative charge and both electrons attached to it. Another kind of split yields neutral "free radicals", i. e., atoms "A" and "B" with one electron attached and no charge. Such free radicals are among the most reactive species known to chemists, and have long defied study because of their extreme instability, that is, their tendency to recombine almost at once. Recently techniques have been worked out whereby the free radicals are formed and immediately trapped on cold surfaces (20° K., or −424° F.). This freezing permits detailed spectroscopic study of their properties, and a slow warming of the surface per-

mits investigation in "slow motion" of their reactions. For example, a National Science Foundation grantee has formed such a free radical, CH_2, and has brought about its reaction with ethene, ketene, and other compounds, a yield cyclopropane, cyclopropanone, and the like—reactions which would not take place at ordinary temperatures. The combination or reaction of these free radicals produces a vast amount of energy, which, if it could be captured, would be promising for rocket propulsion. The radicals might also be used as unique reagents to carry out otherwise unattainable chemical syntheses.

GRAVITY STUDIES REVEAL EARTH SUBSTRUCTURE.—Recent geological and geophysical work in Utah and eastern Nevada has shown that the rock structure of the area is exceedingly complex. A team of researchers under a grant from the National Science Foundation has made detailed measurements of variations in the pull of gravity throughout the area and, from these variations, has been able to chart the major contours of the buried bedrock and obtain important clues as to the configuration of fault blocks and other structural patterns. This represents a significant advance in the technique of "underground mapping." In addition, the fact that these particular structural patterns have now been mapped may be of economic importance in determining where mineral deposits and ground water are likely to be found. These patterns are also important because of the relationship between the faults and earthquake hazards in the region. In the Salt Lake region, for example, earthquakes tend to occur along the Wasatch fault zone, which passes through Salt Lake City and was mapped in part by this survey.

CHEMISTS CONSTRUCT MOLECULES BY STEREOSPECIFIC SYNTHESIS AND POLYMERIZATION.—Organic chemists have long been aware that a given compound can exist in two or more forms which differ only in the geometric relationship of a given atom or group to the rest of the molecule. Only recently, however, has the vital importance of this spatial arrangement or "molecular configuration" been appreciated. Very often one form will possess much greater biological activity than its isomers. Therefore, chemists have put much effort into learning how to manipulate molecules to produce the desired configurations.

One researcher partially supported by a Foundation grant has successfully completed the total stereospecific synthesis (producing only the desired molecular configuration) of several antibiotics. The techniques devised for doing this can be applied to future syntheses, thus leading to new antibiotics. Another grantee recently announced the first total stereospecific synthesis of the alkaloid yohimbine, after four years of work.

Yohimbine is structurally related to reserpine, which has found use as a tranquilizer and hypertensive agent. This work thus paves the way for synthesis of the structurally more complicated reserpine, and ultimately of improved derivatives.

Other workers have been studying the molecular configurations of compounds which can undergo polymerization to yield high molecular weight compounds. One researcher has produced a substance which is identical with natural rubber in its physical characteristics, by carefully controlling the spatial relationships of the groups in the molecule. Through this control of configuration, many new synthetic substances—potential fibers, rubbers, and plastics—have already been produced and are being considered by industry for development.

Facilities for Research in the Mathematical, Physical, and Engineering Sciences

Facilities support in this area during 1958 totaled approximately $5 million. A supplemental award of $1,130,000 was made to the Associated Universities, Inc., for the construction of the National Radio Astronomy Observatory in Green Bank, W. Va. This is in addition to a previous grant of $4,000,000. Complete installation of an 85-foot Blaw-Knox equatorially mounted paraboloid telescope is expected before the end of calendar year 1958. Design of a 140-foot telescope has been completed, and a contingent contract for construction has been signed.

After a 3-year program of site survey and testing, the National Optical Astronomy Observatory will be established at Kitt Peak, Arizona. The Association of Universities for Research in Astronomy, Inc., has been given a grant of $3,100,000 to go ahead with construction. Plans for a 36-inch reflecting telescope and associated housing have already been completed. Designs for an 80-inch telescope are being developed. A permanent director for the Observatory, Dr. A. B. Meinel, was appointed.

Three grants for computer installation were made—$50,000 to the University of Oklahoma, $50,000 to Iowa State University, and $100,000 to the University of Minnesota.

Support for nuclear reactors was provided to two universities—$150,000 to the University of Virginia, and $300,000 to the State College of Washington.

SOCIAL SCIENCE RESEARCH PROGRAM

On August 1, 1957, a unified Social Science Research Program was established as an outgrowth of a 4-year study of the Foundation's re-

sponsibilities within this area. The new program replaces the program in "convergent fields of natural and social sciences" previously conducted by the two research divisions, and is concerned with selected fields in the scientific study of human social behavior. The present Social Science Research Program includes four areas: anthropological sciences, sociological sciences, economic sciences, and the history and philosophy of science.

Current Research Support

The *Anthropological Sciences* program includes basic research in archaeology, physical anthropology, ethno-botany, ethnology, psycholinguistics, and related fields. One project is concerned with the utilization of electronic computers in linguistic analysis. Another grantee is studying the order and acquisition of consonant clusters in child language. An archaeological investigation and a study of an aboriginal American Indian group by a team of anthropologists, biologists, and geographers may yield knowledge of the relationships of culture, ecology, and environmental adaptation.

A grantee in the *Sociological Sciences* is exploring new techniques in research on migration. The achievement and potential of Soviet science, as viewed by American scientists returning from Russia, is the subject of another study. In still a third area an investigator is studying problems of identification and family structure to determine how variations in parental behavior may affect the child's personality.

Problems of primary importance to the Foundation, in the light of its congressional mandate to investigate the social and economic consequences of science, are encompassed in the *Economic Sciences.* One grantee is investigating technological change from an econometric point of view, while another is studying the economics of invention. A third grant is mentioned below under research developments.

Grants were made in the area of *History and Philosophy of Science* for research on early American science, on the origins of anatomy and physiology, and on the philosophical foundations of physics.

Significant Research Developments

COMPUTERS PROGRAMED TO PREDICT BUSINESS CYCLES.—The results of a study on the use of electronic computers in analyzing current economic indicators, which has received an additional grant for refinement of techniques, have significantly advanced computer-analysis knowledge.

In the past, seasonal and irregular business fluctuations, usually much larger than changes in underlying cyclical or major trends, made trustworthy prediction most difficult. The new method provides a quicker and more sensitive measure for determining the stages of the business cycle and separates meaningful trends from temporary irregularities. It is already in use and has proved of value both to Government and private industry in gauging the direction and strength of current trends.

Scientific Conferences and Symposia

During the past fiscal year, the Foundation sponsored and provided partial support for 34 scientific conferences and symposia. In most instances sponsorship was shared with one or more private or public agencies, including universities and scientific societies.

INTERNATIONAL CONFERENCE ON CURRENT PROBLEMS IN CRYSTAL PHYSICS—Cambridge, Massachusetts, July 3–6, 1957; Chairman: John C. Slater, Department of Physics, Massachusetts Institute of Technology, Cambridge, Massachusetts; Cosponsors: Massachusetts Institute of Technology, The International Union of Pure and Applied Physics.

CONFERENCE ON NATURAL AND SYNTHETIC MINERALS—University Park, Pennsylvania, July 5–8, 1957; Chairman: Joseph V. Smith, Department of Mineralogy, Pennsylvania State University, University Park, Pennsylvania; Cosponsor: Pennsylvania State University.

FOURTH GENERAL ASSEMBLY AND CONGRESS OF THE INTERNATIONAL UNION OF CRYSTALLOGRAPHY—Montreal, Canada, July 10–19, 1957; Chairman: John S. Coleman, National Academy of Sciences—National Research Council, Washington, D. C.; Cosponsors: Philips Electronics, Inc., Research Corporation, General Electric Co.

WORLD CONFERENCE ON PRESTRESSED CONCRETE—Berkeley, California, July 28–August 1, 1957; Chairman: T. Y. Lin, University of California, Berkeley, California; Cosponsors: University of California, American Society of Civil Engineers, American Institute of Architects, American Association of State Highway Officials, American Concrete Institute, Prestressed Concrete Institute.

CONFERENCE ON LIQUID SCINTILLATION COUNTING—Evanston, Illinois, August 20–22, 1957; Chairman: Carlos G. Bell, Jr., The Technological Institute, Northwestern University, Evanston, Illinois; Cosponsor: Northwestern Technological Institute.

FIFTH INTERNATIONAL CONFERENCE ON LOW TEMPERATURE PHYSICS AND CHEMISTRY—Madison, Wisconsin, August 26–31, 1957; Chairman: Joseph R. Dillinger, Department of Physics, University of Wisconsin, Madison, Wisconsin; Cosponsors: University of Wisconsin, International Union of Pure and Applied Physics.

GORDON RESEARCH CONFERENCES—New Hampshire, Summer 1957; Chairman: W. George Parks, Department of Chemistry, University of Rhode Island, Kingston, Rhode Island; Cosponsor: American Association for the Advancement of Science.

CONFERENCE ON PHOTOCHEMISTRY OF SOLID AND LIQUID SYSTEMS—Dedham, Massachusetts, September 3–7, 1957; Chairman: Farrington Daniels, Department

of Chemistry, University of Wisconsin, Madison, Wisconsin; Cosponsor: National Academy of Sciences—National Research Council.

SYMPOSIUM ON SYSTEMATICS: BASIC CONCEPTS AND TECHNIQUES IN SYSTEMATICS—St. Louis, Missouri, October 25–26, 1957; Co-Chairmen: Carl Epling, University of California, Los Angeles; and Ernest Mayrl, Harvard University, Cambridge, Massachusetts; Cosponsor: Missouri Botanical Garden.

SYMPOSIUM ON PHOTOPERIODISM—Gatlinburg, Tennessee, October 29–November 2, 1957; Chairman: Robert B. Withrow, Smithsonian Institution, Washington, D. C.; Cosponsors: None.

CONFERENCE ON THE CHEMISTRY OF SULFUR AND CHLORINE COMPOUNDS IN THE ATMOSPHERE—Cincinnati, Ohio, November 4–6, 1957; Co-Chairmen: J. P. Lodge, Jr., Robert A. Taft Sanitary Engineering Center of the Public Health Service, Cincinnati, Ohio; and Waldo E. Smith, American Geophysical Union, National Academy of Sciences—National Research Council, Washington, D. C.; Cosponsors: Public Health Service, National Academy of Sciences—National Research Council.

SIXTH INTERNATIONAL CONFERENCE ON COASTAL ENGINEERING—Gainesville, Florida, December 2–7, 1957; Chairman: Murrough P. O'Brien, The Council on Wave Research, University of California, Richmond, California; Cosponsors: University of Florida; The Council on Wave Research, University of California.

CONFERENCE ON HIGH TEMPERATURE RESEARCH—Chicago, Illinois, December 11–13, 1957; Chairman: Mark G. Inghram, Department of Physics, University of Chicago, Chicago, Illinois; Cosponsor: University of Chicago.

CONFERENCE ON NUCLEAR SIZES AND DENSITY DISTRIBUTIONS—Stanford, California, December 17–19, 1957; Chairman: Robert Hofstadter, Department of Physics, Stanford University, Stanford, California; Cosponsor: Stanford University.

INTERNATIONAL SYMPOSIUM ON THE AXIOMATIC METHOD—Berkeley, California, December 26, 1957–January 4, 1958; Co-Chairmen: Delon Henkin and Alfred Tarski, Department of Mathematics, University of California, Berkeley, California; Cosponsors: University of California, International Union for the History and Philosophy of Sciences.

CONFERENCE ON BIOCHEMICAL AND SEROLOGICAL CHARACTERIZATION OF PROTEINS—New Brunswick, New Jersey, January 24–25, 1958; Chairman: Alan Boyden, The Serological Museum, Rutgers, The State University, New Brunswick, New Jersey; Cosponsor: Rutgers, The State University.

SYMPOSIA ON THE STRUCTURE AND FUNCTION OF MICROSOMAL PARTICLES AND ON THE NATURE OF MUSCLE PROTEIN—Cambridge, Massachusetts, February 5–7, 1958; Chairman: Cyrus Levinthal, Department of Biology, Massachusetts Institute of Technology, Cambridge, Massachusetts; Cosponsor: The Biophysical Society.

A SEMINAR SERIES ON DEVELOPMENTAL BIOLOGY—New York, New York, February 5–March 13, 1958; Chairman: Paul Weiss, Laboratory of Developmental Biology, The Rockefeller Institute, New York, New York; Cosponsor: Rockefeller Institute.

CONFERENCE ON RESEARCH POTENTIAL AND TRAINING IN THE MATHEMATICAL SCIENCES—Chicago, Illinois, February 12–13, 1958; Chairman: A. A. Albert, Division of Mathematics, National Academy of Sciences—National Research Council, Washington, D. C.; Cosponsors: University of Illinois, National Academy of Sciences—National Research Council, University of Chicago.

CONFERENCE ON BASIC ENGINEERING SCIENCES RESEARCH IN THE WEST—Boulder, Colorado, February 17–18, 1958; Chairman: W. G. Worcester, Engineering Experi-

ment Station, University of Colorado, Boulder, Colorado; Cosponsor: University of Colorado.

SYMPOSIUM ON CELESTIAL MECHANICS—New York, New York, March 17–18, 1958; Chairman: Jan Schilt, Rutherford Observatory, Columbia University, New York, New York; Cosponsor: Columbia University.

SYMPOSIUM ON THE CHEMICAL BASIS OF DEVELOPMENT—Baltimore, Maryland, March 24–27, 1958; Chairman: William D. McElroy, Department of Biology, Johns Hopkins University, Baltimore, Maryland; Cosponsor: The McCollum-Pratt Institute of Johns Hopkins University.

CONFERENCE ON SALT MARSH RESEARCH—Sapelo Island, Georgia, March 25–28, 1958; Chairman: Robert A. Ragotzkie, University of Georgia Marine Biology Laboratory, Sapelo Island, Georgia; Cosponsor: University of Georgia Marine Biology Laboratory.

THIRD ANNUAL MIDWEST CONFERENCE ON THEORETICAL PHYSICS—St. Louis, Missouri, March 1958; Chairman: Edward U. Condon, Department of Physics, Washington University, St. Louis, Missouri; Cosponsor: Washington University.

CONFERENCE ON SYSTEMATIC BIOLOGY IN PRIVATE INSTITUTIONS—Philadelphia, Pennsylvania, May 19–20, 1958; Chairman: H. Radclyffe Roberts, The Academy of Natural Sciences of Philadelphia, Philadelphia, Pennsylvania; Cosponsor: The Academy of Natural Sciences of Philadelphia.

SYMPOSIUM ON SULPHUR IN PROTEINS—Falmouth, Massachusetts, May 23–24, 1958; Chairman: Reinhold Benesch, Marine Biological Laboratory, Woods Hole, Massachusetts; Cosponsors: American Heart Association, Marine Biological Laboratory.

CONFERENCE ON COMPARATIVE ENDOCRINOLOGY—Cold Spring Harbor, New York, May 26–29, 1958; Chairman: Aubrey Gorbman, Department of Zoology, Columbia University, New York, New York; Cosponsor: Columbia University.

CONFERENCE ON HYPERCONJUGATION—Bloomington, Indiana, June 2–4, 1958; Co-Chairmen: V. J. Shiner, Jr., and E. Campaigne, Department of Chemistry, Indiana University, Bloomington, Indiana; Cosponsors: Indiana University Alumni Foundation, American Cyanamid Company, Eli Lilly and Company, Esso Research and Engineering Company, Humble Oil and Refining Company.

XXIII COLD SPRING HARBOR SYMPOSIUM ON QUANTITATIVE BIOLOGY—Cold Spring Harbor, New York, June 3–11, 1958; Chairman: Bruce Wallace, Biological Laboratory, Long Island Biological Association, Cold Spring Harbor, New York; Cosponsors: Carnegie Corporation of New York, Association for the Aid of Crippled Children, The National Institutes of Health.

CONFERENCE ON THE STRUCTURE OF MUCOPOLYSACCHARIDES—Ipswich, Massachusetts, June 5–7, 1958; Chairman: Endre A. Balazs, The Retina Foundation, Boston, Massachusetts; Cosponsor: The Retina Foundation.

17TH GROWTH SYMPOSIUM: DIFFERENTIATION AND GROWTH IN RESPONSE TO A CHANGING CHEMICAL ENVIRONMENT—South Hadley, Massachusetts, June 9–11, 1958; Chairman: James D. Ebert, The Carnegie Institution of Washington, Baltimore, Maryland; Cosponsor: The Society for Study of Development and Growth.

SYMPOSIUM ON STATISTICAL METHODS IN RADIO WAVE PROPAGATION INVESTIGATIONS—Los Angeles, California, June 18–20, 1958; Chairman: W. C. Hoffman, Department of Engineering and Engineering Extension, University of California, Los Angeles, California; Cosponsor: University of California, Los Angeles.

INDUSTRY-UNIVERSITY CONFERENCE ON RESEARCH ON ELECTRICAL ENGINEERING—Columbus, Ohio, June 19–20, 1958; Chairman: M. S. Oldacre, Stanford Research Institute, Menlo Park, California; Cosponsors: American Institute of Electrical Engineers Committee on Research, Ohio State University.

CONFERENCE ON ANALYSIS OF COMPOSITE RADIATION FROM STELLAR SYSTEMS—Madison, Wisconsin, June 30, 1958; Chairman: A. E. Whitford, Washburn Observatory, University of Wisconsin, Madison, Wisconsin; Cosponsor: University of Wisconsin.

Research-Related Activities

Support of Travel to International Scientific Meetings

Because direct contact among scientists is important to the advancement of scientific knowledge, the Foundation partially defrays travel expenses for a limited number of American scientists to attend selected international meetings and congresses abroad. In addition, travel grants are sometimes made for such purposes as visits to laboratory or research sites. The awards to the scientist generally amount to round trip air-tourist fare between his home institution and the location of the meeting. In 1958, 190 scientists received such grants at a cost of $113,220.

Training Aspects of Research Grants

Research grants play an important role in the training of both predoctoral and postdoctoral research assistants and associates. During 1958, approximately 1,165 in this category received advanced training through participation in research projects under the direction of many of the Nation's most capable scientists.

When this number is added to the 1,348 awards made through the Foundation's formal fellowship programs, we find that a total of 2,515 have been given the chance to further their scientific education and to gain valuable laboratory experience while working under the aegis of seasoned and highly competent investigators.

Miscellaneous Grants

Among these are support for short-term research by medical students, an extension of the previous year's program; grants to biological field stations to provide summer research training stipends for postdoctoral investigators, graduate students, and teachers from small colleges; grants to provide summer training for college and high school teachers who serve as research assistants to scientists; and support for an internship program in mathematical research under which postdoctoral mathematicians investigate selected fields of applied mathematics under special guidance.

Fiscal Analysis of Research Programs

The Foundation during the 1958 fiscal year made grants totaling $25,049,155 for the support of basic research in the sciences, including $5,934,250 for the maintenance and construction of research facilities. These funds provided 1,120 grants in the biological, medical, mathematical, physical, engineering, and social sciences to 293 institutions in all 48 States, Alaska, Bermuda, Canada, Great Britain, Hawaii, Lebanon, Puerto Rico, and Switzerland. Research grants for fiscal year 1958 averaged $18,085 for a period of 2.09 years, or about $8,653 a year.

Facilities grants were discussed in detail previously in the sections dealing with the programs of the research divisions.

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

National Science Foundation Research Grants by Fields of Science, Fiscal Year 1958

	Number	*Amount*
Biological and Medical Sciences:		
Developmental	48	$604,300
Environmental	78	953,600
Genetic	57	711,150
Metabolic	74	1,482,350
Molecular	78	1,609,100
Psychobiology	62	968,800
Regulatory	70	1,075,280
Systematic	103	1,036,450
General	35	440,100
	605	8,881,130
Mathematical, Physical, and Engineering Sciences:		
Astronomy	33	1,017,830
Chemistry	134	2,323,900
Earth Sciences	70	1,246,395
Engineering	88	1,538,400
Mathematics	72	1,242,100
Physics	69	2,139,200
	466	9,507,825
Social Sciences:		
Anthropology	22	384,100
Sociology	14	182,100
Economics	5	93,300
History and Philosophy of Science	8	66,450
	49	725,950
Total	1,120	19,114,905

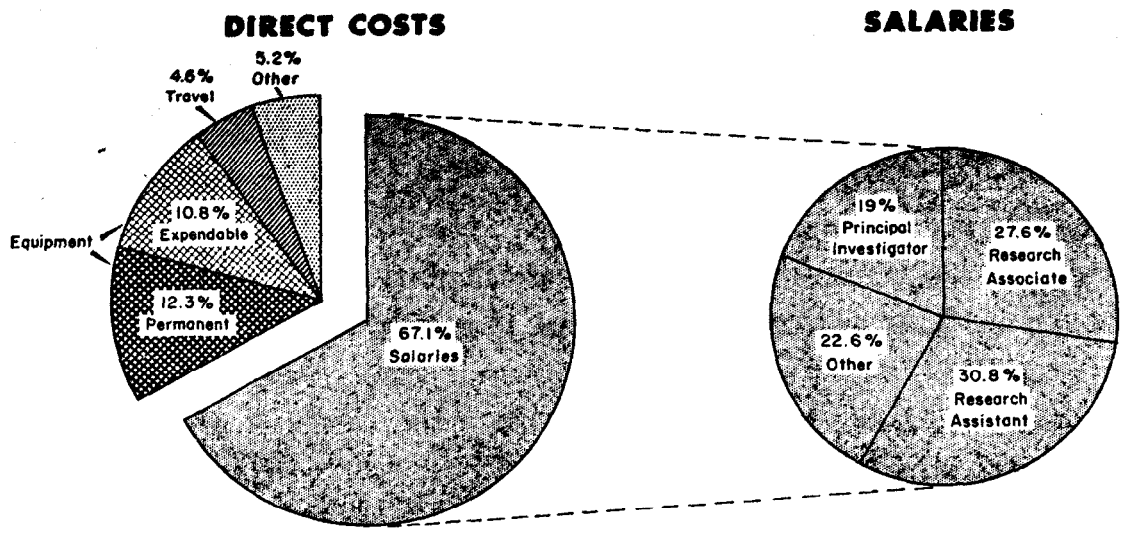


Figure 1.—*Analysis of the average National Science Foundation Research grant in fiscal year 1958 by types of expenditures (estimated).*

Analysis of Salaries Paid From Research Grant Funds,[1] Fiscal Year 1958

	Average grant, fiscal year 1958	
	Amount	*Percent of salaries*
Principal Investigator (total)	$2,027	19.0
Summer	(1,503)	(14.1)
Sabbatical	(84)	(.8)
Academic	(440)	(4.1)
Research Associate [2]	2,953	27.6
Research Assistant [3]	3,283	30.8
Other [4]	2,412	22.6
Total	10,675	100.0

[1] Based on Budget Estimates at the time of Board approval.

[2] Includes post-Ph. D. scientific personnel normally spending full time on research and usually not occupying tenure positions at the institituon when they are doing the research.

[3] Includes graduate assistants enrolled at the grantee institution and working towards a master's degree or a doctorate.

[4] Includes laboratory technicians and assistants, undergraduate assistance, miscellaneous direct labor charges and retirement charges where the grantee's accounting system treats these as a direct charge.

From figure 1 and the accompanying table, it can be seen that salaries accounted for 67.1 percent and equipment 23.1 percent of the total funds distributed. Indirect costs were estimated at 13.6 percent of direct costs.

TRAINING AND EDUCATION IN THE SCIENCES

The program activities of the Division of Scientific Personnel and Education are directed toward encouraging policies that will insure that the Nation's educational system will produce enough highly trained scientists, engineers, science teachers, and other scientific workers to meet our ever-increasing national needs.

The most serious and urgent problem at the present time in the training of future scientists and engineers is not to find great numbers of additional students, but to provide a high caliber of training in science for the competent student who will seek it. In addition to properly motivated, capable students, a high quality of science instruction requires a sufficient number of well-trained, dedicated teachers. It also requires text and instructional materials which both reflect the current status of scientific knowledge and meet the needs of the students.

Among the approximately 140,000 high school teachers of science and mathematics, there are admittedly a goodly number of well-trained full-time teachers, but a significant fraction of the total group is not adequately trained to teach either modern science or mathematics with optimum efficiency. A great many of these teachers are aware of their academic deficiencies and are eager to improve their qualifications. Evidence is provided by the fact that in the spring of 1958, 16,000 science and mathematics teachers applied for admission to Foundation-supported Summer Institutes—approximately 1 in every 9 high school science and mathematics teachers in the country.

Although it is sometimes stated that the problem of providing new teachers to meet expanding enrollment is a more serious one than the upgrading of present teachers, the fact remains that these present teachers will bear the brunt of the teaching load for a number of years. Since they will be providing the leadership and much of the in-service training for their newly graduated colleagues, it is of prime importance that these already committed teachers receive the training that they themselves deem necessary.

A crucial factor involved in providing a continuing high level of excellence in the training of our future college and university science

students is an adequate supply of well-qualified faculty members. In 1955, colleges and universities employed less than 200,000 teachers; by 1970, approximately one-half million will be needed. Evidently, financial and other inducements at present are not strong enough to attract our most capable science scholars into teaching.

One NSF study has shown that in 1953–54, more than 3 out of 4 of our college and university teachers were over 34 years of age, 44 percent were over 44 years old. More than one-third were between 45 and 60 years of age; many of these will be retired when the large enrollment reaches college in the 1970's.

The prospect of progressive erosion in the quality of faculties is real. Using the ratio of faculty members holding doctorates to the total staff, the NEA has found that this ratio for all college faculties was 40.5 percent in the 1953–54 academic year. The President's Committee on Education Beyond the High School envisages a decline in this ratio to 20 percent by 1970—assuming generally accepted anticipated supply-and-demand conditions.

Of the new faculty in all fields hired during the 1953–54 and 1954–55 academic years, 30.8 percent held doctorates; by 1955–56, the percentage dropped to 26.7 and in 1956–57, to only 23.5. During 1953–54, 18.5 percent of all newly hired faculty had less than a master's degree. The percentage increased to 20.1 in 1955–56 and to 23.1 in 1956–57.

Even if we were able to solve the problems of providing enough competent teachers at all levels, the science training provided would still not be adequate. Too much of the content of science and mathematics courses in our high schools and colleges is outdated. The time lag between the discovery of new facts and their presentation in the classroom has always been a problem, but it has now become so serious as to pose a major threat to the effectiveness of our educational system. The task of modernizing the subject matter of science is one of tremendous proportions.

Evaluation of this country's scientific training needs requires the gathering and analysis of data dealing with scientific and technological personnel resources and with the educational system, especially the element which relates specifically to science education. Much of this needed information has not yet been obtained.

The objective of all Scientific Personnel and Education Division programs has been and will continue to be the alleviation of the critical situation resulting from the previously mentioned inadequacies in science education. The programs fall into four categories—Fellowships, Institutes, Special Projects in Science Education, and Scientific Manpower.

Fellowships Program

The fellowships program is designed to strengthen the Nation's scientific potential by providing support for advanced training in the sciences, mathematics, and engineering directed toward the development of highly qualified research scientists, and for further study in the sciences directed toward increasing the competence of college science teachers. A total of 1,527 fellowships were offered in fiscal year 1958; their value was approximately $5.6 million. (Accompanying tables show distribution of fellowship awards by type, field, and State.) In 1959 about 2,500 full-year and 1,200 summer fellowships are to be awarded.

National Science Foundation Fellowship Awards, by Type and Field, Fiscal Year 1958

Field	Predoctoral			Post-doctoral (regular)	Senior post-doctoral	Science faculty	Total
	First year	Intermediate	Terminal year				
Life sciences	65	122	63	59	32	67	408
Chemistry	76	95	53	33	12	37	306
Engineering	71	49	27	2	3	41	193
Earth sciences	18	26	14	2	4	9	73
Mathematical sciences	58	60	22	19	11	36	206
Physics and astronomy	98	111	40	33	11	21	314
Physical sciences general	0	0	0	0	0	1	1
Natural sciences general	0	0	0	0	0	4	4
Convergent fields	3	8	5	3	3	0	22
Total	389	471	224	151	76	216	1,527

Predoctoral

Now in its seventh year of operation, the predoctoral fellowships program is designed to offer support to unusually able students, thus enabling them to complete their graduate studies with the least possible delay. The prestige of these fellowships is so high that they are much sought after by top quality graduate science students. The objectives of the predoctoral fellowships program are best served by keeping these fellowships highly selective and highly competitive. From the 3,804 applications, a total of 1,084 fellowships were offered during 1958. In 1959, 1,000 fellowships will be awarded under this program.

National Science Foundation Fellowship Applications and Awards, Fiscal Year 1958

Region and State	Applications	Awards	Region and State	Applications	Awards
NORTHEAST			NORTH CENTRAL		
Connecticut	106	38	Illinois	344	111
Maine	21	7	Indiana	145	40
Massachusetts	283	88	Iowa	82	25
New Hampshire	28	7	Kansas	90	27
New Jersey	205	71	Michigan	178	51
New York	792	235	Minnesota	122	47
Pennsylvania	373	99	Missouri	112	26
Rhode Island	28	11	Nebraska	41	7
Vermont	11	5	North Dakota	17	3
			Ohio	201	61
SOUTH			South Dakota	26	5
			Wisconsin	117	40
Alabama	52	7			
Arkansas	33	9	WEST		
Delaware	18	5	Arizona	34	6
Florida	64	15	California	493	181
Georgia	41	9	Colorado	56	13
Kentucky	44	7	Idaho	25	7
Louisiana	44	5	Montana	16	2
Maryland	130	30	Nevada	8	1
Mississippi	30	8	New Mexico	17	3
North Carolina	76	18	Oregon	73	16
Oklahoma	75	11	Utah	56	18
South Carolina	28	2	Washington	112	39
Tennessee	60	14	Wyoming	11	5
Texas	179	43			
Virginia	79	25	POSSESSIONS		
West Virginia	22	5	Alaska	9	2
District of Columbia	42	11	Hawaii	9	4
			Puerto Rico	15	2

Regular Postdoctoral

Also in its seventh year, the regular postdoctoral fellowships program is designed to provide support to individuals who have recently received doctoral degrees in science to enable them to obtain additional high level training. In fiscal year 1958, 151 of the 513 applicants were offered regular postdoctoral fellowships. About 150 awards are planned for 1959.

Senior Postdoctoral

This 3-year-old program of senior postdoctoral fellowships provides opportunities for scientists who have demonstrated superior accomplish-

ments in a particular field to become still more proficient, by studying and doing research during a leave of absence from their regular positions. This program is kept highly individualized and variable in nature to adjust to the particular needs of the Fellow. In 1958, 76 fellowships were offered under this program selected from among 259 applications. About 75 awards will be made in 1959.

Science Faculty

The science faculty fellowships program, the newest of the Foundation's fellowship programs, was initiated during fiscal year 1957. It is designed to improve the quality of science teaching in our colleges, especially the small colleges. Many of these instructors were drawn into teaching with very little training beyond the bachelor's degree; others have been teaching for a good number of years with little opportunity for intellectual growth. These fellowships permit teachers belonging to either of these groups to undertake further study to increase their competence as teachers.

During fiscal year 1958, science faculty fellowships were offered to 216 of the 694 applicants. Plans for 1959 call for 300 awards.

New Fellowships Programs for Fiscal Year 1959

1. Cooperative Graduate Fellowships.—Similar to present predoctoral fellowships except that applicants will apply through the participating institution of their choice. The institution will then do the initial screening with final evaluation and selection by the Foundation. The institutions will also have the responsibility of administering certain funds associated with the program. Approximately 1,000 awards will be offered under this program in 1959.

2. Summer Fellowships for Graduate Teaching Assistants.—Permit graduate teaching assistants to pursue their own study programs full time during the summer months, thus shortening the time required to obtain their advanced degrees. This program should encourage more highly capable graduate students to accept teaching assistantships as a means of support during the academic year, thereby benefiting the student through the teaching experience he gains and benefiting the university through the availability of the most capable graduate students as teaching assistants. About 550 awards will be offered for the summer of 1959.

3. Summer Science Fellowships for Secondary School Teachers.—For in-service science and mathematics teachers in secondary

schools, who hold baccalaureate degrees. It permits the selected teachers to undertake a personal study program (extending over 1, 2, or 3 summers) leading to improved subject matter competence and often to an advanced degree. Approximately 750 awards are planned.

Institutes Program

Institutes are designed to improve the subject-matter competence of high school and college teachers of science and mathematics. During fiscal year 1958, they consisted of the following three types: (a) Summer Institutes for high school and college teachers, (b) Academic-Year Institutes for high school teachers, and (c) In-Service Institutes for high school teachers. Expenditures for the 125 Summer Institutes, 19 Academic-Year Institutes, and 85 In-Service Institutes totaled $12.4 million.

The institutes are planned and conducted by colleges and universities. Beyond providing broad, general directives and the needed financial support, the Foundation does not participate in the operation of the institutes. It makes financial grants to institutions whose plans, as outlined in the proposals submitted to the Foundation, appear practical and most likely to result in the greatest benefit to the teachers who would enroll.

In order to determine efficiently and fairly which proposals would be supported, advisory panels are employed to review and evaluate the proposals received from colleges and universities. The membership of the panels is chosen from individuals recommended by the scientific societies and other sources as being highly qualified to render judgment in questions involving education in the sciences. The membership encompasses all disciplines in the natural sciences, including mathematics. Industrial as well as educational institutions are represented. High school teachers and officials from State departments of public instruction are among the members. The evaluations of the advisory panels determine in large measure the proposals which are supported. The directive of Congress "to avoid undue concentration" in carrying out the programs of education in the sciences is heeded in the final selection. Balance is sought in geographic distribution, and in representation of the various science areas and types of host institutions.

Summer Institutes

These institutes ordinarily provide courses that are tailormade to fit the needs of the teachers, most of whom completed their formal course work a number of years ago and frequently teach other subjects as well

as their specialty. In addition to the courses, the institutes commonly provide appropriate lecture series, opportunities for discussions, and informal activities that add to their value to participants.

Of the 126 Summer Institutes held in 1958, 5 were for college teachers only; 3, for both high school and college teachers; and the remaining 118 were for high school teachers only.

Three of the college institutes were for biology teachers, one was for geology teachers, and the fifth was for junior college teachers of chemistry, mathematics, or physics. The institutes for college and high school teachers were in biology, chemistry, and mathematics, respectively. Of the 118 institutes for high school teachers, 10 were in biology, 4 in chemistry, 12 in mathematics, 6 in physics, 1 in earth science, and 5 in general science. The remaining 80 offered courses in 2 or more areas. Twelve of the institutes for high school teachers were sponsored jointly with the Atomic Energy Commission and provided work in radiation biology.

Summer Institutes during 1958 were held in 47 States and in 3 Territories—Alaska, Hawaii, and Puerto Rico. New York had the greatest number, 7. There were 54 institutes west and 72 east of the Mississippi. There were 18 institutes in New England and New York, 31 in the other Eastern States and the District of Columbia, 19 in the Southeastern States, 23 in the Midwest Plains States, 18 in the Southwest including California, 13 in the Rocky Mountain and Northwest region, and 4 in the Territories.

The institutes varied in length, the shortest being 4 weeks, and the longest, 12. The average was 7 weeks. The number of participants in each institute varied from 20 to 110, and averaged 50. Participant support funds not needed for travel or dependents were used by many institutes to provide a few additional stipends. In all, approximately 6,000 high school teachers and 300 college teachers received support from National Science Foundation funds in the 1958 Summer Institutes.

The National Science Foundation grants provided funds for participant support. The maximum award to a participant was set by the Foundation at $75 per week for stipend, plus allowance for dependents and travel. Most institutes followed this schedule and granted the maximum allowable amounts to each awardee. (A few distributed their available funds in smaller amounts to more participants.) Many of the institutes accepted a few registrants beyond those who received stipends.

The Foundation grants to each institution paid necessary tuition and fees for the stipend holders, and paid the direct costs occasioned by the

institute to the extent that these exceeded the amount already allowed for tuition and fees.

FUTURE PLANS.—Continued expansion of the Summer Institutes program is expected in 1959 to a number in excess of 300. The Foundation expects to exercise greater latitude in providing opportunities to teachers at all levels for improvement of their mastery of science and mathematics. Although most of the 1959 Summer Institutes will doubtless be for high school and junior high school teachers, relatively more will be scheduled for college teachers. This will be of particular advantage to teachers in the small colleges and in teacher-training institutions. Thus, not only will present teachers be aided, but through them, prospective teachers also.

Elementary school science teaching is in drastic need of strengthening. Therefore, a number of experimental Summer Institutes for elementary school supervisors and teachers is being planned. It may even be possible to provide for other groups of teachers not yet reached—those in technical institutes not offering the baccalaureate degree.

Academic-Year Institutes

In fiscal year 1958 the Foundation awarded grants to 19 universities for Academic-Year Institutes to be conducted during the 1958-59 school year. The courses in these institutes are based on the subject matter of science and mathematics. High school teachers are able in many cases to earn a graduate degree such as the Master of Science in Science Education. In order to enable as many of the deserving teachers as possible to earn this degree, the Foundation has made it possible for the institutes to offer summer awards which permit the selected teachers to continue their studies during the summer following the Academic-Year Institute.

Foundation grants for these institutes provide a maximum stipend of $3,000, plus additional allowance for dependents and travel. Tuition and other fees are covered as well as an allowance for books.

Approximately 925 teachers will be trained in the 1958–59 program, and evidence gained from past programs indicates that very few of these teachers will leave the teaching profession—proportionately fewer, in fact, than normally leave teaching. It is also worthwhile to note that appointments were available for fewer than 10 percent of those who applied.

FUTURE PLANS.—In academic year 1959–60, the Foundation plans to support about 30 Academic-Year Institutes, the maximum level it is felt this program should attain.

In-Service Institutes

The Foundation initiated this program to fit the needs of high school teachers of science and mathematics through courses offered on Saturday morning or during after-school hours.

The success of the In-Service Institutes program during the previous 2 years resulted in support by the Foundation of 86 such institutes during the 1958–59 academic year. About 3,000 high school teachers are able to participate in this institute program which provides for their supplementary training in the subject matter of science and mathematics while at the same time, they maintain their teaching responsibilities. The institutes are located in 35 States, the District of Columbia, and Puerto Rico.

FUTURE PLANS.—Because of the popularity and proved value of this institute program, the Foundation plans to support about 200 In-Service Institutes for high school teachers of science and mathematics during the 1959–60 academic year. Considerable interest has been shown in the potential use of this mechanism to prepare teachers for dealing with the new materials being developed for teaching science and mathematics in the Course Content Improvement Program.

Extending the successful pattern established by the preceding programs, the Division proposes to initiate institutes of a similar type to serve the needs of elementary school teachers in their teaching of science and mathematics.

Special Projects in Science Education Program

Complementing the Institutes Program of the Foundation, this program is concerned principally with the experimental testing and development of promising new ideas for the improvement of science instruction, and with new and more effective methods of increasing the understanding of science on the part of our young people. Approximately $1.5 million was obligated in fiscal year 1958 to carry out this program. Projects fall readily into the three following types: (a) Student Participation Projects, (b) Teacher Training Projects, and (c) Course Content Improvement Studies.

Student Participation Projects

These projects are planned to enlist the interest in and understanding of science, mathematics, and engineering by students at all educational levels. Activities in this area that have been supported by the National Science Foundation include the following:

1. *The Traveling High School Science Library Program.*—In many areas of the United States high school students with an interest in science have little or no access to books about science and mathematics other than their textbooks. The primary purpose of this program is to furnish to secondary schools, on a loan basis, a carefully selected library of general-interest books chosen to cover a broad spectrum of science and mathematics. A secondary but important result is the stimulation of book purchases by school and other libraries in response to student demand.

The program is conducted for the Foundation by the American Association for the Advancement of Science. It was started on an experimental basis in fiscal year 1956, and has been expanded each year since then. In fiscal year 1958, 54 sets of 200 books each were circulated among 216 high schools. Each school receives 50 books at a time. Through periodic exchange, all 200 books are made available to each school served during the academic year. In the summer, the libraries are made available to Foundation-sponsored Summer Institutes.

A list of the books in the Traveling Science Libraries is published separately and is given wide distribution. It is being used in many communities as a guide to the purchase of books for libraries. A larger and more comprehensive list of science and mathematics books for secondary school and community libraries is being prepared, and a special list of science and mathematics books available in inexpensive paperbound editions is also issued to encourage students who wish to buy them for their own use.

An evaluation study of the program has been conducted applicable to the 1956–57 program which served 104 schools. This developed considerable information regarding the reading habits of high school students. Outstanding among the conclusions were the following:

a. In schools served by the Traveling Science Libraries, 39 percent of the students read at least one of the books. Half of these read more than three of the library books.

b. Small high schools make more intensive use of the library books than large schools.

c. At schools where there is a strong teacher interest in science, as determined by the number of library books checked out by the teacher, student interest in the books is more intense.

d. A majority of the schools served by the libraries subsequently added some science books to their own libraries. Lack of funds is the principal reason for not buying more books.

The Foundation plans to continue this program in the future, and to expand it as funds permit. There are over 13,000 high schools in the United States with a student body of less than 200 students.

2. *The Traveling Science Demonstration Lecture Program.*—Supported jointly with the Atomic Energy Commission and administered by the Oak Ridge Institute of Nuclear Studies, this program provides opportunities for secondary school students and teachers to see and hear science lecture demonstrations stressing the scientific principles involved in such subjects as solar radiation, atomic structure, nuclear reactions, space travel, and other subjects of scientific interest. Selected high school teachers are trained at Oak Ridge during a Summer Institute session and then during the academic year travel widely over the country providing lecture-demonstrations in selected high schools.

The training program for 1957–58 was much like that for the first year. Seven teachers were carefully selected for participation in the program and underwent a period of preparation and special training at Oak Ridge during the summer. The summer training period included courses and lectures on fundamentals of physical sciences, radioisotope techniques, science experiments, and techniques in science teaching.

Six weeks of the three-month summer session consisted of lectures and demonstrations in chemistry, physics, biology, and mathematics given by prominent scientists and teachers. Concurrently with the lecture-demonstration training, the traveling teachers designed and built many pieces of apparatus for use in their subsequent visiting lectures. Many of these inexpensive "home-made" assemblies were used as models which later were duplicated by high school teachers working with their students. During the 1957–58 school year the traveling teachers made visits of 1-week duration to 260 high schools throughout the country. They gave, on the average, one lecture-demonstration per day in the schools and were usually invited to provide many added lectures to parent and civic clubs. In addition to the schools visited, other neighboring schools were often reached while the teacher was in the community, so that a total of 892 schools (including some elementary schools) received at least one demonstration-lecture. More than 226,000 high school students and some 5,700 high school teachers were reached by this program.

The activities and previsits of the traveling teachers were cooperatively planned by the high school principals and the science departments of the various high schools. This cooperation aided the high school teachers to anticipate what would be covered by the visiting lecture-

demonstrator and permitted them to arrange their work in the science courses to fit into the material covered by the visitor.

From reports of school principals, teachers, and parents, there is abundant evidence that the high school traveling lecture-demonstration program has had increasing success. By May 1, 1958, the number of visits requested for the year 1958–59 had exceeded 3,200.

The 1958–59 program will make use of a group of 19 traveling teachers—7 completely supported by National Science Foundation and Atomic Energy Commission funds and at least 12 supported during the 9 months of the school year by State departments of education, with National Science Foundation funds covering the teachers' stipends during the summer months and Atomic Energy Commission funds providing the demonstration equipment.

The fact that educational systems in individual States are willing and able to include the Traveling Science Demonstration Lecture Program in their "normal" educational pattern is an indication of the validity of the program. It is a good indication that this program will probably function smoothly when it is expanded during the coming year to provide a more widespread coverage of schools.

3. *The Visiting Scientists Program.*—This is a program which enables distinguished scientists to visit small colleges and universities for periods of several days to give lectures, to conduct classes and seminars, and to meet students and faculty members on a formal as well as informal basis in order to stimulate interest in science.

The Visiting Scientists Program was initiated in the 1954–55 school year when the National Science Foundation made a grant to the Mathematical Association of America for a series of visits to various small colleges and universities. Since that time the program has been expanded to include similar programs in chemistry, physics, biology, and astronomy.

In the past year, grants have been made to the following organizations to support Visiting Scientists Programs: American Chemical Society, American Institute of Physics, American Institute of Biological Sciences, American Astronomical Society, and the Mathematical Association of America. About 500 visits to colleges and a few high schools will have been made during the academic year, reaching an audience of over 60,000 students. The visiting scientists and the administrators of the institutions visited, as well as the faculties and students, have expressed enthusiasm for the value of the program.

The present programs in mathematics, chemistry, biology, physics, and astronomy have proved so successful in arousing interest in the subject matter presented that in 1959 they will be expanded to make

more contacts possible. In addition, new scientific disciplines will be included, such as the earth sciences and engineering.

In view of the importance of interesting high school students in scientific careers, an active program, administered by appropriate scientific groups, will be developed in the next fiscal year, so that able scientists can visit high schools, lend their stimulus to science education at that important level, and provide a better appreciation of career opportunities.

4. *Science Clubs and Student Projects.*—This program stimulates interest in science and in scientific and engineering careers among students below the college level by supporting extracurricular science projects under the guidance of national youth organizations.

Since 1952, the National Science Foundation has been providing a limited amount of support to Science Clubs of America, administered by Science Service, Inc., a nonprofit organization with other sources of income. Approximately 19,500 local Science Clubs, composed predominantly of students of senior and junior high schools, are affiliated with Science Clubs of America. Each has an adult adviser, usually a science teacher.

Many club members carry out individual projects which frequently culminate in exhibits displayed at a school science fair. The most worthy of these are selected for showing at a city, regional, or State science fair, and each of these in turn usually selects two finalists who are sent, with their exhibits, to the annual National Science Fair.

At the National Science Fair held May 9–11, 1958, exhibits were shown by 281 finalists from 146 areas. The supporting fairs showed a more impressive growth rate. On the basis of reports from 98 of the 146 affiliated fairs, it is estimated that the 281 exhibits at the national fair were selected from a total of more than 468,000 exhibits at local fairs, an increase of 60 percent over the preceding year.

Public attendance at science fairs is encouraged. In 1958 attendance at the national fair was over 30,000, and an estimated 4 million persons saw the exhibits at the supporting fairs.

Geographic coverage of this program is extensive but not intensive. There are only three States where there are no science fairs, but few of the remaining States have anything approaching complete coverage. Of about 16 million students of the 7th through 12th grades, about 4 million would probably be interested in this kind of activity if the opportunity were available. Total membership in the 19,500 Science Clubs is estimated at about 500,000 students.

A recent study of National Science Fair finalists from 1950 to 1957 reveals a very high degree of interest in higher education. Of 589

individuals on whom data were received, 156 were still in high school and 23 were in military service. Of the remaining 410, 95 percent were taking college courses or had received a college degree.

In view of the results obtained from this program, the Foundation plans to continue its support of Science Clubs of America and also to explore the possibilities of science programs in cooperation with other national youth organizations such as the 4–H Clubs, Future Farmers of America, the Boy Scouts, and the Girl Scouts.

5. *Summer Training Program for Secondary School Students.*—A primary purpose of this program is to encourage the scientific interests of high-ability secondary-school students by providing them with opportunities to participate in study and research programs set up especially for such students by interested college groups.

Pilot programs supported for the summer of 1958 include those of two State university short summer institutes for high school students and one research foundation's summer-long research participation program. In the two university institutes—"science camps"—two or three weeks were devoted to lectures, laboratory experience, visits to other laboratories or museums, and field trips, together with orientation lectures in the various branches of science and mathematics. Their aim was to acquaint the students with the many facets of scientific activity so as to provide a better comprehension of the sciences and a better basis for a choice of future careers. In the Waldemar Research Foundation summer program, high school students participated in supervised research which not only complemented their wintertime classroom instruction, but also offered them the stimulation and intellectual discipline of experimental scientific research.

Both types of programs utilized high school science teachers as counsellor-participants, to the ultimate benefit of their future classes. In these 3 pilot projects, 145 students and 8 high school teachers participated.

High school students also took part as members of demonstration classes in mathematics and science which were part of the program of some of the Summer Institutes for high school teachers.

A number of other proposals for the summer of 1958 to aid in developing the scientific interests of high school students were received, but the Foundation was unable to support them all. However, for 1959, the Foundation expects to support as many as 80 such projects.

6. *Other Student Participation Projects.*—Included under this heading are projects such as support of the preparation and distribution of pamphlets and brochures describing career opportunities in the various

science disciplines and designed to awaken student interest; a program to bring to science teachers and their students, by means of poster exhibits, a balanced and comprehensive understanding of the IGY and a constructive realization of the interdependence of the scientific disciplines involved; studies of ways in which the Foundation can best provide assistance to State Academies of Science in furthering their interests in science education; production of pilot films relating to science to be made available to American schools, not strictly as teaching aids but directed to achieving a broader understanding of science by all students; support of a 4-week summer workshop at the University of Chicago to introduce qualified college students to the field of meteorology as a subject for graduate study and as a profession, and partial support to the American Institute for Research to conduct a planning study for research on the identification, development, and utilization of human talents.

Teacher Training Projects

Teaching is not a static profession in which the education attained in one's youth can serve until retirement. In science, mathematics, and engineering, new developments of a profound nature are constantly occurring and affecting the fundamental principles in important areas of subject matter. Associated with the new discoveries are novel laboratory and demonstration procedures. Today's teacher finds it essenital to seek periodic refresher training, or if necessary, more advanced training, if he expects to retain his competence as a teacher. The problem varies with the teaching level, but this need applies to the professor charged with graduate training, the secondary school teacher, and the elementary school teacher. Whereas the college or university-associated teacher may hunger for recent developments at the frontiers of his field, the precollege teacher is usually isolated from contact with the broad advances in science. Thus, the refresher work required depends on the goals of the participants, and a flexible program is needed to supplement the activities of the regular institutes programs.

During the past year, the National Science Foundation helped various institutions to offer a wide variety of opportunities for the improvement of teachers. Conferences and symposia were supported in such diverse fields as the teaching of astronomy, recent advances in protozoology, approaches to the teaching of "freshman" chemistry, the uses of projection equipment in planetaria, selected problems in statistics, and the use of research problems at the undergraduate level. One example of the needs at a level of education which may require increasing attention was the pilot course given for teachers in technical

institutes in the theory of process instrumentation and automatic control. Another illustration of the productive outcome of a long-standing problem was a workshop centered on the various approaches to improving the electrical engineering curriculum, attended by representatives of 100 engineering schools. The National Science Foundation also contributed support to an important conference on problems of higher education in science and engineering, with the Scientific Manpower Commission, Engineering Manpower Commission, and the National Academy of Sciences-National Research Council as cosponsors. Many national leaders in science, industry, and education attended to discuss the issues on a broad scale, and significant results are expected.

Not only the college teacher has benefited from these projects. In an effort to come to grips with the overwhelming problem of elementary school teachers for science teaching, an exploratory conference by the National Science Teachers Association was supported on this subject. In addition, two experimental approaches were tried in bringing science content closer to the elementary school teacher: one, an in-service institute for all of the interested elementary teachers in a small city; the other, an institute for elementary science teacher-coordinators who were nominated by their schools to receive this training and then return to teach and to coordinate the science programs in their own schools.

Opportunities for secondary school teachers included specialized summer programs in junior high school mathematics, marine biology, and earth science. Of particular interest was a plan used in connection with several mathematics summer institutes. In order to provide the teachers participating in the institutes an opportunity to see new mathematics concepts actually taught in class, or even to try presenting these new ideas themselves, several institutes offered demonstration classes for high school students. The Special Projects in Science Education Program supported these demonstration classes, which seemed not only to help the teachers master the subject but also brought a stimulating experience in mathematics to several hundred superior high school students.

Course Content Improvement Studies

Progress in the sciences has been so rapid in recent years that the courses in science and mathematics offered in most secondary schools now reflect neither the current state of knowledge nor the attitudes of mind which characterize modern scientific study. The course work in mathematics that now makes up the program of most modern high schools has been taught essentially unchanged for approximately 60 years and, therefore, does not emphasize many of the aspects of mathematics

now considered important. Similarly, courses in physics, chemistry, and biology as taught in most secondary schools not only contain much obsolete material, but—even more important—represent a point of view that has long been discarded by the scientists working in these areas. The basic concepts of these sciences have been altered beyond recognition and whole new fields, unknown a few years ago, are now areas in which important and active contributions to knowledge are being made.

Two consequences of this failure of science instruction in the primary and secondary schools to keep pace with the growth of knowledge have been a conspicuous lack of interest in science and mathematics on the part of students and a seriously inadequate preparation for more advanced study in colleges and universities. The quality of the scientific training given our young people has so vital a role for the safety and economic welfare of this country that it can no longer be neglected if America is to maintain its position of leadership in science and technology.

The seriousness of the situation has led many eminent scientists to devote their efforts to a thorough and critical reexamination of science programs in the public schools. The Foundation has provided support for major studies of science curricula in the secondary schools in which the knowledge, judgment, and experience of distinguished scientists and skillful teachers have been welded together to produce new and imaginative approaches to science instruction.

One of the most encouraging activities in high school science instruction today is the development of an entirely new course in physics for the high schools. This has resulted from the cooperative efforts of a large group of senior physicists working with a similar number of experienced and successful high school science teachers. The new course represents a drastic departure from traditional methods of instruction both in selection of subject matter and in the methods of presentation. A new textbook has been written, a new laboratory manual prepared, ingenious and inexpensive equipment has been designed for use in laboratory study, films to supplement class and laboratory instruction are being produced, a large number of monographs extending and enriching the student's understanding of specific topics are being written, and a comprehensive guide to assist teachers in presenting the new course has been prepared. Everything possible has been done to bring maximum appreciation and understanding of the science of physics to the high school student. The new course has been tested in a number of high school classes with most encouraging results, and preparations are now under way to have the course tried in more than 200 classes during the next school year.

A similarly massive study of mathematics curricula in the elementary and secondary schools has been started with Foundation support. Here, also, eminent mathematicians are working cooperatively with experienced high school teachers to develop an approach to mathematics that will both reflect modern concepts in this important field and create interest and understanding in the minds of the students.

Mathematics today is an entirely different discipline from what it was even a generation ago. Its applications have been so extended that scientists in many new fields use it as physicists and engineers used it early in the twentieth century. Industrial employment of mathematicians is many times greater today than was considered probable by the best informed experts of only twenty years ago. The incredible speed with which mathematics has come to play a role in almost every aspect of modern life makes imperative a thorough restudy of the teaching methods whereby young minds are brought into contact with this subject. It is the purpose of the Mathematics Study Group to so reorganize the work in mathematics in the upper levels of the elementary schools and in the high schools that it will become a way of thinking rather than a system of artificial devices to solve problems. Successful advancement of this goal could become one of the important landmarks in the history of educational progress during the twentieth century.

It should be emphasized that these studies have been cooperative efforts in which scientists have sought and obtained the cordial assistance of the professional educational organizations so that the knowledge and experience of both groups could be utilized in the development of the new courses.

Interest in the comprehensive studies of physics and mathematics curricula in the secondary schools has been widespread and has encouraged similar studies in other sciences. The professional scientific societies representing the chemists and biologists have approached the Foundation for the support of comparable studies in these disciplines.

The Foundation provided support for a conference of college teachers of chemistry which was held early in the summer of 1958 at Wesleyan University, Connecticut. The conference discussed both the appropriate materials to be included in college courses in elementary chemistry and the most effective ways of presenting the material to students.

In the area of teaching aids, Foundation support has been given to the production of a series of films in which skillful teachers of mathematics discuss current ideas in special subject-matter areas of mathematics. The films are designed to enlarge and enrich the grasp of mathematics of college students of this discipline.

Support has also been granted for experimental color television films in biology because it is believed that wide-scale use of films and television is a partial answer to increasing enrollments, shortages of teachers, and presentation of educational experiences difficult to provide in other ways. This project enlists, under the sponsorship of the American Institute of Biological Sciences, distinguished biologists and experienced production personnel in presenting both factual and theoretical topics on film, together with an evaluation of the effectiveness of this type of teaching.

Scientific Manpower Program

The Scientific Manpower Program is designed to provide the Federal Government with knowledge about the Nation's resources of scientific manpower, such as supply, demand, utilization, and characteristics. This is accomplished through maintenance of the National Register of Scientific and Technical Personnel and through the conduct of Scientific Manpower Studies. Expenditures for this program during 1958 totaled approximately $352,000.

The National Register of Scientific and Technical Personnel

The Register provides a means for quickly locating specialized scientific manpower in case of emergency and serves as a source of data concerning scientific manpower supply and characteristics. It is maintained by the Foundation in cooperation with the Nation's professional organizations of scientists and engineers. At present the Register lists more than 175,000 names, an increase of over 25,000 during the year.

During 1958, an analysis was completed of data received during 1954–55 from 126,000 scientists. The reports are currently being processed. The data deal with a wide variety of factors, such as salary, age, level of education, field of study, professional specialization, function, and type of employer. In addition, special studies are being made of the proficiency of scientists in various foreign languages.

A "Survey of Earned Doctorates" is proceeding under grant to the National Academy of Sciences-National Research Council. The object is to collect information by means of specially designed questionnaires from all individuals now being granted science or technical doctorates, as a continuing program. Statistical analyses are aready under way.

Register personnel have been cooperating with the Civil Service Commission in the establishment of a special placement roster of Federal scientists and engineers in grades GS–13 and above. (The starting salary for GS–13 is $9,890.) This roster is expected to be in operation in the fall of 1958.

During the past year the Register has been used to provide data on mathematicians in certain specialties to the Bureau of the Budget; salaries of scientists to the Civil Service Commission; resident scientists to the State of Florida; older scientists to the National Committee on Aging; etc.

FUTURE PLANS.—To place the Register program on a more current operating basis and extend the coverage of the Register to new fields of vital importance to the Nation, such as rocket and missile technology, communications and electronics, aeronautical science, ceramics and metallurgy. Methods of increasing the usefulness of the data currently within the Register are also under study.

Scientific Manpower Studies

This program acts as a clearinghouse for the collection, interpretation, and dissemination of information concerning scientific and technical personnel.

During fiscal year 1958, at the request of the Bureau of the Budget, a major study was initiated by the Foundation aimed at the development of a coordinated program of scientific manpower data collection. An advisory panel consisting of experts in the field was appointed jointly by the Foundation and the President's Committee on Scientists and Engineers, under the chairmanship of Dr. Philip M. Hauser of the University of Chicago.

The results of this panel's study served as the basis of the Foundation's report to the Bureau of the Budget, "A Program for National Information on Scientific and Technical Personnel." The Foundation indicated the many gaps now existing in scientific manpower information and the need for better planning and coordination in the operation of existing data collection programs. Among the report's recommendations for urgent action, three general areas of need are most urgent: (a) better definitions and classification of scientific and technical manpower; (b) a continuing flow of basic employment information; and (c) projections. Other recommendations include intensive surveys of scientific manpower characteristics, improvement of data collection on education, and studies of qualitative aspects of scientific and technical manpower. A key recommendation is that an appropriate Federal agency should be given the responsibility for coordinating that part of the work which involves Government support for analyzing the data produced and for making the findings known.

The Foundation in cooperation with the Engineers Joint Council, the National Academy of Sciences-National Research Council, and the Scientific Manpower Commission sponsored the Conference on Higher

Education and Technology held in Chicago, Illinois, October 31–November 2, 1957. The Western Society of Engineers was the local sponsor. The immediate objectives of the conference were to: (a) provide an up-to-date picture of the scientific and engineering manpower situation and its implications for educational resources; (b) highlight the unique problems of higher education in science and engineering and explore remedial measures; and (c) contribute to the general understanding of problems of higher education in technology and the need to rally our Nation's resources to meet the challenge. The proceedings of the conference were published under the title *Engineering and Scientific Education—Foundation of National Strength.*

During the fiscal year 1958, the following studies were completed:

Immigration of Professional Workers to the United States, 1953–56.—An analysis of approximately 60,000 immigrants, classified as professional, technical, and kindred workers, who entered the U. S. for permanent residence during fiscal years 1953–56 (July 1, 1952–June 30, 1956).

Scientific Manpower–1957.—The papers presented at the Sixth Conference on Scientific Manpower held in conjunction with the AAAS meeting at Indianapolis, Ind., in December 1957. The conference theme was "Scientists and Scientific Research in a Changing Economy."

Reports prepared as a result of Foundation grants include *Engineering Enrollment and Faculty Requirements, 1957 to 1967; Availability of Retired Officers to Teach Mathematics and Science;* and *Doctorate Production in United States Universities, 1936–56.*

Other projects included analysis of data for 1954–55 from the National Register of Scientific and Technical Personnel; analysis of data from the 1957 Survey of Doctorate Degrees; continuing analysis of information on scientific manpower in foreign countries; and special research on various subjects in the field of education, such as high school—college attrition and qualifications and preparation of high school science and mathematics teachers.

FUTURE PLANS.—To enlarge the program so as to begin to adopt urgent recommendations which have been made concerning an integrated and expanded program of scientific manpower data collection, to expand the analysis of the relative scientific manpower positions of the Free World and the Soviet Bloc nations, and to initiate a program of experimental research on scientific manpower data collection.

EXCHANGE OF SCIENTIFIC INFORMATION

The ultimate goal of the Office of Scientific Information is to insure the ready availability to all United States scientists of the world's current and past output of significant scientific information. With the ever-increasing volume of scientific research throughout the world has come a proportionate increase in the body of the world's scientific knowledge. These factors pose a severe problem in dissemination, for research, no matter how significant, is of little value unless the results are easily accessible to other scientists.

The Foundation, through the Office of Scientific Information, fosters cooperation and coordination of scientific information activities among agencies of the Federal Government and among non-Government organizations engaged in activities in this field.

The four major programs of this Office are: *Research on Scientific Information, Publications and Information Services, Government Research Information, Foreign Science Information.* During fiscal year 1958, approximately $2 million were spent in pursuit of these programs.

Research on Scientific Information

The objective of this program is the development of new or improved means of organizing, translating, storing, searching for, and disseminating large quantities of scientific information. Scientists need new tools to help them find and digest the material they want without time-consuming searches through the literature. The design of improved systems and the development of procedures for using high-speed machines in the processing of scientific information require thorough study of the actual information requirements of scientists, experimentation with possible ways of organizing and searching information so as to best meet their requirements, and, finally, testing and evaluation of proposed new procedures and systems.

Machine Translation

Active research programs on the use of electronic machines in preparing translations are being carried on in the U. S. S. R. and England,

as well as in the United States. The 71 technical papers presented at a 6-day conference in Moscow in May 1958 on research in mechanical translation demonstrate the size of the Russian effort.

The Foundation is continuing its support of the following programs in this field. The Massachusetts Institute of Technology is continuing work on methods of machine translation with emphasis on the study of sentence structure in German and English and procedures for converting German sentences into the correct English word order. At Georgetown University research continues on translation of Russian chemical papers into English. Several promising techniques which have been developed are being tested on general-purpose computers.

At the Harvard Computation Laboratory a full-scale automatic Russian-to-English "electronics dictionary" will soon be in operation, and will be used as a research tool in the continuing program to develop rules for the fully automatic production of translations.

The Cambridge Language Research Unit, Cambridge, England, is continuing work on the development of generalized procedures for handling syntactic structures and semantic choices in machine translation. The procedures are being tested first on punched cards.

Organizing and Locating Information

Several new studies have been started and others continued dealing with problems involved in organizing and locating information. A study of the use of a computer to prepare a coordinate index for bibliographies in book form was begun at George Washington University. Western Reserve University has undertaken a test program of chemical notation systems, which in time may be used to facilitate the preparation of indices and the use of machines in searching chemical structure files. A basic research project looking toward a systematic means of reducing the linguistic complexities of scientific publications to simpler, more uniform construction is in its second year at the University of Pennsylvania.

Operations Research Studies of Scientific Communication

Continuing support was given to an exploratory operations research study of scientific communication at the Case Institute of Technology. This project is a pilot study of the pattern of communication among chemists and their use of recorded information. A final report was received from a related study, based on interview survey methods, of scientific information exchange at Columbia University. The report discusses the occasions of information exchange and the characteristics of information-gathering patterns in a university environment and sug-

gests additional studies looking toward the improvement of channels of information exchange.

Research Information Center and Advisory Service

The Foundation called a series of conferences and meetings with directors of research and representatives of other Federal agencies to discuss means of facilitating research on information processing and searching, as well as on machine translation. As a result of these discussions, plans were made for the establishment at the National Bureau of Standards of a research information center and advisory service in the field of information processing (including machine translation), whose services will be available to Federal agencies and other organizations conducting or supporting research in the field. The new service is expected to be in operation early in fiscal year 1959.

International Conference on Scientific Information

Both financial assistance and staff time were given to the planning of a large international research conference on scientific information, to be held in Washington, D. C., late in 1958 under the auspices of the National Academy of Sciences—National Research Council, the American Documentation Institute, and the National Science Foundation. Approximately 75 papers have been accepted for the conference.

Publications and Information Services

The principal objective of this program is to aid the dissemination of scientific information by helping to maintain, improve, and expand present means of publication, and by helping to establish and maintain information centers that provide scientists with specialized reference services, where such aid is necessary.

Support of Scientific Publications

As in the past, the Foundation granted temporary, emergency support to valuable research journals facing financial or other crises (such as the *Astronomical Journal*), or to help journals with a specific problem such as the publication of an extensive backlog or a cumulative index (such as the *Journal of Parasitology*). Support was also given to help defray the publication costs, and sometimes part of the preparation costs, of other types of significant publications that could not be published without such aid. These included monographs (such as *World Monograph on*

the Fontinalaceae), specialized bibliographies (continuation of a bibliography of the International Geophysical Year), compilations of data (*Organic Electronic Spectral Data, 1946–55*), volumes of special tables (*Geographical Conversion Tables*), and critical reviews of recent developments in a field (a comprehensive volume of reviews on all aspects of phytopathology by leading experts from all over the world).

Abstracting and Indexing Services

Special attention was given this year to the problems of abstracting and indexing services. Besides giving emergency support to *Mathematical Reviews* and *Sociological Abstracts,* the Foundation provided funds and staff work for a conference of major United States scientific abstracting and indexing services. The conference met to consider operating problems of the services and to explore the possibility of increased cooperation among the various services to achieve systematic coverage of the world's scientific literature. A major accomplishment of the conference was the formation of the National Federation of Science Abstracting and Indexing Services, which will strive to coordinate the work of the various services, seek ways to improve them, and encourage the development of abstracting and indexing services for those specialized subject fields not at present covered by such services.

Data and Reference Centers

Support was given for the establishment of an Office of Critical Tables at the National Academy of Sciences—National Research Council to coordinate the activities of the various data compilation projects now in progress in this country and of the data centers currently in operation, and to stimulate new projects and centers in areas not presently being covered. The Foundation again joined with other Federal agencies to support the Bio-Sciences Information Exchange, which collects information on current research projects in the biological sciences, organizes and classifies this information, and makes it available upon request.

Studies and Experiments

Several studies were undertaken, under grants from this program, of problems connected with publishing and disseminating scientific information. The American Institute of Physics began a major program of research on publishing problems in the field of physics, including such matters as the nature of the problems, comparisons of techniques and methods that might be used in physics, publications, and the pub-

lication needs and uses of physicists. *Biological Abstracts* undertook a survey of the coverage of botanical literature by abstracting services. Herner and Company made a study of the importance of subject slanting in published abstracts, where the same papers are abstracted for scientists in different fields.

Support was given to the Conference of Biological Editors for the preparation of a style manual for biological publications, which will establish standards in such matters as literature citations, terminology, abbreviations, and preparation of illustrations. These standards will be arrived at by agreements among biological editors, and it is expected that most biological journals will adhere to them after the manual is published, thus establishing badly needed consistency and saving considerable time and effort of both editors and authors.

The American Physical Society was given partial support for the establishment of an experimental type of journal for the rapid publication of physics research results. New editorial procedures will be used, and it is hoped that improved production methods will also be developed. The results of the experiment will be watched with great interest by other scientific groups.

Government Research Information

The objective of the Government Research Information program is to make unpublished results of federally supported scientific research as available to United States scientists as are the results published conventionally in journals and books.

Inventory of Government Scientific Reporting

An inventory of Government agencies has been underway to determine the quantity and subject matter of the scientific reports which they issue, the availability of these reports to scientists outside Government, and the policies and procedures of these agencies with respect to their scientific information programs. Additional agencies were surveyed during fiscal year 1958, and the data from the entire survey will be published in a series of Foundation pamphlets. The first, dealing with the Department of Agriculture, will appear early in fiscal year 1959.

Government Research Information Clearinghouse

The second year of operation of the GRI Clearinghouse saw an increase in the comprehensiveness of replies to inquiries from scientists. More than 9,000 information sources were cited in response to requests

by scientists for information on where Government-sponsored research is being carried on and how access to the resultant reports can be obtained.

Clearinghouse staff members, in a prototype declassification program, are searching the Armed Services Technical Information Agency's classified collection for significant reports that appear to be susceptible of declassification. Subjects are selected on the basis of interest as expressed by queries directed to the Clearinghouse. Declassification recommendations are handled by the Office of Technical Services.

Office of Technical Services, U. S. Department of Commerce

Financial support of the Office of Technical Services was increased to enable it to continue and expand its vigorous program of obtaining, announcing, and making generally available scientific reports in basic research fields. As a result, OTS was able substantially to augment its automatic acquisition agreements with other Federal agencies and now believes it is receiving nearly all significant, unclassified reports in basic science issued by the Department of Defense and its contractors.

Library of Congress

The Report Reference Center, established in the Library's Science Division in fiscal year 1957, increased its work as a result of an increase in the funds granted to it, and now has the country's principal collection of unclassified scientific reports available for general reference use. About 40,000 titles were added during the fiscal year, bringing the total to approximately 100,000.

With Foundation support the Library will complete early in fiscal year 1959 its preparation of the Armed Services Technical Information Agency subject index to the unclassified reports within AD numbers 1 to 75,000.

Foreign Science Information

The basic goal of this program is the widest possible dissemination in the United States of the published results of foreign scientific research. To date it has been necessary to limit work toward this goal almost exclusively to Russian scientific literature, emphasizing translations into English.

Midwest Inter-Library Center (MILC)

Continued support was given to the MILC in Chicago, a cooperative endeavor of 19 major midwestern universities. The Center is establish-

ing a comprehensive collection of foreign chemical and biological serial publications. The Foundation grant for fiscal year 1958 will maintain the subscriptions to the 800 journals acquired last year and permit the addition of 1,000 in chemistry and 500 in biology. When present gaps are filled, the holdings will make 9,500 of the world's most significant serials in these two fields available to U. S. scientists.

Translations of Russian Documents

Grants made during the year brought to 29 the number of Russian scientific journals receiving cover-to-cover translation with Foundation support and with the cooperation of the Atomic Energy Commission, the National Bureau of Standards, and the Office of Naval Research; 14 new translation projects were begun during the year. These together with translations sponsored commercially and by other agencies make available in English by subscription more than 50 important Russian scientific periodicals. Grants were also made for the translation of 10 important Russian scientific monographs in the fields of biology, ceramics, geochemistry, geology, and mathematics. Support was granted for the fifth consecutive year for translation by the American Mathematical Society of approximately 1,500 pages of carefully selected papers from Russian mathematics journals.

Special Libraries Association Translation Center

In collaboration with the National Institutes of Health, the Foundation continued to support the Special Libraries Association Translation Center of the John Crerar Library in Chicago. The Center's holdings were increased during the year to approximately 20,000 titles. New titles are being added at the rate of about 500 per month.

Foreign Technical Information Center

In line with its efforts to assist agencies of Government to coordinate foreign information programs for maximum effectiveness, the Foundation chaired a series of interagency meetings to plan methods for disseminating Government-prepared translations to the public. Out of these meetings grew a new program which the Congress has authorized to be established within the Office of Technical Services of the Department of Commerce. The primary function of the new Foreign Technical Information Center, to begin operation in fiscal year 1959, will be to act as a clearinghouse and to channel to the public large quantities of abstracts, translations, and studies of foreign science prepared by a number of Government agencies in the course of their normal operations.

Other grants during the year included support for a supplement to *Bibliography of Eastern Asiatic Botany,* a study of the current status of Russian biological research publications and another on certain Russian engineering publications, and preparation and publication of *A Selected Bibliography of Japanese Publications in Science and Technology.* Continued partial support was given to the International Council of Scientific Unions for its program of assisting international cooperation in scientific abstracting.

Special Scientific Exhibits

In 1957–58 the Foundation coordinated the United States program for large-scale science exhibits in the International Science Section of the Brussels World's Fair. Funds transferred from the Department of State paid for the conception, design, construction, and display of approximately 6,000 square feet of exhibits. The United States is represented by 51 displays of a total of about 500 from 15 nations.

The scientific achievements of more than 100 prominent American scientists, combined with cooperation and generous assistance from 50 American industries, contributed to the production of the United States exhibits. American exhibits range from the very popular to the very technical, and include a display of manmade diamonds, an operating nuclear reactor, and an exhibit on the recent Nobel prize-winning discovery of the nonconservation of parity.

With the cooperation of the Naval Research Laboratory and the National Academy of Sciences-National Research Council, 4 outstanding earth satellite exhibits were produced, which have been shown a total of 61 times in 25 States, the District of Columbia, and 3 foreign countries, as well as having had 4 television appearances. These exhibits are currently being modified to include the Explorer satellite as well as Vanguard.

SURVEYS OF THE NATIONAL RESEARCH AND DEVELOPMENT EFFORT

The vastly increased public attention given to basic science, following the launching of the Soviet sputniks, made apparent the need for more information on the present research and development efforts in the United States. Fortunately, factfinding in this area had been part of the program of the National Science Foundation for several years. Early studies provided much otherwise unavailable information. This year the Foundation accelerated the development of a long-range plan for obtaining annual data on the volume of research and development.

To carry out this program, the Foundation's Office of Special Studies was reorganized. Four program objectives were outlined to collect and analyze data on the nature and extent of the Nation's scientific activities, and thereby assist in the formulation of Federal science policies. These program objectives are as follows:

1. To measure the Nation's research and development effort.
2. To undertake such special studies as may be indicated by the analysis of the results under (1), in order to throw additional light on the problems involved.
3. To appraise the impact of research and development on selected areas as well as the economy as a whole.
4. To promulgate the findings in a series of monographs and reports.

Long-range statistical studies on research and development in four sectors of the economy are now materializing. On an annual basis data are being collected on the Federal sector; in the other three sectors—private industry, colleges and universities, and other nonprofit institutions—periodic benchmark surveys are planned with intervening annual summary surveys. The continuity of these surveys will make possible time series for the individual sectors as well as for the national totals, with accompanying analyses on the flow of funds.

Work has begun on analytical studies, including examination of the relationship of research and development to the growth of a company, and investigation of decision-making as related to innovation and to research and development expenditures. Still another will survey the trends and volume of scientific research and development expenditures

and manpower in the Soviet Union. Plans are also being made to develop special studies in the colleges and universities area and in the Federal Government sector.

During the year, the publications issued by the Foundation in this field were as follows:

Government

Two studies of Federal scientific activity and one on scientific activity in six State governments were released during the year. These studies, along with brief comments on their findings, are noted below.

Federal Funds for Science VI. The Federal Research and Development Budget, Fiscal Years 1956, 1957, and 1958.—This issue of the *Federal Funds for Science* series continued the annual analysis of the Federal Government's obligations and expenditures for scientific research and development. As shown in figure 2, both obligations and expenditures for this purpose increased in the three fiscal years covered by the study.

These obligations and expenditures represent the funds administered by more than 20 Federal agencies for basic research, applied research, development, and the expansion of R&D plant which accounted for 10–15 percent of the totals shown in figure 2. Of the Government's total obligations for basic and applied research and development, more than 60 percent is for development and less than 40 percent is for research, including basic research.

The Federal research and development budget, which has shown a multifold increase since 1940, includes funds for work conducted not only in Government laboratories but under contract or grant arrangements with numerous private organizations, such as industry and educational and other nonprofit organizations.

In the past decade Federal expenditures for scientific research and development have advanced from around 2 percent of the total Federal budget to more than 4 percent.

Funds for Scientific Activities in the Federal Government.—Along with a number of surveys of research and development initiated in 1954, a study of the Federal Government's organization, personnel, and funds for scientific activities was undertaken. Previous publications have summarized the information developed on organization and personnel. This publication focused on Government funds applied to a wide range of scientific activities, including, in addition to conduct of research and development, amounts for planning and administering R&D, increase of R&D plant, scientific data collection, training of scientific manpower, and scientific information. Since more than 80 percent of the total

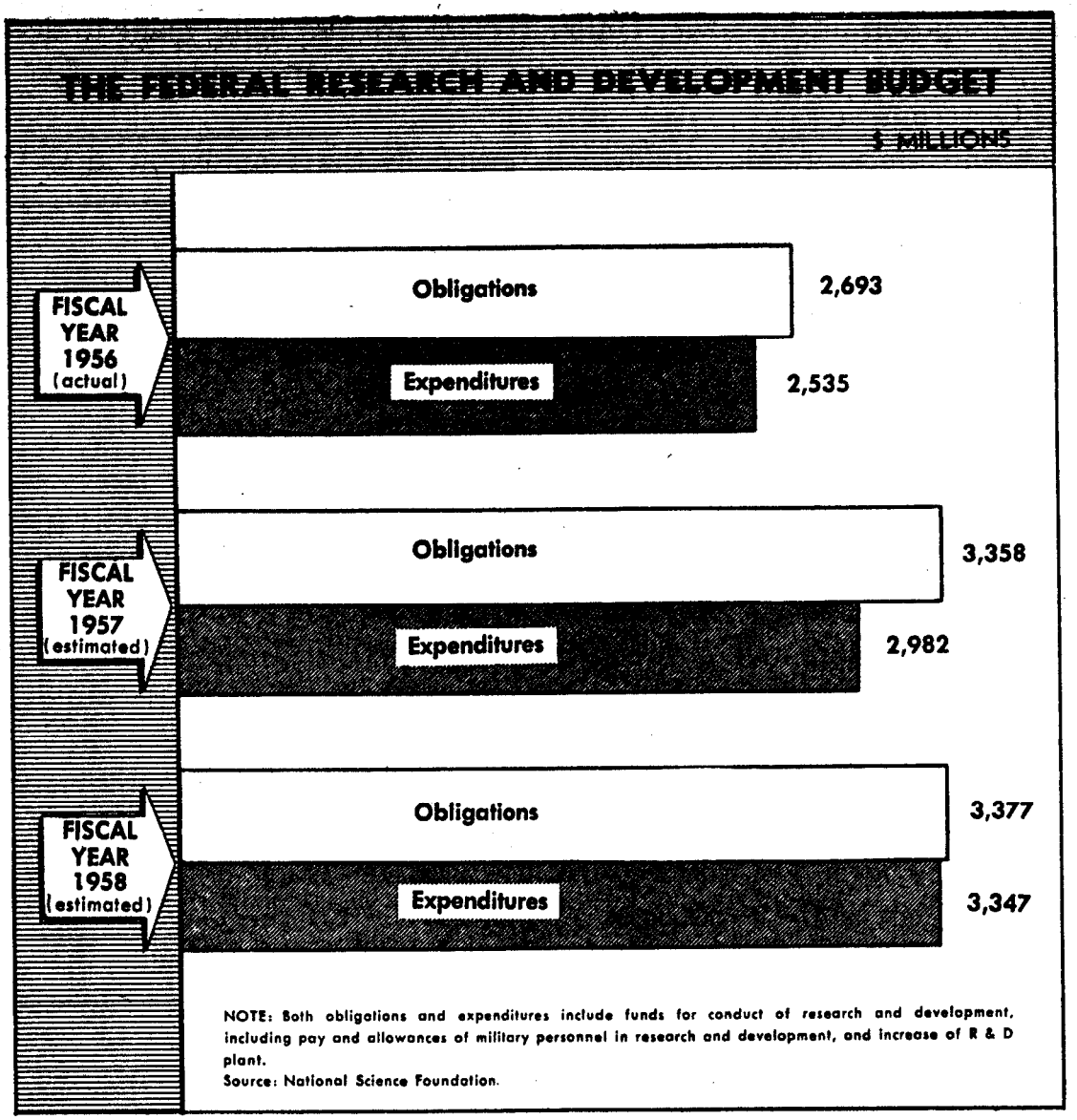


Figure 2.—*The Federal research and development budget, fiscal years 1956–58.*

funds for scientific activities was applied to conduct of research and development in fiscal year 1954, the major emphasis in the publication is on this activity.

Scientific Activities in Six State Governments.—In addition to the survey of scientific activities in the Federal Government, an exploratory study of such activities in six selected States was initiated during the same period and a summary of the findings was published.

The combined expenditures of California, Connecticut, New Mexico, New York, North Carolina, and Wisconsin for scientific activities amounted to $69 million out of a total of $4.3 billion for all purposes in fiscal year 1954. As shown in the accompanying table, conduct of research and development accounted for $57 million of the total scientific activity expenditures. Almost two-thirds of the funds for research and development were expended for such purposes in the Agricultural Experiment Stations and the State universities.

Expenditures for Conduct of Research and Development in the Six States, by Functional Areas, Fiscal Year 1954

[Dollar amounts in thousands]

Functional area	Total	California	Connecticut	New Mexico	New York	North Carolina	Wisconsin
Total	$57,007	$29,892	$1,926	$1,425	$13,795	$4,425	$5,544
Agriculture, total	20,584	9,938	971	419	4,078	2,333	2,845
(Agricultural experiment stations)	(19,195)	(9,293)	(971)	(416)	(4,022)	(1,648)	(2,845)
State universities [1]	16,782	10,725	467	319	1,405	1,586	2,280
Other education	506	42	36	67	309	52	.....
Health and welfare	[2] 8,381	1,778	174	23	6,320	23	63
Resource development and public works	7,675	[3] 5,724	208	550	471	406	316
Fiscal and administrative control	397	155	20	.....	214	8	.....
Legislative and judicial agencies	1,327	[4] 923	42	24	313	.....	25
Public safety	77	52	8	.....	.....	17	.....
Business, labor, and vocational licensing	1,278	555	.....	23	685	.....	15

[1] State universities include colleges of agriculture.

[2] All of this total except $770,000 went for research and development in the field of health.

[3] This total represents $2,580,000 for research in public works and the remainder in "resource development," e. g., such as that performed by the department of fish and game, which received $1,540,000.

[4] Of this total, $923,000 went largely for applied social science, such as work by interim commissions to study legislative and judicial problems.

Source: National Science Foundation.

Colleges and Universities and Other Nonprofit Institutions

Several reports, offering insight into research and development within these institutions, were published during the year. These studies, based on previous surveys, are enumerated below.

Faculty Scientific Research Activities at Colleges and Universities, 1953–54 (Reviews of Data on Research & Development, No. 6).—This survey covered 1,120 institutions. Detailed data were reported by 180 schools out of the 190 which had large research programs. The remaining 807 responding institutions were primarily liberal arts and teacher colleges.

The survey showed that the preponderance of total academic research effort is carried on in the large complex institutions—those having schools of medicine, agriculture, and engineering. The 180 large institutions reported total faculty of 46,560, of whom 30,060 were engaged in research; the 807 small institutions reported total faculty of 15,691, of whom 1,359 were engaged in research.

The greatest number of faculty members and full-time equivalents (*i. e.,* estimated equivalent of full-time faculty work performed by part-time faculty) engaged in research were in the life sciences, reflecting the large amount of medical research in academic institutions. The next greatest number were in the physical sciences, of which the largest number were in engineering fields.

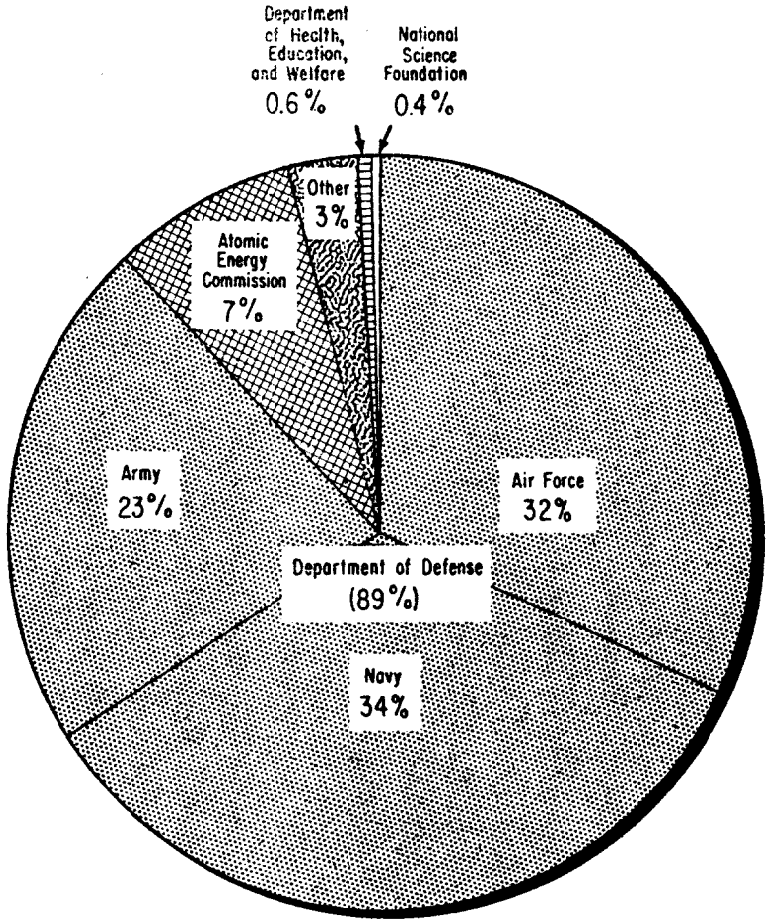
Funds for Research and Development at Engineering Schools, 1953–54 (Reviews of Data on Research & Development, No. 7).—The 109 engineering schools submitting usable returns in this survey conferred 92 percent of all graduate degrees in engineering in the United States during the period covered by the survey, July 1, 1953 to June 30, 1954.

The estimated total research funds spent by these schools during the year was $72.8 million. Approximately $64.4 million, or 88 percent, of this was separately budgeted for research; the remainder was for departmental research and indirect costs of separately budgeted funds.

Of considerable interest is the fact that more than four-fifths of the funds for separately budgeted research in engineering schools, $53.7 million, came from the Federal Government. Most of this was from the Department of Defense. (See figures 3 and 4.)

Funds for Research in Agricultural Experiment Stations, 1953–54 (Review of Data on Research & Development, No. 8)—This survey covered the 53 agricultural experiment stations in the United States, Alaska, Puerto Rico, and Hawaii which received Federal grants-in-aid for research.

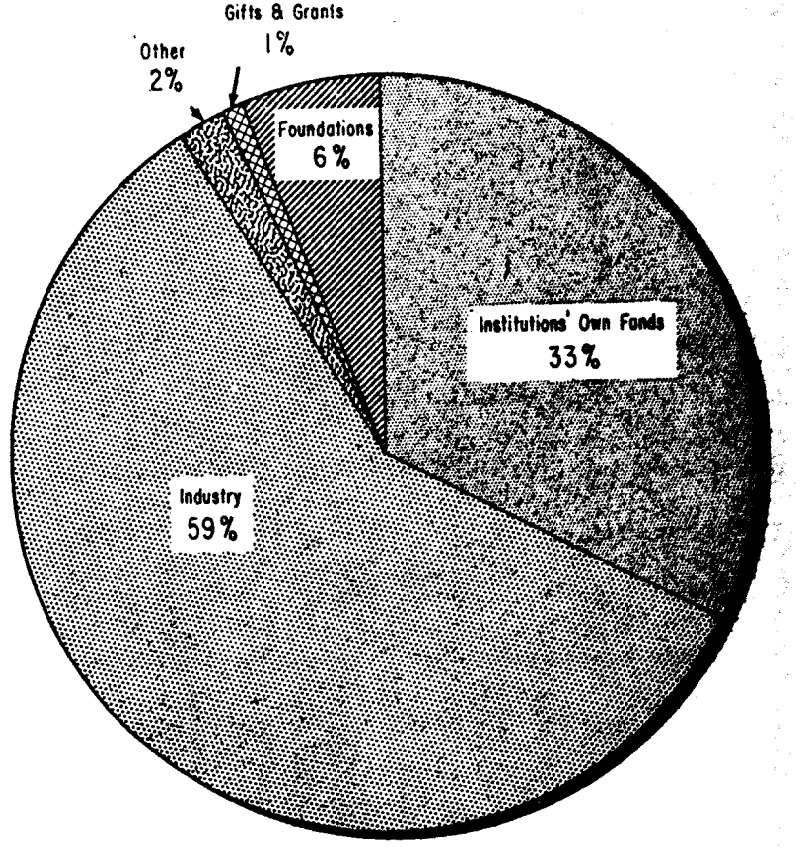
FEDERAL SOURCES—53.7 MILLION



SOURCE: National Science Foundation

Figure 3.—*Percent distribution of Federal expenditure for separately budgeted engineer-school research, by agency, 1953–54.*

NON-FEDERAL SOURCES—10.7 MILLION



SOURCE: National Science Foundation

Figure 4—*Percent distribution of non-Federal expenditures for separately budgeted engineering-school research, by source, 1953–54.*

Total Number and Full-Time Equivalents of Faculty in Scientific Research Activities, by Field, Academic Year 1953–54 (987 Institutions)

Field	Number in research		Percent distribution	
	Total (1)	Full-time equivalent (2)	Total (3)	Full-time equivalent (4)
Physical sciences	10,450	5,481	33	33
Engineering sciences	4,168	2,281	13	14
Chemistry	2,179	1,077	7	7
Physics	1,517	837	5	5
Mathematics	1,214	564	4	3
All other physical sciences	1,372	722	4	4
Life sciences	11,332	5,679	36	34
Biological sciences including medical preclinical	6,560	3,508	21	21
Clinical sciences	4,772	2,171	15	13
Agricultural sciences	5,139	3,658	16	22
Psychology	986	389	3	2
Social sciences	3,548	1,327	11	8
Total	31,455	16,534	100	100

NOTE.—Detail will not necessarily add to totals because of rounding.
Source: National Science Foundation.

Unlike the research in colleges and universities, the greatest amount of effort in agricultural institutions was for applied research. The academic institutions had reported that 62 percent of their research was basic, while these stations reported only 23 percent as basic. However, some of the land-grant universities may have had a relatively high percent of their basic research conducted by the agricultural experiment stations.

Primary source of support for the agricultural experiment stations comes not from the Federal Government, but from the States. The U. S. Department of Agriculture contributed $13.5 million for the year, while State governments contributed $44.9. However, the Federal

funds provided to these stations constitute the nucleus of their support and the incentive for State and private support of agricultural research. Funds from all other sources, such as sales, industry and foundation contributions, and others, came to $15.8 million.

Research Expenditures of Foundations and Other Nonprofit Institutions, 1953–54.—Included in this report are a diverse group of nonprofit organizations such as private philanthropic foundations, health agencies, research institutes, professional societies, academies of science, science museums, and botanical and zoological gardens. These organizations, which accounted for expenditures of approximately $70 million for scientific research and development, play an important and, in some respects, a unique role in the Nation's scientific community.

Industry

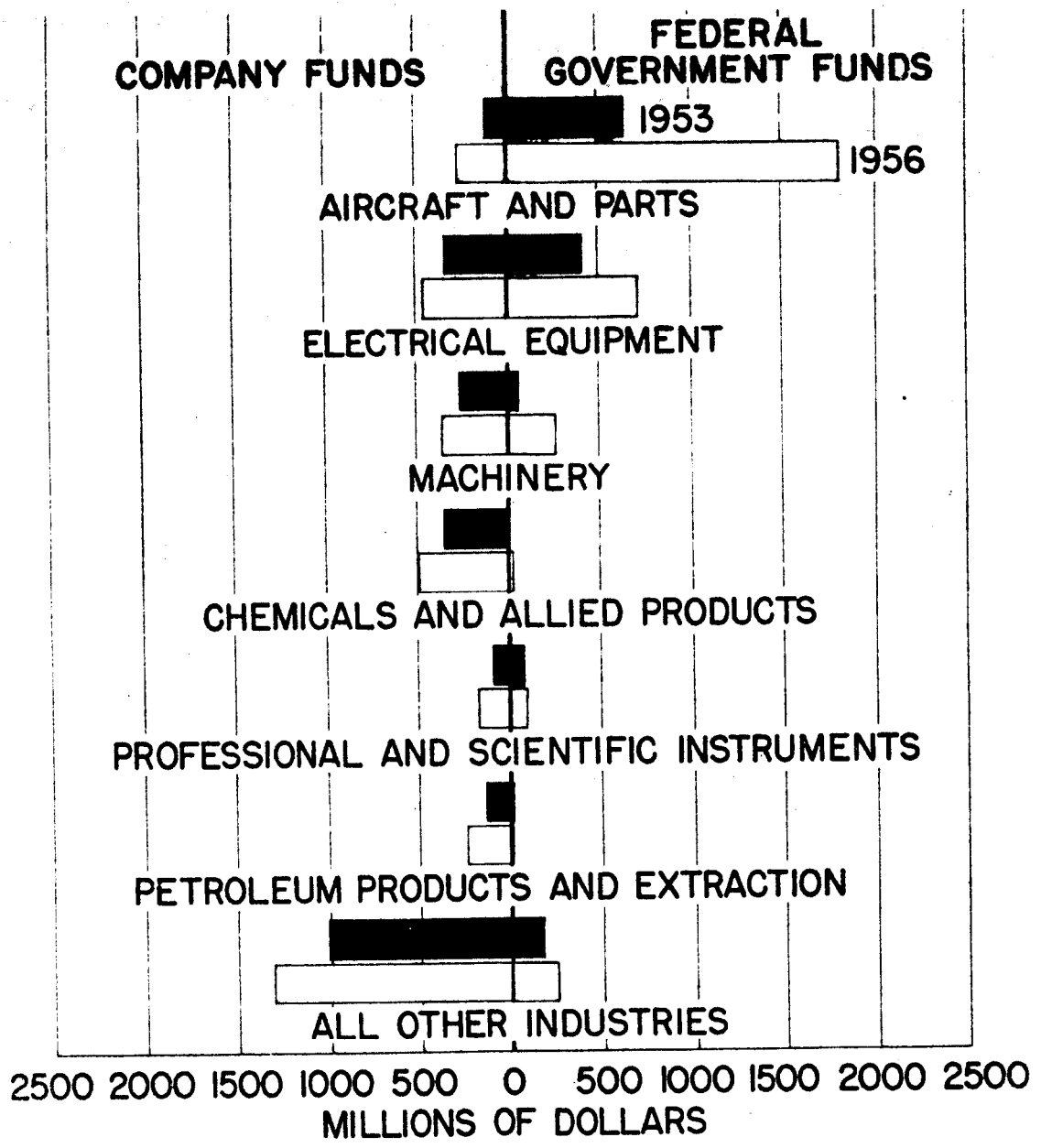
Two publications which dealt with research and development in the industrial sector were issued during the year.

Research and Development Costs in American Industry, 1956.—A preliminary report of research and development costs in American Industry in 1956 was issued by the Foundation in *Reviews of Data on Research and Development, No. 10.* The study was conducted by the Bureau of Labor Statistics and was based on a stratified random sample of manufacturing and most other nonagricultural industries. Commercial laboratories and trade associations were the subject of a separate survey.

Compared with 1953, the date of an earlier study, industrial research and development costs showed a 76 percent rise, from $3.7 billion to $6.5 billion in 1956. Federal Government-financed work accounted for $1.8 billion of the increase, while privately financed work accounted for the remaining $1.0 billion. Of total industrial research and development funds, the federally supported proportion rose from 37 percent to 49 percent.

Four major industries accounted for 68 percent of all research and development expenditures in 1956—aircraft and parts, electrical equipment, machinery, and chemicals and allied products. Aircraft and parts and electrical equipment alone accounted for just over 50 percent of total research and development costs. (See figure 5.)

INDUSTRIAL RESEARCH AND DEVELOPMENT FUNDS IN THE UNITED STATES, BY SOURCE AND BY INDUSTRY, 1953 AND 1956 [1]



1/DATA FOR 1956 ARE PRELIMINARY. DATA FOR EACH YEAR ARE EXPRESSED IN CURRENT DOLLAR TERMS.

SOURCE: NATIONAL SCIENCE FOUNDATION, OFFICE OF SPECIAL STUDIES, BASED ON DATA COMPILED BY BUREAU OF LABOR STATISTICS.

Figure 5.—*Industrial research and development funds in the United States, by source and by industry, 1953 and 1956.*

The largest increase in research and development occurred in aircraft and parts industry, which rose 174 percent, from $758.0 million in 1953 to $2,078.7 million in 1956. The machinery industry was next in line with a 92 percent increase, from $318.9 million in 1953 to $610.6 million in 1956. As for the electrical equipment industry, it increased 58 percent, from $743.3 million in 1953 to $1,173.4 million in 1956. Growth in the chemicals and allied products industry amounted to 42

percent, increasing from $361.1 million in 1953 to $511.7 million in 1956. Expansion in research and development costs from 1953 to 1956 ranged between 70 percent and 75 percent for fabricated metal products and ordnance, petroleum products and extraction, and stone, clay, and glass products. In the lower 50 percent to 60 percent range were to be found telecommunications and broadcasting, rubber products, and professional and scientific instruments.

Four-fifths of total Federal funds for industrial research and development in 1956 went into the aircraft and parts and the electrical equipment industries. In the aircraft and parts industry, 87 percent of their total funds were derived from the Federal Government, and in the electrical equipment industry, 54 percent was the comparable figure. By contrast, in chemicals and allied products, only $13.3 million or 2.6 percent came from the Federal Government. As figure 5 indicates, the role of Federal Government financing is expanding for the three leading industries receiving Federal Government funds—aircraft and parts, electrical equipment, and machinery.

Directory of Independent Commercial Laboratories Performing Research and Development, 1957.—This is the most recent available listing of such laboratories and was compiled by Syracuse University under Foundation contract.

Number*[1] *of Scientists and Engineers Engaged in Research and Development by Sector and Occupational Field, 1954

Major sector	Physical sciences and engineering			Life sciences	Natural sciences total
	Physical sciences	Engineering	Total		
Federal Government[2]	13,800	16,700	30,500	4,800	35,300
Industry-oriented organizations[3]	45,700	116,600	162,300	4,200	166,500
Colleges and universities[3]	7,600	5,600	13,200	12,000	25,200
Other institutions[3]	700	300	1,000	1,000	2,000
Total	67,800	139,200	207,000	22,000	229,000

[1] For the most part these data consist of numbers of full-time personnel plus the full-time equivalent of personnel engaged part time in research.

[2] Includes military personnel.

[3] Includes research personnel employed at research centers administered by organizations in this sector under contract with Federal agencies.

Source: National Science Foundation.

Overall Data

A synthesis of previous survey data on scientific personnel was released during fiscal year 1958.

Scientists and Engineers in Research and Development, 1954.—Summary data on employed scientists and engineers in the conduct of research and development in the natural sciences (including engineering) in the United States were presented in the ninth issue of *Reviews of Data on Research & Development.* According to this summary, based on a number of surveys conducted in 1954, approximately 230,000 scientists and engineers were engaged in R&D activities. The following table shows a distribution of these people on the basis of their occupational fields and the major sectors of employment.

Conference on Research and Development and Its Impact on the Economy

The increase in research and development expenditures from $5.4 billion in 1953 to an estimated $10 billion in 1957 has sharpened the need for knowledge of research and development as an economic factor. To marshal such knowledge by virtue of its responsibility under Public Law 507, 81st Congress, "to appraise the impact of research upon industrial development and upon the general welfare," the Foundation called a conference on "Research and Development and Its Impact on the Economy," held May 20, 1958. More than 500 noted economists and spokesmen for science attended.

The continuing themes of the conference, as Dr. Alan T. Waterman saw them, were the interrelationship of natural science research with the state of knowledge in economics and social sciences, the interdependence of basic and of applied research, and the interdependence of government, industry, and universities and other nonprofit institutions in furthering research and development.

Scientific Research and the State of the Economy

Many conference speakers emphasized that research is not only a good investment, but is in time of recession indispensable. Professor Sumner H. Slichter, Lamont Professor of Economics, Harvard University, outlined in detail his thesis of research as a dynamic force in a free competitive society.

"Within the last thirty years," Professor Slichter stated, "technological research has become a large activity that introduces fundamental changes into the operation of the economy. Measured in terms of the number of scientists and engineers devoting full time to it, re-

search "is more than five times as large as it was in 1930, and measured by the ratio of research expenditures to the gross national product, it is about thirteen times as large. * * * Today it is unthinkable that anyone should attempt to construct a theory of employment or a theory of growth without taking account of technological research."

Research for profit he calls "the industry of discovery," whose "product is knowledge." Because the product is knowledge, its utility does not diminish as the supply increases, but rather increases as it combines with the output of other units of the industry.

"One may think of knowledge as consisting of a body of tested propositions," Dr. Slichter explained. "The larger the number of tested propositions, the more numerous are the cases in which the addition of a new tested proposition will yield new useful applications and, in addition, will suggest hypotheses useful in adding still more tested propositions to the body of knowledge. Thus, the greater the body of existing knowledge, the greater is likely to be the value of the new discoveries. * * *

"It is obvious that technological research increases the capacity of the economy to raise productivity. Less obvious and indeed generally overlooked is the fact that research gives the economy the capacity to bring about planned increases in the demand for goods—both by creating new demands for consumption goods and by creating new investment opportunities. * * *"

Research, he said, tends to introduce into industry the sort of technology that must be financed by long-range plans outside the business cycle. Furthermore, technological research greatly increases the number of industries in the economy and this, in itself, is a stabilizing influence. "Hence, * * * technological research tends to moderate the cyclical movements of the economy as a whole."

The remarks of Dr. Dexter Keezer of the McGraw-Hill Publishing Company confirmed Professor Slichter's thesis. He stated, "There is no recession in research and development. * * * Industry plans to spend billions of dollars more this year for research and development than it spent last year. Expenditure indicated is over $8 billion."

Relationship of Research Process to Research Resources

Several speakers emphasized that growth of our economy requires nurturing the roots of research and development. Dr. James R. Killian, Jr., Special Assistant to the President for Science and Technology, said: "We need to increase basic research now because it is through basic research as it is conducted in the universities that we educate the pro-

fessional scientists and engineers of the future; and the Nation, in the technological contest it faces, cannot afford any alternative."

Dr. C. Guy Suits, Vice President and Director of Research, General Electric Company, referred to basic research as necessary "learning work" that must precede "applied work." Along with other speakers, he particularly emphasized the high risk factor inherent in basic research, where the immediate result, knowledge, normally is years removed from profit. But, he said, "If you don't expect to be in business five years from now, there's no need for expenditures for scientific research, especially in the learning category." Experience has proven that a competently staffed, well-organized laboratory can obtain commercial success over the long run from its basic research expenditures.

Both Dr. Killian and Dr. Charles Hitch, the latter from RAND Corporation, expressed the view that universities continue to provide the best environment for basic research. Both also pointed out the need for innovation in institutional forms, including further development of industrywide cooperative research and the establishment of research institutes.

Distribution of resources within the research and development effort was also discussed. Dr. Martin R. Gainsbrugh of the National Industrial Conference Board contended that Federal allocations of resources for research are "primarily motivated by noneconomic considerations"—chiefly military.

Mr. Robert E. Johnson, Western Electric Company, discussed operations research, which he defined as "research into the nonphysical aspects of our economy." More and more operations research studies are being channeled into problems of research and development budget planning and decision making to maximize return from limited resources. Dr. Russell Ackoff, Case Institute of Technology, outlined three categories of decision-making in which tools of the social science disciplines—economics, psychology, and sociology—are all put to use along with mathematics:

(a) Determining the amount of company resources to be devoted to research and development.

(b) Dividing funds between basic and applied research.

(c) Selecting individual projects and determining when they should start and when they should end.

Mr. Ralph E. Burgess, American Cyanamid Company, touched on the same point: "It becomes clear that industry's participation in the nation's achieving its research needs is virtually contingent upon advances in knowledge about research as a science in itself."

Speakers stressed the need for effective use of human resources to avoid a research bottleneck resulting from shortages of scientific personnel. Dr. M. H. Trytten, National Academy of Sciences—National Research Council, noted that our historic concern with education as a whole had by "accident" produced enough technically trained people to meet past needs. However, the present rate of growth is too great to depend on chance. The temptation to draw the best brains away from teaching was noted by Dr. Bertrand Fox, Graduate School of Business Administration, Harvard University.

Dr. Suits defined the technical personnel problem as follows: "In our system we require an economic balance, and to use more technical people we have to learn how to employ them effectively. Although there is an economic limit to the *numbers* of technical people we can employ in industry, there is no limit to the *quality* of the required skills. * * * I think we should focus more attention on quality and less on quantity."

Dr. Killian noted that perhaps "more first-rate research is now done in the sciences in the United States than in any other country of the world. Our deficiency is at the very top, in the area over and above the first-rate, where the great intellectual breakthroughs occur, where great concepts and discoveries originate."

Foundation statistics released at the time of the conference demonstrated the bifurcation of industrial R&D support. The preliminary findings of a survey showed that in 1956 private industrial R&D totaled $6.5 billion; industry financing, $3.3 billion; and the Federal Government, $3.1 billion.

INTERNATIONAL GEOPHYSICAL YEAR

General

The International Geophysical Year (IGY) officially opened on July 1, 1957, with 66 nations and more than 10,000 scientists participating. This was the culmination of five years of international planning conducted by committees of scientists in many nations and the coordination of such planning by the Comité Spécial de l'Année Géophysique Internationale (CSAGI).

On this date, observations of geophysical measurements over the entire earth were begun at more than 2,500 stations. These observations will extend through December 31, 1958, and are being coordinated both in time and geographic coverage.

The countries participating in the International Geophysical Year are:

Argentina
Australia
Austria
Belgium
Bolivia
Brazil
Bulgaria
Burma
Canada
Ceylon
Chile
China, Republic of
Colombia
Cuba
Czechoslovakia
Denmark
Dominican Republic
East Africa
Ecuador
Egypt
Ethiopia
Finland
France
German Democratic Republic
German Federal Republic
Ghana
Greece
Guatemala
Hungary
Iceland
India
Indonesia
Iran
Ireland
Israel
Italy
Japan
Korea, Democratic Republic of
Malaya
Mexico
Mongolian Peoples Republic
Morocco

Netherlands
New Zealand
Norway
Pakistan
Panama
Peru
Philippines
Poland
Portugal
Rhodesia, Southern
Rumania
Spain
Sweden
Switzerland
Tunisia
Union of South Africa
Union of Soviet Socialist Republics
United Kingdom
United States of America
Uruguay
Venezuela
Vietnam Democratic Republic
Vietnam (Republic)
Yugoslavia

The planning and execution of the United States program for the IGY is being conducted by the U. S. National Committee for the International Geophysical Year and a group of related technical panels. This committee was created by the National Academy of Sciences-National Research Council. Funding and Government coordination are provided by the National Science Foundation.

The United States is conducting observational programs in aurora and airglow, cosmic rays, geomagnetism, glaciology, gravity measurements, ionospheric physics, longitude and latitude determinations, meteorology, oceanography, seismology, and solar activity. High-altitude rockets and earth satellites are being used because they are essential for extending the coverage of geophysical measurements to the outer limits of the high atmosphere.

World Data Centers

In readiness for the flow of data resulting from IGY observations, three World Data Centers have been established and are in operation under CSAGI agreements. These are World Data Center A, maintained by the United States; World Data Center B, established by the USSR; and World Data Center C, composed of eight nations of Western Europe (Sweden, Spain, France, Italy, Switzerland, United Kingdom, the German Federal Republic) and centers in Japan and Australia. The location and organization of these three centers will serve the geographical convenience of the scientists of all nations.

All original IGY data is sent to one or more of the three World Data Centers, where it is cataloged and stored. The receiving Center in turn immediately makes copies of the data for the other two Centers if these have not been supplied, and provides these copies free of charge. Thus three complete sets of IGY data are coming into existence. The

World Data Centers issue periodic catalog lists of the data in their archives at the end of each six months of the period of the IGY, and any institution or individual may obtain copies of the data from a Center at a nominal sum to cover reproduction costs.

The United States World Data Center is directed by the National Academy of Sciences' Coordination Office, Washington, D. C., and is organized into 11 subcenters, each responsible for the handling of data in a particular discipline or disciplines. The location of these subcenters are:

(1) Airglow and ionospheric physics—Central Radio Propagation Laboratory, National Bureau of Standards, Boulder, Colorado.

(2) Aurora (instrumental observations)—Geophysical Institute, University of Alaska, College, Alaska.

(3) Aurora (visual observations)—Rockefeller Hall, Cornell University, Ithaca, New York.

(4) Cosmic rays—School of Physics, University of Minnesota, Minneapolis, Minnesota.

(5) Geomagnetism, gravity, and seismology—United States Coast and Geodetic Survey, Geophysics Division, Washington, D. C.

(6) Glaciology—American Geographical Society, Broadway at 156th Street, New York, New York.

(7) Longitude and latitude—United States Naval Observatory, Washington, D. C.

(8) Meteorology and nuclear radiation—National Weather Records Center, United States Weather Bureau, Asheville, North Carolina.

(9) Oceanography—Department of Oceanography and Meteorology, Agricultural and Mechanical College of Texas, College Station, Texas.

(10) Rockets and satellites—National Academy of Sciences-National Research Council, Washington, D. C.

(11) Solar activity—High Altitude Observatory, Boulder, Colorado.

Time schedules for submission of data to the World Data Centers arranged by CSAGI differ widely for the various disciplines, and therefore reports on the status of flow of data differ widely among the Centers. To date, World Data Center A reports the receipt of data from 56 of the 66 nations participating in the IGY.

Agreements for the interchange of data between the Centers are being met, as are those for the reproduction of copies of material to meet the demands of scientific bodies or investigators. World Data Center A has initiated several series of reports. One series for rockets and one for satellites will make available the results of rocket and satellite launchings

to interested scientists. Three issues of the satellite series have been published to date. Under an IGY General Report Series, World Data Center A has released one issue, a report of the Antarctic atmospheric circulation from observations made at the Antarctic Weather Central, Little America Station. Responsibilities for the interchange of data include the interim publication of data in some cases, and, as part of this latter function, Center A has already published solar data entitled "Reports of Surges and Active Prominence Regions" for the months of July, August, and September 1957. Other reports are in preparation for publication.

Antarctic Operations

In the fall of 1957, the Navy expedition DEEP FREEZE III, under the command of Rear Admiral George J. Dufek, USN, left the United States for the Antarctic, transporting the wintering-over team for the second year and the summer team for 1957–58, as well as materiel for the resupply of all stations. A second orientation program at Davisville, Rhode Island, was held for the second IGY scientific team. The scientific leaders named for the next 18-month period were:

Laurence Gould—Director of the U. S. IGY Antarctic Program.
Harry Wexler—Chief Scientist of the U. S. IGY Antarctic Program.
A. P. Crary—Deputy Chief Scientist and Scientific Leader at Little America Station.
Matthew Brennan—Scientific Leader at Ellsworth Station.
Stephen Barnes—Scientific Leader at Byrd Station.
Willis Tressler—Scientific Leader at Wilkes Station.
Palle Mogenson—Scientific Leader at Amundsen-Scott Pole Station.
Kenneth Salmon (New Zealand)—Scientific Leader at Hallett Station.

During the past year the planned program of observations at the six United States IGY stations has been under way. These observations included the fields of aurora and airglow, ionospheric physics, cosmic rays, geomagnetism, meteorology, seismology, and glaciology; and certain preliminary findings resulting from these observations are mentioned later in this section under the heading "Results of the First Twelve Months of Observations." In addition, during the 1957–58 summer season, 3 major traverses covering over 4,000 miles were undertaken from the Little America, Byrd, and Ellsworth Stations to study the

properties of the Antarctic icecap and other phenomena. Findings of these traverse parties supplement those resulting from observations at the 6 established stations and have added considerably to the knowledge of the Continent. The Ross Ice Shelf traverse party of 6 covered a distance of 1,440 miles in 113 days and studied principally properties of the Ross Ice Shelf. The Byrd traverse party covered 1,180 miles from November 19, 1957, to February 20, 1958. Its main purpose was to determine the general nature of the ice and protruding mountains in Marie Byrd Land and in the Ellsworth Highland east of the Byrd Station. The Ellsworth traverse investigated the Filchner Ice Shelf and the inland ice of Edith Ronne Land. This traverse left Ellsworth Station on October 28, 1957, and traveled 1,250 miles in 81 days. The traverse parties were supported by Naval air reconnaissance and resupply groups.

Earth Satellite

Responsibility for the United States earth satellite program was assigned as follows:

1. The National Science Foundation, for Government coordination and funding of the scientific aspects of the program.

2. The United States National Committee for the International Geophysical Year, for planning of the program's scientific aspects.

3. The Department of Defense, for provision of launching vehicles, for actual placing of the satellites into orbit, and for development of radio tracking and telemetering equipment.

The program is now based upon two launching vehicles, the Vanguard developed by the Navy, described in previous Annual Reports, and the Jupiter C contributed by the Army to the program.

During the past fiscal year, 6 successfully flown scientific earth satellites were launched as part of the IGY program, 3 by the Soviet Union and 3 by the United States. The following table gives information on the size, weight, and payload of the six satellites, as well as details of their launching vehicles. (See accompanying table.)

Eleven radio tracking stations have been established by the Naval Research Laboratory at the following locations:

Blossom Point, Maryland
Fort Stewart, Georgia
Havana, Cuba
Quito, Ecuador
Lima, Peru
Antofagasta, Chile
Santiago, Chile
Antigua, British West Indies
San Diego, California
Woomera, Australia
Esselen Park, Union of South Africa

IGY Satellite Table,[1] May 28, 1958

	1957 ALPHA (SPUTNIK I)	1957 BETA (SPUTNIK II)	1958 ALPHA (EXPLORER I)	1958 BETA (VANGUARD I)	1958 GAMMA (EXPLORER III)	1958 DELTA (SPUTNIK III)
Weight (lbs.)	184	1,120	30.8	3.25	31.0	2,925.
Shape	Sphere	Complex	Cylinder	Sphere	Cylinder	Conical.
Dimensions	22.8″		80″ long; 6″ in diameter.	6.4″ in diameter.	80″ long; 6″ in diameter.	11′ 9″ long; 5′ 8″ wide at base.
Experiments	Internal temperatures and pressures "and other data."	Cosmic rays; solar ultraviolet and X-radiation; test animal (dog); temperatures, pressures.	Cosmic rays; micrometeorite impact and erosion; temperatures.	Temperatures	Cosmic rays (with tape recorder); micro-meteorite impact and erosion; temperatures.	Atmospheric pressure and composition; satellite electrical and geomagnetic measurements; intensity of sun's corpuscular radiation; primary cosmic radiation; micro-meteorites; temperatures.
Power supply	Chemical batteries.	Chemical batteries.	Mercury batteries	a) Mercury batteries; b) solar batteries.	Mercury batteries	a) Chemical batteries; b) solar batteries.
Initial perigee (miles).	138	132	224	404	118	143.
Initial apogee (miles).	598	1,009	1,573	2,465	1,740	1,181.
Initial period (minutes).	96.25	103.3	114.8	134.29	115.9	106.
Inclination to Equator.	64.3°	65.4°	33.5°	34.25°	33.37°	65°.
Lifetime	October 4, 1957–January 4, 1958.	November 3, 1957–April 13, 1958.	January 31, 1958–(3 to 5 years).	March 17, 1958–(200 years).	March 26, 1958–.	May 15, 1958–.

[1] Shortened version of table prepared by U. S. National Committee for the IGY. Initial orbital elements from Naval Research Laboratory, based on latest refinements.

These stations were originally equipped to track the U. S. earth satellite at a frequency of 108 megacycles per second and to use the same frequency in the receipt of scientific information telemetered from the satellites. Because of the use of 20 and 40 megacycle-per-second transmitters by the USSR in their satellites, several of the "Minitrack" stations have been modified to receive the 40 megacycle-per-second frequency as well as the 108 megacycle-per-second frequency. Several additional tracking and telemetry stations using the electronic circuitry designated as "Microlock" have been established by various groups.

Twelve optical tracking stations have been established by the Smithsonian Institution and are in operation. These stations are located at the following sites:

White Sands, New Mexico	Cadiz, Spain
Florida, near Palm Beach	Shiraz, Iran
Curacao, Netherlands West Indies	Naima Tai, India
Arequipa, Peru	Woomera, Australia
Villa Dolores, Argentina	Mitaka, Japan
Olifantsfontein, South Africa	Haleakala, Maui, T. H.

The "Moonwatch" volunteer visual observing program being conducted by the Smithsonian Institution now numbers some 240 stations of which over 140 are in the United States and more than 100 in locations throughout the world other than in the United States or the USSR. Some 50–70 stations have been established within the USSR as part of the Russian equivalent of "Moonwatch."

In addition, a volunteer radio amateur satellite observation program called "Moonbeam" has been set up, as well as a program of amateur satellite photographic tracking under the auspices of the Society of Photographic Scientists and Engineers.

Some preliminary data resulting from the satellites launched so far have been exchanged, but it will take a number of months before complete interpretations of these data can be exchanged.

Results of First 12 Months of Observations

A report on the scientific results of the IGY must await careful, prolonged study and interpretation of the data. However, interesting findings during the first 12 months of observations in the various disciplines have been reported to date, some of which are influencing existing scientific theories and are indicative of the values to be derived from the program.

Solar Activity

For the first time in history, the sun has been kept under continuing observation by more than 100 stations. As a consequence of these observations, the World Warning Agency (AGIWARN) issued 25 alerts, and 11 Special World Intervals had been declared as of May 26, 1958. Significant events, such as geomagnetic, ionospheric, and/or cosmic ray disturbances took place during at least nine of these intervals. This patrol is also maintained for solar research purposes such as measuring the amount of energy released in solar flares by measuring the absolute change in transmission through the ionosphere at radio frequencies, measuring the brightness of light scattered by free electrons in the electron corona, and measuring magnetic fields at the sun's surface. Both optical and radio techniques are used.

Upper Atmosphere

In the upper atmosphere, an investigation in cosmic ray intensity has shown that the cosmic ray equator deviates systematically from the geomagnetic equator, suggesting that there may well be important magnetic fields, probably of extraterrestrial origin, which alter the trajectories of the incoming primary particles. Likewise, X-radiation not of cosmic origin has been found in the upper atmosphere, occurring at the same time that aurorae were observed overhead. Rocket penetrations of the ionosphere and aurorae have demonstrated the presence of an additional layer of ionization at a level some 12 miles below normal layers, apparently associated with solar X-ray emission associated in turn with the occurrence of solar flares. As of early 1958, the total cosmic ray intensity had decreased to about one-half the intensity present in 1954, varying inversely with the level of solar activity.

Observations indicate that aurorae occur simultaneously in the northern and southern hemispheres. Cosmic noise absorption data obtained by a joint auroral-ionospheric program show a generally progressive decrease in absorption at stations located at successively lower geomagnetic latitudes. The data begin to delineate an auroral absorption zone and confirm that nighttime absorption is definitely associated with visual auroral activity. X-radiation now appears to be associated with the occurrence of aurorae.

In the observations of whistlers (atmospheric electrical disturbances resulting in electromagnetic propagation in the audio frequency range, e. g., lightning), early experiments have demonstrated that the ion density and molecular concentration occurring at altitudes up to twice the earth's radius must be much greater than formerly anticipated. This

may confirm the theory that the earth's atmosphere extends far beyond the level where it had been previously thought to end and indicates that there may be a very tenuous atmosphere—possibly the sun's corona—filling all the space between the earth and the sun. A program of recording of subaudiofrequency geomagnetic fluctuations reveals that a number of the wave forms of these fluctuations, if increased in frequency, bear a high similarity to the wave forms of whistlers and other atmospheric radio phenomena. Because of current belief that some of the noise associated with whistlers is due to ionized gas entering the magnetic field of the earth, it is clear that these geomagnetic studies have a close connection to the studies of the transient conditions in the nearby interplanetary medium. Studies of magnetic effects in equatorial regions tentatively confirm the existence of the equatorial electroject, the equatorial electric current, possibly of several hundred thousand amperes, which is believed to encircle the earth high in the atmosphere and which plays a role in the magnetic effects observed on earth near the equator.

In the ionosphere, the vertical sounding program is giving new information about the several ionospheric layers. "True-height" determinations show that the F-layer undergoes a pronounced pinching, so that it changes from a very thick layer in the daytime to a very thin and high-density layer at night. Scatter measurements have led to the discovery of large-scale traveling disturbances in the F-region, which appear to be a kind of gigantic wave motion in the ionosphere. At times there also appear to be tilts in the F-layer that allow signal propagation over extremely long distances. The vertical sounding program in the Antarctic is aimed at determining whether the electronic clouds observed at the Pole Station during the polar night drift in from the region of the sunlit Antarctic Circle or whether a single cloud somehow persists throughout the winter. A diurnal variation is observed in the degree of ionization at the South Pole, and this variation may be related to the geomagnetic field behavior.

Meteorology and Oceanography

In the meteorology program, the concentration of carbon dioxide in the uncontaminated atmosphere appears to be remarkably constant over the world. As a consequence of the surface and high altitude observations now being collected from so many stations, weather forecasting is being improved. North American weather charts of useful accuracy can now be drawn up to 100,000 feet (10 millibars). The

high altitude observations along the 75th meridian have improved by 50 percent the forecasting in South America of winds aloft. Observations in the Antarctic for the first time reveal a significant warming trend of about five degrees Fahrenheit in annual mean temperature over a period of approximately 50 years, or less than one-half the warming trend in the Greenland Arctic. The Antarctic circulation for the first time is being plotted in considerable detail.

In oceanography, observations at the island stations confirm that there seems to be an exchange of water between the two hemispheres as the seasons change. The cruises and the deep current studies now being made, including the analysis of water samples, will yield valuable data on ages of water masses. The water samples also indicate that chlorophyll and productivity in the open sea may be two times as great as previously estimated. New deep currents and counter-currents are being charted. Cruise ships have run seismic profiles, taken bottom sediment samples, and made heat flow measurements. It was found that in regions of uplift the heat flow was larger than normal, while near severe downwarpings, the values were much less than expected. These findings lend support to the theory that there exist within the earth's mantle great convection currents that bring hot material up towards the bottom of the crust in regions of uplift and return this material, which has cooled in the meantime, back down toward the core of the earth in regions of downwarp. In fact, the convection currents themselves may be the cause of the uplifted and downwarped regions.

Seismology, Gravity Measurements, and Glaciology

In the seismology and gravity programs, detailed studies of the structures of the North American and South American continents indicate great nonuniformities and regional geographic differences in the mantle of the earth, as there are in the crustal rocks. In some regions mountains are held in isostatic balance by substructures of lighter crustal rocks extending downward into the heavier rock of the mantle. In other regions it now appears that another kind of structure may hold mountains up. A network of relatively narrow roots or veins of crustal rock may project into the mantle to depths as great as 200 kilometers. Long-period wave measurements will yield information on the variation of elastic properties in the earth's crust and mantle. Earth tides are being measured and sea surface gravity measurements are now extending the gravity network.

In the Antarctic, earthquakes are being measured from station seismographs. These will give much information about the structure of Antarctica itself and are also of other interest, since the majority of earthquakes occur in Pacific borders. Seismographic profiles obtained on the oversnow traverses lend additional information concerning Antarctic structure. Measurements of ice thickness indicate that the bottom of the ice sheet is far below sea level in various points. This may mean that the Antarctic is not a continent but may be composed of several land masses or may have frozen fjords or inland lakes. Glaciological and geological studies reveal that the Antarctic ice mantle is much thicker on the average than was previously assumed and that it was once about 1,000 feet thicker than it is now. It is not yet known whether the total ice mass is at present increasing or decreasing.

Rocketry

The rocketry program of the IGY has yielded much data concerning the chemical and ion composition of the Arctic atmosphere and ionosphere, and the diffusive separation of gases in the upper atmosphere. The distribution of temperature and pressure of the atmosphere at high northern latitudes has been partially measured. In the Antarctic, cosmic ray flights indicate that total intensity is within 5 percent of that in high northern latitudes.

Scientific Earth Satellites

In the U. S. satellites flown so far, skin and interior temperatures have been measured, and somewhat inconclusive data concerning a low incidence of micrometeorite impacts have been obtained. The chief finding to date is that of a tremendous intensity of cosmic radiation above approximately 600 miles, which overwhelmed the sensory device. It is hoped to adapt the sensory devices to measure this large intensity in future flights. Finally, observations of the orbits of the several satellites flown by the U. S. S. R. indicate that the density of the atmosphere at altitudes around 225 kilometers is higher than was previously supposed from theoretical considerations and calculations. Ionospheric measurements using radio signals from the U. S. S. R. satellites have yielded considerable data, among them an interesting but unexplained phenomenon—the discovery of radio signals coming apparently from a point antipodal to the actual satellite. Certain signals have been heard over remarkable ranges and wide angles, indicating the possibility of a channeling effect at certain altitudes in the ionosphere.

Conclusion

The IGY program has been gratifying to all concerned, not only in the elaborateness and completeness of the material preparations and the tremendous number of observing stations involved, but also in the enthusiasm with which all scientific groups and individual scientists are participating and the great evidence of the deepest international collaboration.