PART II

Program Activities

of the

National Science Foundation

Conferences in Support of Science

The National Science Foundation helped underwrite 21 conferences convened to examine special areas of science during the year ending June 30, 1955—largely in instances where adequate support was not available from industrial or other institutional sources. These conferences served as an effective clearinghouse for exchange of thought among scientists working in new or incompletely explored fields. One or more private or public agencies, including universities and scientific societies, shared sponsorship of the conferences with the Foundation.

The list of conferences (below) shows a widely diversified subject matter, over many areas of physical and biological science with related fields of the social sciences. In many cases the conferences attracted leading foreign scientists who shared their knowledge with associates in the United States working in the same disciplines. Some of the most significant conferences impinged on two or more areas of interest, resulting in a healthy cross fertilization of ideas.

To insure wide distribution of conference subject matter, proceedings and papers are frequently published by the sponsors. Normally, the request for support of conferences originates with the scientists working in the field under review. Brief notes on the conferences are given below.

Scientific Conferences Supported by the National Science Foundation in Year Ending June 30, 1955

Subject	*Sponsoring Organizations*	*Chairman*
Nuclear Emulsion Research in Colleges.	DePauw University.....	Marcel Schein, Co-Chairman; Malcolm Correll, Co-Chairman.
International Arid Lands Symposium and Conference.	American Association for the Advancement of Science. United Nations Educational, Scientific and Cultural Organization. University of New Mexico.	George W. Beadle.
The Crust of the Earth....	Columbia University.....	Paul F. Kerr.
Anomalous Magnetization of Rocks.	University of California, Los Angeles.	Louis B. Slichter.

Scientific Conferences Supported by the National Science Foundation in Year Ending June 30, 1955—Continued

Subject	*Sponsoring Organizations*	*Chairman*
Man's Role in Changing the Face of the Earth.	Wenner-Gren Foundation for Anthropological Research, Inc.	William L. Thomas, Jr.
Cosmic Distance Scale.....	University of Virginia.....	H. L. Alden, Local Chairman. J. J. Nassau, Chairman
Mechanics in Engineering Education.	American Society for Engineering Education. New York University.	F. L. Singer.
Genetic, Psychological, and Hormonal Factors in the Regulation of Patterns of Sexual Behavior in Mammals.	University of Kansas.....	William C. Young.
Mathematical Tables.....	Massachusetts Institute of Technology.	Philip M. Morse.
Gordon Research Conferences.	American Association for the Advancement of Science.	W. George Parks.
Research in the History, Philosophy, and Sociology of Science.	American Philosophical Society.	L. P. Eisenhart.
Mechanics of Sediment Transport.	American Society of Civil Engineers. University of Tennessee.	M. A. Mason.
Radiocarbon Dating.....	Robert S. Peabody Foundation for Archaeology; National Research Council.	Frederick Johnson.
Evolution of Behavior.....	American Psychological Assn. and the Society for the Study of Evolution.	Anne Roe.
The Theory of Numbers...	California Inst. of Technology.	H. F. Bohnenblust.
Mathematical Statistics and Probability.	University of California.....	Jerzy Neyman.
Quantitative Biology.....	Long Island Biological Assn.; the Carnegie Corp.; the Atomic Energy Commission.	M. Demerec.
Problems of Nuclear Structure.	University of Michigan.....	E. F. Barker.
Fourteenth Growth Symposium.	The Society for the Study of Development and Growth.	V. C. Twitty.
Molecular Quantum Mechanics.	University of Texas.....	F. A. Matsen.
High Energy Nuclear Physics.	University of Rochester.....	R. E. Marshak.

Nuclear Emulsion Research in Colleges

An interesting type of cooperative research project involving physicists in colleges and those in large research centers was critically evaluated

in a conference held March 31, 1955 at DePauw University. These research projects are concerned with nuclear processes as recorded in photographic emulsions where the emulsion is exposed either at large accelerations or during cosmic ray balloon flights. Typical investigations using nuclear emulsion techniques are those in which the distribution of cosmic ray stars is sought, the energy and momentum balance for nuclear events is studied or the event-history for unstable elementary particles is analyzed. Both groups of participants, namely the research-physicists and the teaching-physicists, endorsed these cooperative projects as effective instruments for producing good research, for indirectly improving undergraduate teaching and for making it easier to staff physics departments in small colleges and universities. Discussions brought out the unique ways in which nuclear emulsion research projects can encourage significant research and can improve the teaching in research-isolated institutions with only modest demands on space and funds. The conferees recommended that meritorious projects continue to be encouraged through grants and that summer research institutes be established to assist those interested in initiating a program of this kind. The conferees also requested that the steering committee for the conference be established as a liaison body during this period of intense interest in nuclear emulsion cooperative projects.

International Arid Lands Symposium

Top-ranking meteorologists, climatologists, geologists, hydrologists, geographers, botanists, biologists, and zoologists of the United States and other nations convened in the spring of 1955 to consider on an international basis problems relating to arid lands. Government and university scientists presented papers on such problems as the predictability of precipitation in arid regions, drought cycles, ground water resources, usage, and reusage. The group considered as well the plant and animal ecology of arid areas and possible changes which would favorably affect plant and animal populations and revegetation. The National Science Foundation sponsored the conference jointly with the American Association for the Advancement of Science, the United Nations Educational, Scientific and Cultural Organization, and the University of New Mexico.

The Crust of the Earth

What is the nature and behavior of the earth's crust? Attempts to find answers were made by geologists of international standing at a confer-

ence held at Columbia University, New York City, in October 1954, sponsored jointly by the National Science Foundation and Columbia University. The program coincided with the Bicentennial Celebration of the founding of Columbia. Agenda for the meeting centered around: (1) the nature and constitution of the earth's crust; (2) recent deformation and sedimentation; (3) petrogenesis and structural synthesis; and (4) historical (geological time) development of the crust. Papers were read by scientists of this and other countries and arrangements were made for their publication with the Geological Society of America.

Anomalous Magnetization of Rocks

The National Science Foundation sponsored a conference held August 7–8–9, 1954, on the "Anomalous Magnetization of Rocks", at the Institute of Geophysics, University of California, Los Angeles, California. Interest focused on certain rock formations which have a magnetic polarization that does not conform to present day magnetic field flux. Participants included a number of outstanding American scientists as well as experts from England, Canada, Japan, and France. Discussions emphasized the differences of opinion in this important field of study between the physicists and the geologists. Much additional study is needed in order to work out details of the anomalous magnetization problem.

Man's Role in Changing the Face of the Earth

Keyed to the central theme of man-nature relationship, a conference was held in June 1955, at Princeton, New Jersey, jointly sponsored by the Wenner-Gren Foundation for Anthropological Research, Inc., of New York, and the National Science Foundation. Attracted to the conference were scientists from the United States and abroad working in interrelated disciplines, including anthropology, geography, mathematics, geochemistry, botany, zoology, demography, anatomy, microbiology, culture history, limnology, climatology, and sociology.

The conference explored the dynamic effects, present resources and future prospects of: (1) the earth's resources; (2) the relation of population to these resources; and (3) man's differing cultures, or ways of life. Represented at the conference were scientists from many disciplines who, for the first time, attacked as a unified whole problems which heretofore had been touched upon only in "piece-meal" fashion by individual disciplines.

Cosmic Distance Scale

Sponsored jointly by the University of Virginia and the National Science Foundation, a conference was held in Charlottesville, Virginia, in April 1955, on the cosmic distance scale. Cosmic distances are basic data in almost any astronomical study. Recent advances in astronomical knowledge have revealed the complexities and difficulties in some of our concepts on which cosmic distances have traditionally been based. The present state of uncertainty of the distance scale of galaxies is but one outstanding example.

Some thirty astronomers met at Charlottesville to attempt to throw new light into this difficult area. Particular items on their agenda were: (1) current problems with regard to distance scale, ranging from nearby trigonometric to distant photometric distances; (2) determination of cosmic distances and technical difficulties encountered; and (3) a review of the problems whose solutions depend on a knowledge of distances.

Mechanics in Engineering Education

Engineers, physicists and mathematicians convened in January 1955 to review the desirability of modifying present engineering courses to keep them in stride with rapidly advancing science. Of particular concern to the conference were: (1) items that can be eliminated from an elementary physics course; (2) the rearrangement of subject matter for a modernized physics course; and (3) the re-orientation of the mechanics courses in relation to the engineering curriculum, together with a rearrangement of topics in the mathematics sequence, that would permit the rearrangements of course topics to be taught effectively. Jointly sponsored by the American Society for Engineering Education, New York University and the National Science Foundation, the conference brought together outstanding scientists and engineers for a 3-day discussion at the Gould House, Ardsley, N. Y.

Genetic, Psychological and Hormonal Factors in the Regulation of Patterns of Sexual Behavior in Mammals

Contributions to our knowledge of the physiology of reproductive behavior and to an understanding of the bases for different patterns displayed are being made by anatomists, anthropologists, biochemists, endocrinologists, physiologists, psychiatrists, psychologists, and zoologists. In order to bring together scientists representative of these several disciplines, the National Science Foundation underwrote a conference

which was held at Northampton, Mass., in December 1954. The conference served to facilitate an exchange of information with respect to latest research in the several fields of reproductive behavior and helped, as well, in systematizing new research approaches.

Mathematical Tables

Government and industry alike have benefited materially by the comparatively recent development of high-speed data processing equipment. In order to canvas, from the point of view of both users and producers, new ways of making mathematical tables and new forms of storing tabulated material, the National Science Foundation sponsored jointly with the Massachusetts Institute of Technology a 1954 summer conference in the Hayden Library of the Institute. The conference attracted both producer and consumer representatives from academic, industrial and Government sources—mathematicians, computors, and scientists actively interested in tables of functions. This workshop group sought answers to such immediate questions as how tables are made, functions needed to be tabulated, form the tables should take, and what the United States should do about producing tables.

Gordon Research Conferences

The Gordon Research Conferences are among the most significant scientific meetings called each year in the United States. They were first organized in 1931. They have been continued annually under the auspices of the American Association for the Advancement of Science, and have drawn not only leading American scientists, but eminent foreign scientists in the disciplines covered. During the past year the Rockefeller Foundation supported conferences in the fields of food and nutrition, medicinal chemistry, cancer, steroids and other subjects related to biology and medicine. The grant provided by the National Science Foundation assisted in the support of conferences in the physical sciences in such subjects as analytical chemistry, catalysis, chemistry and physics of metals, chemistry at interfaces, elastomers, ion exchange, and solid state reactions. The Foundation support enabled 137 scientists from the United States and abroad to attend these conferences during the year.

History, Philosophy, and Sociology of Science

A conference to discuss research in the history, philosophy, and sociology of science was held in February 1955 in Philadelphia under the

joint sponsorship of the American Philosophical Society and the National Science Foundation. Studies in the history and philosophy of science have contributed greatly to a better understanding of science as a logical and empirical system. They have served to clarify the factors, both external and internal, which promote progress in the sciences. It has been increasingly clear, however, that the sociology of science is of equivalent significance in our civilization, which depends so largely upon scientific and technological progress. Participants in the conference were drawn from all three areas, and the discussion centered largely on a review of recent developments in these fields, the inter-relation among the fields, and the selection of promising fields for future research.

Mechanics of Sediment Transport

Problems relating to sedimentation are encountered on a grand scale in such projects as river and flood control and the silting of large dams, and on a smaller scale in such problems as the treatment of sewage. There is wide current interest in the fate of radioactive sediments that arise in the operation of nuclear reactors.

A conference on Mechanics of Sediment Transport was sponsored jointly by the American Society of Civil Engineers, the University of Tennessee, and the National Science Foundation at Fontana Village, N. C., in October 1954. Participants discussed the physical factors which pertain to such processes as deposition, erosion, and transport of various types of sedimentary material in a fluid environment.

Radiocarbon Dating

The use of radiocarbon techniques for dating human and other biological remains over the past 30,000 years has been one of the most exciting interdisciplinary developments in science during the past decade. At the present time many laboratories have installed the necessary equipment to carry out dating measurements on a fairly routine basis. Experience of these laboratories has brought to light, however, a number of problems involving both theory and practice, which have led to confused, and in some cases, contradictory results. In order to resolve some of these difficulties, the R. S. Peabody Foundation for Archaeology, the National Research Council, and the National Science Foundation jointly sponsored a conference on radiocarbon dating, which was held at Andover, Mass., during October 1954. The conference enabled physicists,

chemists, archeologists, geologists, paleontologists, and soil scientists to review the technical problems involved in the application of radiocarbon dating to archaeological sites, geological deposits, and soil genesis.

Evolution of Behavior

The study of the evolution of behavior is fundamental for an understanding of both functional biology and psychology. A conference on the evolution of behavior was held in April 1955 at Arden House, Columbia University, under the joint sponsorship of the American Psychological Association, the Society for the Study of Evolution, and the National Science Foundation. The meeting enabled scientists from several disciplines to exchange ideas regarding the evolution of behavior. Participants discussed such topics as genetic and developmental behavior and the place of behavior in the study of evolution. Of particular interest were the sessions devoted to fairly well-defined aspects of behavior, such as learning, food-getting, locomotion and defense, reproductive behavior, and social behavior. An important session of the conference considered the relationship between biological and cultural evolution.

Theory of Numbers

For the past three centuries investigation of the mathematical theory of numbers has inspired some of the most significant developments in mathematics. Mathematicians are agreed, moreover, that this well has not run dry, and that such studies will continue to provide impetus to further development in a wide range of mathematical fields. In June 1955 a conference on the theory of numbers sponsored jointly by the California Institute of Technology and the National Science Foundation was held at Pasadena, Calif. About 30 specialists in number theory from all parts of the United States assembled to review recent advances and discuss unsolved problems. One of the most interesting sessions dealt with the use of modern high-speed computing machines in number theory.

Mathematical Statistics and Probability

In December 1954 and August 1955 the Third Berkeley Conference on Mathematical Statistics and Probability was sponsored jointly by the University of California and the National Science Foundation. The symposium was held in two sections to permit the attendance of a substantial number of scholars attending the Christmas meeting of the

American Association for the Advancement of Science. Three American societies immediately concerned with statistics also met in Berkeley at the same time. These were the American Statistical Association, the Institute of Mathematical Statistics and the Biometric Society.

The Berkeley symposia have been noted for the appearance of a number of substantial technical papers in rapidly developing areas of statistics and probability. These have served to sort out and combine fruitful recent ideas in the field, establish relations among them, and outline new problems that still await satisfactory solution. The proceedings of the symposium, which total some 700 pages, are being edited for publication.

Quantitative Biology

The Twentieth Cold Spring Harbor Symposium held in June 1955 at Cold Spring Harbor, Long Island, was devoted to the subject of quantitative biology with particular emphasis upon population genetics. These annual meetings have, over the past two decades, brought together some of the outstanding biological scientists in the United States and abroad and have proved extraordinarily fertile as a source of new ideas in both theory and experiment. The Twentieth Symposium was sponsored jointly by the Long Island Biological Association, Carnegie Corporation, the Atomic Energy Commission, and the National Science Foundation.

Nuclear Structure

During the summer of 1955 a conference was held on problems of nuclear structure at Ann Arbor, Mich., under the joint sponsorship of the University of Michigan and the National Science Foundation. The past 3 or 4 years have seen many improvements for techniques in measuring nuclear properties, and this experimental work has resulted in the development of improved concepts of shell structure of the nucleus. Several other types of models have also been proposed to explain or describe various nuclear reactions. The conference was particularly notable in that it was attended by numerous young scientists currently engaged on problems relating to nuclear structure.

The Fourteenth Growth Symposium

In 1955 for the third year in a row the National Science Foundation provided support for the Growth Symposium sponsored by the Society

for the Study of Development and Growth. This annual symposium enabled students of growth in such varied fields as genetics, pathology, biochemistry, botanical sciences, and embryology, who normally do not meet together, to exchange information and ideas on recent development in their respective fields. An outstanding contribution of the symposia has been publication of the presented papers. The major topics discussed in 1955 were differentiation of cells and tissues in plants and animals, acquired tolerance to tissue transplants, and the cytochemistry of nucleic acids.

Molecular Quantum Mechanics

Quantum theory is finding extensive application in molecular physics and chemistry. The techniques of quantum mechanics have been effectively used in giving theoretical knowledge on the physical and chemical behavior of molecules. In order that scientists in the area might be brought together to review the status of research, the Foundation jointly sponsored a 3-day conference with the University of Texas at Austin, Tex., in December 1954. Agenda for the conference centered around these chief considerations: (1) application of present-day theory to the calculation of the physical properties of molecules; (2) quantum interpretation of chemical valence concepts; (3) forces between molecules; (4) configurative interaction and correlation energy; (5) mathematical developments; and (6) evaluation of integrals.

High Energy Nuclear Physics

The year 1954 was important for furthering knowledge in high energy nuclear physics. The National Science Foundation had aided in University of Rochester in holding two previous conferences in this area, and the conference held in Rochester, N. Y., in late January and early February 1955, was co-sponsored by the Foundation and the International Union of Pure and Applied Physics. Subjects of particular interest to participants, among whom were included several scientists from other nations as well as American scientists, were nucleon-nucleon scattering, nucleon polarization, pion scattering, photomesic production, electron scattering by mesic atoms, field theories, elementary particles and nuclear forces theories. The conference served as a forum for experimental and theoretical physicists to exchange ideas and reports of progress in fields of high energy elementary particles and high energy nuclear physics.

Support of Basic Research in the Sciences

During the year ending June 30, 1955, 588 grants totalling $7,857,395 were made by the Foundation for the support of basic research in the natural sciences. These funds were distributed in the biological, medical, mathematical, physical, and engineering sciences to 184 institutions in 47 States, the District of Columbia, Hawaii, Puerto Rico, England, and Italy. The average research grant for fiscal year 1955 was $13,400, to run for 2.7 years, or about $5,000 per year.

The table below summarizes the research support program by broad

National Science Foundation Research Grants by Fields of Science

Field	Fiscal year 1954		Fiscal year 1955	
	Number	Amount	Number	Amount
Biological and Medical Sciences:				
Anthropological	0	0	5	$51,700
Developmental	13	$110,520	21	156,400
Environmental	7	43,200	25	212,200
Genetic	13	156,900	20	254,800
Molecular	32	458,000	50	819,850
Psychobiology	27	293,450	41	568,500
Regulatory	41	464,800	62	947,895
Systematic	32	238,500	44	357,500
General	12	164,100	7	173,650
	177	1,929,470	275	3,542,495
Mathematical, Physical and Engineering Sciences:				
Astronomy	19	147,900	19	363,800
Chemistry	47	477,400	82	1,091,600
Earth Sciences	27	282,800	29	438,400
Engineering	42	390,900	64	724,200
Mathematics	21	173,950	48	562,400
Physics	41	485,800	67	1,083,800
General	0	0	4	50,700
	197	1,958,750	313	4,314,900
Total Research Grants	374	3,888,220	588	7,857,395

subject categories. A detailed list of the grants, showing institution, principal scientists, title of project, duration, and amount is given in Appendix II.

Four-Year Summary

The National Science Foundation has had a total of 4 years experience in administering research support. During this period, fiscal years 1952 through 1955, a total of 1,232 grants amounting to $14,316,140 have been made for support of basic research in the natural sciences. During the same period a total of 3,561 proposals for research have been submitted to the Foundation requesting $66,591,413. After careful review and evaluation by the scientific advisory panels and staff program directors, approximately 75 percent of the proposals were considered to be meritorious, that is, they were considered of sufficient merit to be worthy of support. The dollar value of grants actually approved and made was about 21 percent of the total of submitted proposals and 28 percent of the total of meritorious proposals.

The capacity of an educational institution to undertake research depends upon a number of factors. The primary factor is undoubtedly the relative emphasis placed by the institution upon teaching and research. Research activities enter into the curriculum most naturally during the course of graduate study. In certain instances and on particular types of research the Foundation has been able to support research activities in undergraduate departments. These are exceptional cases, however, and a useful index of institutional research capacity continues to be the number of graduate students in training.

The desires and aptitudes of the individual faculty members have much to do with the capacity of institutions to conduct research. While teaching ability may in many individuals be associated with excellence in research, this is by no means invariably true. As a result, many excellent teaching departments have carried on little or no research activities in the past, and there is no reason to expect a change in the near future.

The nature of the teaching program of the institution also governs or limits the extent to which that institution will participate in research. Obviously, agricultural research will be concentrated largely in the agricultural colleges and research in the physical sciences is prominent in the engineering schools.

The geographical distribution of Foundation grants and research funds over the 4-year period is illustrated in the map shown in figure 1 and its accompanying tables. As might be expected, there is a definite relationship between the graduate student population and distribution of grants.

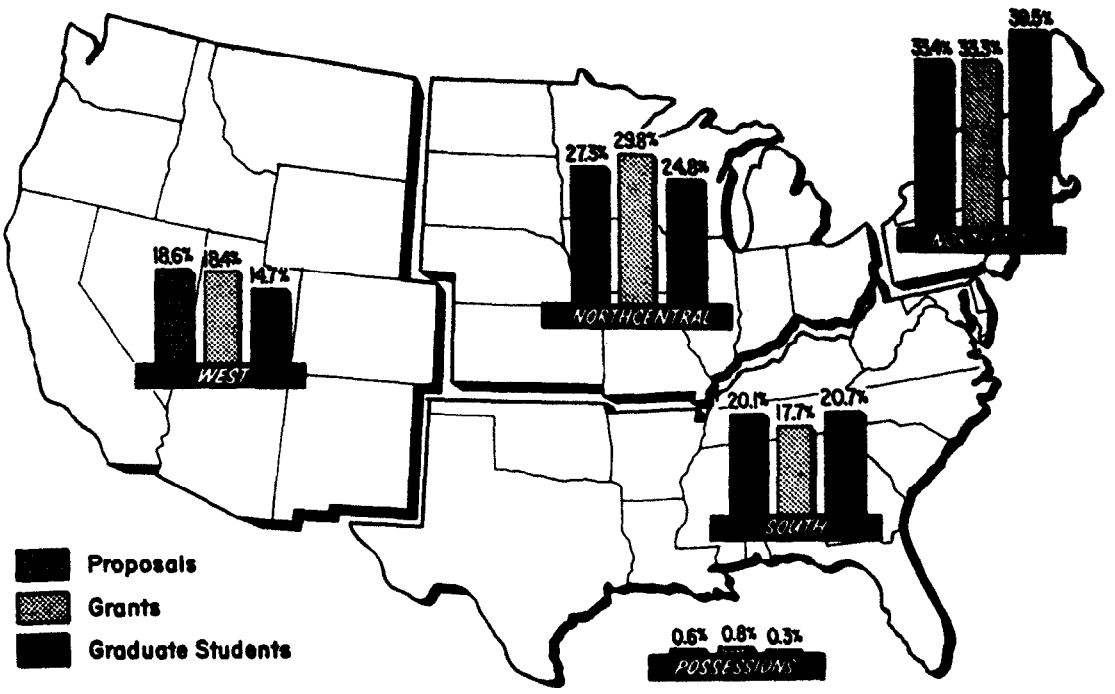

FIGURE 1. *Regional comparison of proposals received (dollars), grants awarded (dollars), and graduate student population, fiscal years 1952 through 1955, expressed in percent of total of each index.*

Regional Distribution of Proposals Received, Grants Awarded Graduate Students, and Total Population

Region	Fiscal years 1952–1955				Academic year 1952–53. Graduate students		1950 Census. Total population (100,000's)	
	Proposals received		Grants awarded					
		Percent		*Percent*	*Number*	*Percent*	*Number*	*Percent*
Northeast	$22,267,980	33.4	$4,771,945	33.3	88,417	39.5	395	26.2
South	13,360,208	20.1	2,537,060	17.7	46,280	20.7	443	29.3
North Central	18,205,167	27.3	4,261,935	29.8	55,425	24.8	471	31.2
West	12,368,994	18.6	2,628,400	18.4	32,987	14.7	197	13.0
Possessions	389,064	0.6	116,800	0.8	723	0.3	5	0.3
Totals	66,591,413	100.0	14,316,140	100.0	223,832	100.0	1,511	100.0

Preliminary analyses have been made of the final fiscal reports submitted by institutions for completed grants. Conclusions, illustrated in the chart and its accompanying table in figure 2, follow from a sampling of 149 completed grants and show a very tight relationship between estimated and actual expenditures for the average research grant. In short, grantees are spending Foundation funds strictly in line with, and for the purposes expressed in, their applications—almost to the dollar.

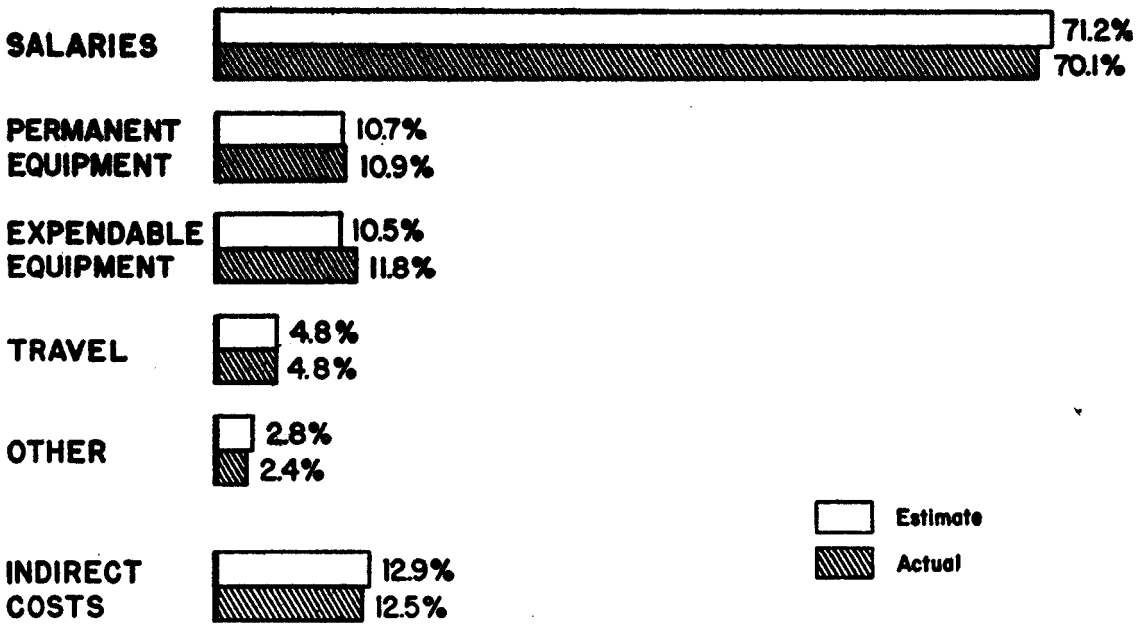

FIGURE 2. *Estimated compared with actual expenditures for the average National Science Foundation research grant, expressed in percent of total direct costs.*

Estimated vs. Actual Expenditures for the Average Research Grant [1]

(Expressed in % of total direct costs)

Object	Actual [2]		Estimated [3]	
		Percent		*Percent*
Salaries	$4,513	70.1	$4,810	71.2
Permanent Equipment	705	10.9	724	10.7
Expendable Equipment	763	11.8	712	10.5
Travel	307	4.8	321	4.8
Other	154	2.4	186	2.8
Total Direct	6,436	100.0	6,753	100.0
Indirect	809	12.5	877	12.9
Total	7,245	.....	7,630	.....

[1] Based on Analysis of 149 completed grants.
[2] Based on data obtained from fiscal reports.
[3] Based on budget estimates at time of Board approval.

Figure 3 and its accompanying table show that nearly three-fourths of the total funds distributed have gone for personal services, primarily for support of research assistants and associates and laboratory and other skilled labor. About 17 percent of the total direct costs were spent for equipment. The allowance for indirect costs averaged 13 percent of direct costs.

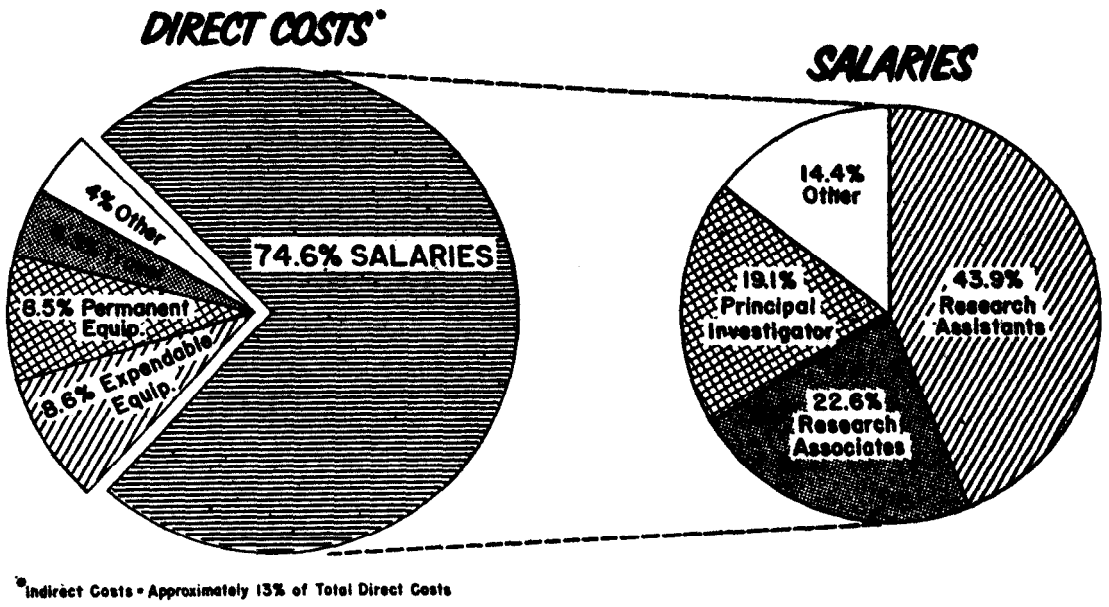

FIGURE 3. *Analysis of the average National Science Foundation research grant by type of expenditure (estimated).*

Analysis of Salaries Paid from Average Research Grant [1]

	Average grant fiscal year 1954	*Percent of salaries*
Principal Investigator (total)	$1,325	19.1
Summer	(872)	(12.5)
Sabbatical	(29)	(.4)
Academic	(424)	(6.2)
Research Associate [2]	1,573	22.6
Research Assistant [3]	3,042	43.9
Other [4]	1,000	14.4
Total	6,940	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 institution 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.

Source: Commission on Human Resources and Advanced Training.

In the paragraphs following mention is made of specific parts of the Foundation's research support program of special current interest. It should be noted that these are selected examples and do not purport to represent the broad overall program for research support in all areas of the natural sciences.

Cooperative Nuclear Emulsion Research

In 1953 the National Science Foundation supported a conference at Amherst College to consider the advisability of sponsoring physics research programs in colleges. After a thorough discussion of its advantages and disadvantages the conference recommended the establishment of more research programs, pointing out that these research programs lead to more stimulated teaching, make it easier to get good men to take on college teaching jobs and help preserve the lifeline of graduate material that flows from the colleges to the graduate schools. A more detailed report on this conference was given in the Foundation's Fourth Annual Report.

Not all research lends itself to adoption by colleges and those universities that have not previously had strong research programs. One field of research that was mentioned at the Amherst Conference as having great promise was research in which nuclear data contained within special photographic emulsions are studied. The facilities required for this research are recognized as being small and the research field is one of great interest to physicists today.

To investigate further the potentialities of research programs using nuclear emulsions a second conference was held under the sponsorship of the Foundation at DePauw University on March 30, 1955. (See p. 36.) This conference concerned itself with cooperative programs in which the research would be jointly carried out by physicists on college staffs and those in universities or other laboratories. Cooperation of this type greatly strengthens the college research program and gives it a certain amount of assurance that it will be kept abreast of the advances being made in the field throughout the world.

At the DePauw Conference the discussions centered on questions dealing with the advantages, disadvantages, and difficulties associated with cooperative nuclear research projects in colleges. To furnish background material for these discussions expository surveys were first given on current nuclear emulsion research in the fields of classical nuclear physics, cosmic ray physics and high energy elementary particle physics. Methods for preparing, processing and measuring nuclear emulsions were also reviewed.

The Foundation has supported several research programs in this area. Dr. K. E. Davis of Reed College has received a grant to study cosmic ray stars in cooperation with the University of Rochester and other laboratories. Dr. A. G. Barkow of Marquette University and Dr. J. J. Lord of Washington University have grants to carry out a study on

elementary particles under the guidance of Dr. Marcel Schein of the University of Chicago. At Principia College Dr. S. L. Leonard is using nuclear emulsion material obtained from Stanford University and the University of California at Berkeley. Dr. Nora Mohler of Smith College is starting to work on a similar project in cooperation with the Massachusetts Institute of Technology and Brookhaven National Laboratory.

At the DePauw Conference it was recognized that it is frequently difficult for a college teacher to undertake a research program in the field of nuclear emulsions without first learning about special instruction on the experimental techniques and the recent theoretical advances that have occurred in the field. Many of these teachers have been trained in other fields which require facilities that are not available on college campuses. These theoretical advances referred to include developments in elementary particle theory, nuclear theory and field theory. The experimental techniques include methods of obtaining scattering data, recognition of cosmic ray events, grain counting, techniques for minimizing distortions, etc.

To facilitate the starting of programs by college staffs the DePauw Conference recommended that one or more summer institutes be held at institutions having active programs in this field. The Foundation plans to carry out this recommendation during the coming year.

Solid State Research

Scientists have been interested in solids from two points of view. First, they have been concerned with the mechanical properties of solids and the puzzling question of what holds the atoms together in a solid. The second interest centers on the electrical and magnetic properties of solids. Grants made by the Foundation have promoted significant research in both areas.

B. M. Warren of the Massachusetts Institute of Technology has successfully measured the atomic force constants in crystals of zinc and copper with methods that leave the sample undisturbed during the measurement. Dr. Warren and his students first made careful measurements of X-ray scattering by the crystals from which the thermal vibration states of the atoms could be calculated. These measurements do not subject the samples to stress or to high temperatures during the test. From the thermal vibration knowledge Dr. Warren next was able to calculate the atomic force constants. Full understanding of atomic behavior in simple crystals under normal conditions is necessary before attempting to describe the more complex characteristics of solids such as tensile strength.

During the past 10 years physicists have learned that imperfections and impurities play a very important part in the properties of solids. Imperfections affect the strength of materials, as well as the electrical and optical properties of many solids. R. L. Sproull at Cornell University has been investigating imperfections in alkali halide crystals by means of heat-conducting waves. He found that at liquid helium temperatures the heat waves are scattered by the submicroscopic imperfections, and simple heat conduction measurements gave precise information on the number and distribution of imperfections in the crystals. The further utilization of this method for investigating imperfections in solids may lead to better understanding of the almost catalyticlike effect that small imperfections seem to set up in many of the new materials that are now being introduced into our current technology.

C. Kittel at the University of California, Berkeley, has been investigating electron conduction in metallic solids. The study of magnetic resonance effects in atomic nuclei has been a favorite method by which physicists learn more about the electrical and magnetic properties of solids. Dr. Kittel first worked out a theoretical study of the interaction between the measurable nuclear resonance effects and electron conduction. His work showed that the conduction electrons should contribute to the broadening of nuclear resonance lines, and the theory was verified experimentally through resonance measurements made on metallic silver.

At Northwestern University J. A. Marcus has been investigating the magnetic properties of single crystals. The study was carried out at liquid helium temperatures using single crystals of bismuth. Dr. Marcus found that certain magnetic properties of the crystals change with the temperature in an oscillatory manner. This result suggested many possible configurations in the magnetic structure of crystals, which will now have to be studied one by one until a satisfactory interpretation of these unusual magnetic effects is arrived at.

F. C. Brown at Reed College investigated the mobility of electrons through single crystals. The study was made on silver-chloride crystals at various temperatures. The series of measurements on the electron mobility coefficients indicated that drift electrons are slowed down by interacting with the acoustic vibrations of the crystal lattice. Many factors can contribute to this effect and the investigators are collecting further mobility data under carefully controlled conditions in an attempt to clarify the matter.

At Carnegie Institute of Technology S. DeBenedetti and his coworkers are investigating the properties of electrons in metals by the use of short-lived positrons emitted by radioactive materials. Gamma rays

are created by the collision and annihilation of the positrons with electrons in the solid. By measuring the gamma radiation the scientists have been able to calculate the momenta and other characteristics of the electrons in the solid at the time of the reaction. They found that positrons are annihilated when at rest, that they usually react with loosely bound or free electrons, and that local lattice effects seem to play little part in the process.

High-Speed Computation

Recent experimental advances in the physical and engineering sciences have rendered useless many linear mathematical models that were formerly adequate concepts. In other cases where linear analysis still remains relevant, the size of the linear system employed has increased enormously. The use of mathematical models in biological and sociological research has induced consequences similar to those in the physical sciences. For example, Professor W. Leontieff of Harvard University has stated that even a highly condensed picture of the United States economy may be described only in terms of a system of at least 100 equations with as many variables.

It is a historically remarkable coincidence that with the development of these difficulties, a means of dealing with them has been found in the art of high-speed computation. The successes achieved by its use have led many scientists to the conviction that further progress in their fields will depend to a large extent on their access to the techniques and facilities of computation. The need for adequate computer facilities for basic research problems must be considered primarily from an interdisciplinary point of view. In addition to the obvious interdependency of computation and research in mathematics and physics, other mathematical, physical, and engineering sciences are using computational methods at an increasing rate.

The need for high-speed computers is most dramatically evident in meteorology. The greatest barrier in the development of the science of meteorology is the inability of research workers to perform large-scale experiments. The meteorologist has to extract information from observation of nature in a vast three-dimensional envelope where weather events occurring in any one portion are interdependent with other, often remote, events. The nature of atmospheric behavior is so complex that progress in understanding its fundamental nature has been slow and discouragingly tedious.

Meteorologists have dreamed for generations of something akin to a laboratory with capabilities reasonably approximating the atmosphere.

This dream now appears to be coming to fruition with completion of the first successful machine-produced predictions of large-scale atmospheric motions. The ultilization of high-speed computing machines obliterates the boundary between dynamic and synoptic meteorology by making it possible to test suggested models simulating the atmosphere and also to evaluate quantitatively the effects of varying parameters believed important in influencing weather.

In astronomy, problems in celestial mechanics have been greatly aided by computer availability for the calculation of the orbits of planets, satellites and comets. Astrophysical problems are highly complex, raising, for example, such questions as turbulence, magnetohydrodynamics, and the relative abundances of chemical elements in the internal constitution of stars. Similarly, the evolutionary development of a star is traced by a series of numerical models representing the time-sequence of configurations of the primeval gas sphere. Such models require elaborate computation.

The fundamental theories such as those of quantum and statistical mechanics, thermodynamics, and kinetic theory, are tools with which to understand the complex problems of modern chemistry. Machine calculations are already being used in the fields of high-temperature and high-pressure phenomena, flame propagation and shock waves, transport phenomena, and the theory of liquids. The information resulting from such computation permits the prediction of probable chemical reactions and thereby increases the selectivity factor in the design of experiments.

The effect on industrial life will, apparently, be no less significant. At a Conference on Training in Applied Mathematics held at Columbia in October, 1953, an industrial producer of high-speed computers asserted that, on the basis of current leases and orders, 1500 mathematicians were needed at that time for their effective use. A Conference on Training Personnel for the Computing Machine Field at Wayne University in June, 1954, indicated a large, but unspecified, demand for people highly skilled in computation not only in the engineering but also in the managerial aspects of industry and government.

In order to meet this need, it will not only be necessary to have adequate computers available but it will be necessary to develop an adequate training program at all scientific levels for the mathematical formulation of the scientific problems. Even with existing machines, efficient as they are, effective utilization requires much more research in numerical analysis. At the same time, in order to solve existing problems that are beyond the capacities of the present computers, investigation into the theory and engineering of the computing machines themselves is essen-

tial. Continual interplay of all these factors is necessary for scientific progress.

The high cost of maintaining a modern computation laboratory is often met by having the facility "earn its keep" on a fee basis, a practice which affects the character of its scientific program. But it seems clear that few universities will be able to support large computing facilities without continuing Federal support. The Department of Defense and the Atomic Energy Commission have supported a considerable number of computer installations for their purposes. However, these facilities often operate under necessarily heavy security regulations.

In 1953 the National Science Foundation entered into an agreement with the Applied Mathematics Laboratories of the National Bureau of Standards for advice on the methods of numerical analysis and the choice of machines for specific computation involved in requests to the National Science Foundation for research support. To date, several grants have been made involving computational work, e. g., to Marshall Hall of Ohio State University, H. S. Vandiver of the University of Texas, J. Neyman of University of California, and A. H. Taub of the University of Illinois.

In May 1954, a conference on "The Significance and Possibilities of High-Speed Computing in Meteorology" was cosponsored by the National Science Foundation and the University of California (Los Angeles).

In order to provide the Foundation with informed advice as to the computer needs of modern science, and its possible role in assisting universities to meet these needs, an ad hoc Advisory Panel on University Computing Facilities was appointed in February 1955.

The panel recommended that the Foundation establish a limited program to provide computing equipment and partial support for appropriate staff in order to carry on research and training in high-speed computation. It also noted that research in the advanced design of computing machines should be recognized as of basic importance. As an example of areas for research the panel stated that it is desirable that the speed of computing machines be increased by a factor of at least 50 and that their capacity be substantially increased.

Geochemistry

The President's Materials Policy Commission in 1952 recommended that a full-scale basic research program be undertaken in the fields of

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mineral exploration and processing. Partly as a result of this recommendation the National Science Foundation established a Committee on Minerals Research. The committee in turn appointed a number of specialized subcommittees which from time to time have reported to the Foundation on areas of basic research which should be supported in the national interest.

During the past year the Subcommittee on Geochemistry proposed that the highest priority be given to basic research into the characteristics of low-viscosity fluids and aqueous solutions in rocks during such geologic processes as burial, metamorphism, intrusion, and vein formation. Such knowledge will have great practical importance in developing better methods for detecting ore deposits.

The subcommittee pointed out that no concerted attempt has been made to apply modern techniques to the study of ore formation. By taking advantage of recent developments in the use of isotopes, in high pressure and high temperature techniques, in precise microchemical methods, and by applying modern chemical and physical principles, an extremely useful increase in our present knowledge of these processes would result. Geologists have a reasonably good understanding of the source and origin of the mineral assemblages in rocks. On the other hand, very little is known about the origin of the accompanying fluids. The subcommittee proposed five principal areas for basic research into the nature of low-viscosity fluids. These are described below.

1. Study of fluids in sedimentary and volcanic rocks. The residual fluids from crystallizing magma are thought to be the source of most sulfide ore deposits. Geologists are uncertain, however, as to whether such fluids were originally contained in the sedimentary and volcanic rocks from which magma was derived or from emanations from lower levels in the earth's crust. An answer to this question would have great theoretical importance, but also practical importance, since it would indicate to what extent ore deposits could be expected in areas where no magmatic rock is present.

2. Temperature-pressure studies of solutions in igneous rocks. It is proposed that solutions contained in igneous rocks, such as natural glasses, be studied in the ranges of concentrations, temperatures, and pressures that appear to be geologically probable. Such studies would have been impossible until recently because of the lack of suitable laboratory equipment. The results would be expected to give useful information on the types of magmatic rock that were likely to

have given off ore depositing solutions and to indicate what types are barren.

3. ENVIRONMENT OF DEPOSITION OF ORE. These studies would be similar in technique to those described in the previous paragraph. The aim, however, would be to obtain information on the mechanisms and conditions of pressure, temperature, and composition involved in ore transport and deposition. One approach would be to study the natural occurrences for evidence of the values of these variables, and then to set up similar laboratory conditions to see if experimental results fit the field evidence.

4. ISOTOPIC STUDIES RELATED TO ORE DEPOSITION. In order to search for ore deposits on a broad scale it is necessary to define when the deposits were formed. For example, age studies of uranium-bearing minerals of the Colorado Plateau have been of the utmost value to uranium prospectors. Geologic time is told by a variety of radioactive clocks, such as uranium-lead, uranium-helium, and potassium-argon. In these examples the ratio of the amount of radioactive material to the amount of nonradioactive daughter product indicates age. The uranium-lead method has been studied in sufficient detail to be immediately applicable. In the other two cases additional basic research in methodology is essential. The study of natural variation in isotopes will also help define the source of materials and whether or not more than one source has been involved. The use of radioactive tracer elements makes it possible to study very slow reactions in the laboratory equivalent to millions of years of geologic time.

5. DETAILED STUDY OF INTRUSIONS AND RELATED ORE DEPOSITS. Basic studies of conditions of formation and the environment of ore deposits are important. It should be possible eventually to work out specific systems. At present, however, the subcommittee suggests that a detailed empirical study of igneous intrusion with its related ore deposits and of a similar intrusion without ore deposits be made. Such a detailed study might yield broad principles and valuable data that could be applied directly to exploration and prospecting.

Biological Field Stations and Research Facilities

A biological field station has been defined as any institution which offers field instruction or research in one or more of the biological sciences and is a separate administrative unit located in the field. Some stations have emphasized a program of field instruction, others have concentrated

on research activities, but most biological stations have tried to combine instruction and research in such relations that each would contribute most to the same end—the advancement of biological science.

About one-half of the biological field stations in the world are marine stations. The rest are about evenly divided for work in fresh-water biology or in terrestrial biology. There are very few biological stations south of the equator. In 1945 R. W. Hiatt listed 145 hydrobiological laboratories in the United States of which 80 were located inland and 65 were on the coast.

The typical biological station of the 20th century has been organized to encourage research and instruction in one or more kinds of environments. The uniqueness of field stations lies in their locations, and in the opportunities they offer students and investigators to study biological forms at close range in their natural environment. Stations are usually located on sites near or within a unique biological environment or else in an area where an abundance and variety of biological forms are easily accessible.

Many proposals for assistance to field stations have been received by the Foundation within the past two years. The greatest demand has been for funds to be administered and distributed by the stations as stipends to students and investigators for assistance in summer research and training activities. Grants were made for this purpose during the past year to the following stations:

Mountain Lake Biological Station
Itasca Biological Station
Bermuda Biological Station
Duke University Marine Laboratory
University of Michigan Biological Station

Probably the next greatest need by field stations has been for funds for construction and the procurement of new equipment. Construction requests have included such items as building of laboratories, housing, electrical and water systems, roads, and renovation of buildings. Major equipment needs include large or expensive pieces of scientific equipment, vehicles, boats, new salt water systems, and, in one or two cases, standard equipment for new laboratories. Modest grants for equipment or facilities have been approved for the White Mountain High Altitude Laboratory, Mt. Desert Laboratory, and Rocky Mountain Biological Laboratory.

Several proposals have included requests for "housekeeping" and administrative expenses. A grant of this type was made to the unique

Barro Colorado Island station in Panama. A grant was also provided the Marine Biological Laboratory (Woods Hole) for repair of hurricane damage.

Research in the Social Sciences

The interrelations of the natural sciences and social sciences have intrigued scientists, philosophers, and logicians for over a century. Auguste Comte, sociology's godfather, effectively set the stage for discussion with his hierarchy of the abstract sciences. Mathematical, physical, biological, social, and even psychological and ethical sciences (*la morale*) were viewed as integral parts of a unitary scheme. From Comte's day on, it has been well nigh impossible for sociologists, psychologists, anthropologists, and other students of human social behavior to avoid such questions as how "scientific" the social sciences are, whether free will or something else makes it impossible to apply scientific method to human behavior, or whether there is a fundamental incompatability between the natural sciences and social knowledge. Such problems still command central consideration by sociological theorists.

In a practical way, this issue has also been faced by administrative officers of colleges, universities and foundations in resolving the problems of organizational structure within their institutions. In which faculty, school, or division, does anthropology or psychology belong? Should physics, genetics, economics, and sociology be grouped together? More recently similar questions have commanded the attention of administrators of governmental scientific research programs in both military and civilian agencies.

Insofar as research support and scholarships and graduate fellowships in the social sciences are concerned, the Congress essentially accepted the "permissive but not mandatory" position put forth by Dr. Vannevar Bush in the House hearings during the 80th Congress. Dr. Bush stated:

> "The Federal Government already does a great deal of work in the social sciences of a research nature. Research in the social sciences is very important indeed. We could well do more. * * * I think it would be a mistake for the Foundation to plunge into work in the social sciences without very careful consideration on what parts it would like to cover, what parts it feels can appropriately be handled under Federal auspices in view of their nature. * * * In other words, the legislation should be permissive but not mandatory, so that the Foundation will not be barred from

entering into the field but on the other hand will not be forced into it until it has given it the study that the subject deserves."

Thus, the science support functions of the Foundation may be summed up in the statement that the Foundation's responsibilities are mandatory with respect to the sciences specifically enumerated (mathematical, physical, medical, biological, engineering) but are permissive with respect to the social sciences. Enumeration of the sciences in the National Science Foundation Act includes the phrase "and other sciences". The legislative history of the Act indicates that this phrase was clearly intended to enable the Foundation to support social science research and award scholarships and graduate fellowships in the social sciences when and if it was deemed desirable to do so.

The legislative history of the National Science Foundation Act and the act itself have been in part responsible for the interest the Foundation has taken in the social sciences. Other factors involved were: (1) cognizance of the relatively large sums of money going into support of social science research by Federal agencies; (2) policy discussions of the role of the Federal Government relative to the social sciences; and (3) inquiries from other Government agencies regarding current research in the social science fields.

As a result of these considerations, the National Science Foundation undertook, in March 1953, a systematic and continuing study of the present scientific status of the social sciences and of the role of the Foundation with respect to social science research. As part of this study, the Foundation has been compiling for the past 2 years a report of extramural, unclassified research projects sponsored or supported by Federal agencies in the social sciences and related interdisciplinary fields. The eighth quarterly report of this series appeared in May 1955.

As a result of this intensive study the Foundation approved a limited program of support of the social sciences in August 1954. This limited program is being developed on an exploratory basis within a framework of four criteria. These are:

(1) the criterion of science, that is, the identification, within the social disciplines, of those areas characterized by the application of the methods and logic of science;

(2) the criterion of national interest, namely, the assignment of highest priority to social science activities directly related to the responsibilities of the Federal Government with respect to national welfare and national defense;

(3) the criterion of convergence of the natural sciences and the social sciences; and

(4) the criterion of basic research.

The program is being administered within the framework of the Foundation's three scientific divisions.

The program in the Biological and Medical Sciences Division is called Anthropological and Related Sciences. It includes support of basic research of an interdisciplinary nature involving the convergence of the biological and social sciences. The disciplines tentatively defined as falling within this program include anthropology, functional archaeology, human ecology, demography, psycholinguistics, and experimental and quantitative social psychology. The program receives guidance and assistance in evaluation of specific proposals from an advisory panel of specialists in the areas covered.

In the Mathematical, Physical, and Engineering Sciences Division, there has been established a program in Socio-Physical Sciences, which includes support of basic research of an interdisciplinary nature in such areas as mathematical social science, human geography, economic engineering, and statistical design. The socio-physical sciences program also embraces support of fundamental research in the history, philosophy, and sociology of science.

A limited extension of the fellowship program for academic year 1956–57 has allowed support for both predoctoral and postdoctoral fellowships in such areas of natural science-social science convergence as the history, philosophy, and sociology of science.

The study of the role of the Foundation, and of the Federal Government generally, with respect to social science research is continuing. In pursuing its responsibilities with respect to national science policy, scientific and technical manpower, assessment of the status of science, study of the impact of science on social welfare, promotion of international relations in science and the improvement of the exchange of scientific information, the Foundation has necessarily had to exploit the techniques, methods and concepts of the social sciences.

In addition to the staff surveys conducted, effective utilization is being made of the facilities and technical skills of such organizations at Battelle Memorial Institute, Maxwell Research Center of Syracuse University, The Institute for Research in Social Science of the University of North Carolina, Roger Williams Technical and Economic Services, Inc., and the American Academy of Arts and Sciences, and such Government agencies as the Bureau of Labor Statistics and Bureau of the Census. It is not surprising, therefore, although it is little realized, that the National Science Foundation, is, among Federal agencies, one of the major supporters of extramural social science research.

A research economic group within the Foundation has been given the responsibility to undertake directly, or to arrange for the support of, research dealing with the economic consequences of scientific research, particularly in terms of the contributions of science to the national economy and gross national product.

Research by Medical Students

An informal survey of 21 of the 80 medical schools in the United States conducted by the staff of the Foundation's Division of the Biological and Medical Sciences indicates that most medical schools try to provide some type of research training for medical students. The magnitude and manner of operation of such programs are quite varied. In some cases the institution provides funds from its own sources although limited funds are sometimes available from industry and other sources. Students are encouraged to undertake research, voluntarily and frequently without compensation, both during the academic year and summer vacation. Stipends vary from nothing at all to several hundred dollars per month, but in most schools available funds are spread so thinly that inadequate stipends are paid in order to provide for as many students as possible.

Estimates of the total numbers of medical students engaged in research each year vary from as few as two or three in some institutions to as many as 80 in the largest schools.

For the most part, deans of the medical schools express the belief that student research should be conducted in preclinical disciplines, although some deans felt that a few carefully selected clinical projects might also be suitable for student research. Students are normally associated with a senior investigator in the conduct of research projects, but the deans agreed unanimously that medical students doing research should not be used solely as technicians or in other routine capacities.

The success of a program of research by medical students ultimately depends on two factors—the quality and interest of the student himself and the confidence, maturity and dedication of the senior staff member under whom he works. Selection of students and of staff members therefore have paramount importance.

During the past 2 years the National Science Foundation has made grants for medical student research programs to the medical schools at Washington University at St. Louis, the University of Minnesota, the University of Wisconsin, and the State University of New York. In these cases the schools selected their own candidates for student stipends.

The success of these grants encouraged the Foundation to establish a continuing program for providing funds to medical schools for the payment of research stipends to medical students. Normally the limiting factor in the amount of funds to be made available is the number of qualified, mature investigators in basic sciences who are interested in guiding the research of one, or at most, two medical students. A secondary factor, of course, is the number of medical students who show the necessary aptitude for such a program. In administering this program, the Foundation has established a special advisory committee to review and evaluate requests for grants.

Graduate Fellowship Program

On March 15 the Foundation announced the award of 715 predoctoral graduate fellowships and 70 postdoctoral fellowships for advanced study in the natural sciences for the academic year 1955–56. This was the fourth year in which such awards were made. The distribution of fellowship awards by field of study and comparative figures for the previous programs are summarized in figure 4. A table giving the number of applicants and awards by State and region, a complete list of fellowship holders, and a list of institutions attended by the fellowship holders as undergraduates and graduate students is given in Appendix IV, p. 133.

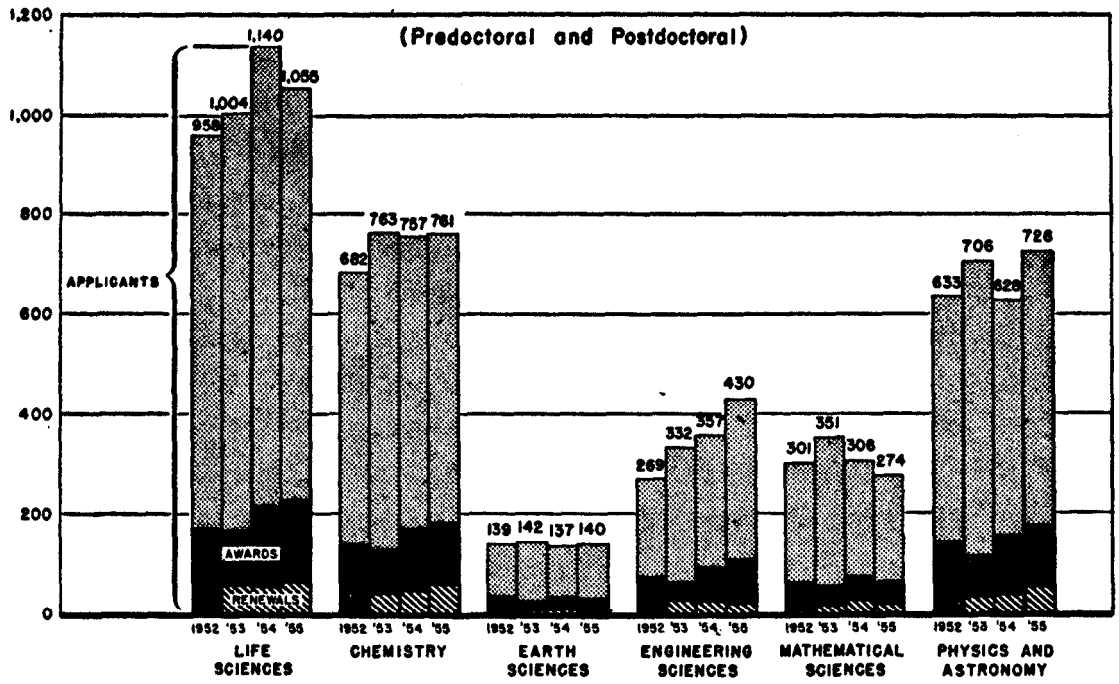

FIGURE 4. *Pre- and postdoctoral fellowships awarded by the National Science Foundation by field of science, 1952–55, illustrating the disparity between number of applications and awards made.*

Research on Fellowship Selection Techniques

Over the past 3 years the National Science Foundation has supported a research program on fellowship selection techniques under the direc-

tion of the Office of Scientific Personnel, National Research Council. This work has resulted in a number of interesting technical studies and two conferences which have led to modifications and simplifications of the methods for selecting Foundation fellows.

All personnel selection procedures involve the prediction of on-the-job effectiveness. The objective of research in this field is to establish the relationship between two sets of measurements:

1. The predictors or criteria on which selections were made.
2. The criteria of on-the-job effectiveness.

In attempting to tackle the research problems related to fellowship selection, the Research Advisory Committee to the National Research Council's Office of Scientific Personnel proposed three lines of study:

1. The development of short range and long range measures of success in science.
2. The isolation and definition of the ability and personality factors that are actually being measured with present selection techniques.
3. A follow-up study of fellowship applicants from previous years to determine which persons have most nearly shown the type of progress in science for which the particular fellowship program was established.

Measurement of Scientific Achievement

The successful pursuit of scientific activities requires a variety of specific abilities. Scientific creativity like artistic creativity, involves a large measure of originality and capacity to synthetize fresh, new ideas from a tangle of seemingly unrelated facts. But creativity is not necessarily the outstanding attribute of a great science teacher or science administrator. The observational powers of a skilled experimentalist must be of unusually high order, and he must have the critical judgment to recognize the point at issue and the ingenuity to design his experiment to test that point without ambiguity. In many areas scientific success depends upon more modest abilities, such as manual dexterity, persistence, and endurance. Study of the lives of the outstanding scientists reveals an unquenchable curiosity and an enormous drive or emotional identification with their work.

At the conferences supported by the Foundation relating to fellowship selection it was clear that scientists disagree among themselves as to suitable criteria for measuring on-the-job effectiveness in scientific fields. Certain obvious symbols of success exist, such as the Nobel prizes or

election to National Academies of Sciences. Ratings by peers may prove to be valuable and the quantity of publication, while not infallible if used alone, may also be a useful index of scientific productivity. Much raw data of this type have been accumulated on American psychologists as part of the American Psychological Association study supported by the Foundation on the development and current status of psychology in the United States. This information is being subject to rigorous statistical analysis to uncover the relationships and degree of consistency among various measures of productivity.

The psychological study and similar surveys in physiology, mathematics, and demography will undoubtedly provide a fertile source of information on the characteristics and social and educational backgrounds of scientists. It remains to be seen whether such information will be helpful in designing more adequate selection techniques.

Fellowship Selection Procedures

The selection procedure used by the Foundation includes the rating of applicants into quality groups. This part of the program is conducted for the Foundation by the National Research Council. Rating panels are chosen from leading American scientists in each of the fields for which awards are made. Each panel evaluates the records of candidates in its respective field. Each candidate's record consists of three parts:

1. Tests scores on verbal ability, quantitative ability, and scientific aptitude in the scientific field.
2. Previous scholastic record.
3. Confidential reports and evaluations obtained from the applicant's faculty advisors.

Another line of research undertaken by the research group on fellowship selection techniques involved intensive statistical studies of the types of ratings obtainable from the applicants' records. The factor analysis technique was used in an attempt to determine what characteristics are now actually being measured or evaluated in the selection process. In this connection psychologists versed in testing procedures have found that one rating scale frequently measures two or more specific abilities while several ratings often have the same or similar discriminating power among abilities. Seldom does a single rating device measure a single ability.

The first study of this type, undertaken at the University of Utah, was an investigation of seven rating scales taken from the confidential

report forms in the files of National Science Foundation fellowship applicants for the year 1952.

A similar, but much expanded study, was carried out on the records obtained on the 1953 fellowship applicants. In that year the Confidential Report Form requested ratings on 19 items as compared with 7 for the year before. The study also included the grades on four ability tests taken by each applicant, his age, three ratings based on previous academic grades, and the final quality group rating established by the panel. Thus, a total of 28 different measurements or ratings were available for each applicant. For the statistical analysis sets of ratings were obtained for a random sample of 175 first year fellowship applicants.

The analysis indicated that five identifiable factors or specific abilities were probably being measured by the 28 ratings used in the 1953 selection procedure. It is interesting to note that only three of the five were apparently being considered by the rating panels in making their quality group determinations. Three additional factors appeared to be statistically significant, but the study group was unable to identify them. The five factors identified are:

FACTOR A was tentatively described as a research ability factor, or more specifically as "the knowledge of and ability to use the basic research techniques in his field." This factor was common to all confidential report ratings, was significantly present in the academic grade ratings, and entered strongly into the quality group judgment of the panel.

FACTOR B was described as a personal soundness factor reflecting emotional stability and maturity. It appeared in most of the confidential report ratings with the exception of those having to do with research methodology. It figured most prominently in the personal soundness evaluation ratings on the confidential report. It apparently had little effect on the quality group judgment.

FACTOR C was described as an ability to evaluate critically and to organize the scientific literature in the applicant's field of interest. It was prominent in the previous academic grade averages and in the critical-mindedness and background preparation scales on the confidential report. It was contained significantly in the quality group judgment.

FACTOR D was tentatively described as an ability involving fertile imagination and originality. It was found primarily in the "new idea" ratings on the confidential report. Although it had no apparent effect on the quality group judgment, it may be of consider-

able importance in selection of young scientists and in the judgment of the study group should be investigated further.

FACTOR E was described crudely as an ability to perform well in the usual aptitude and achievement test situations. It was found in the aptitude test scores and also figured prominently in the quality group judgment.

While the study was highly tentative, it was also highly suggestive and indicated that further research in this direction might prove desirable. On the basis of the study the confidential report form for the 1954 fellowship program was revised in an effort to reduce the "halo effect" of Factor A and to bring out Factors B and D more sharply.

Role of Physics in Engineering Education

The Fourth Annual Report of the National Science Foundation reported that two conferences had been held with Foundation support to discuss the place of nuclear physics and solid state physics in engineering education. During the past year three similar conferences dealing with mechanics at New York University, thermodynamics at Pennsylvania State University, and electricity and magnetism at Lehigh University were held under the joint sponsorship of the American Society for Engineering Education and the Foundation.

In addition to the conferences, the American Institute of Physics was given a grant to establish a committee to review the recommendations and results of the several conferences and to evaluate the teaching of physics in engineering education. This group also agreed on a series of recommendations for enabling physics teachers to contribute a larger share in the development of better engineers.

Members of the committee visited 26 colleges offering engineering programs and discussed the problems of introducing physics courses into these programs with members of both the engineering and physics departments.

In its report the study group noted that the role of physics in engineering education is not static. Rather, it changes continually with the momentous changes that are taking place in both engineering and physics. In earlier times engineering was practiced essentially as an art, but more and more this conception of engineering is giving way to a modern science and technology. Since the beginning of the present century, the advance in physics has been enormous. To the committee, however, the increase in subject matter is not the most significant factor

in introducing physics instruction in engineering education. On the contrary, the committee believes that the cardinal aim should be that of imparting to the student a point-of-view or an attitude and capacity to deal with the principles and methods of analysis of contemporary physics. In its opinion, without training and experience in these new modes of thought neither physicists nor engineers will prove competent to deal with the emerging problems of science and technology.

The recommendations of the committee reflect interest in creating this attitude on the part of the student with respect to basic principles and methods of approach. They include:

1. Improved communication between engineers and physicists at the institutional level to discuss objectives and determine mutual needs.
2. Early contact of engineering undergraduates with physics.
3. Increased participation of research-minded professors in undergraduate teaching.
4. Introduction of more challenging experiments in laboratory instruction.
5. Greater emphasis, particularly in textbooks of general physics, on ideas, principles and methods.
6. More appropriate use of mathematics in general physics teaching.
7. Greater encouragement of experimentation in teaching.

Need for Science Teacher Training

Several years ago the Foundation learned through exploratory studies that a most critical and immediate limiting factor in developing latent science talent in the youth of the United States was the dwindling supply of adequately trained science teachers. In each succeeding year the proportion of college graduates qualified for high school science teaching has declined. Because of the unavailability of science teachers, many schools today have a limited science program or none at all. In other schools science teaching is on an emergency basis and many teachers have less than the minimum training required for certification.

As this trend continues, the introduction of science to our potential young scientists becomes more and more inadequate and distorted. A poorly trained science teacher is unable to capture the imagination of his students, to formulate and teach them up-to-date and vigorous courses, and to guide their scientific development according to their abilities.

In accord with these findings, the Foundation for the past 3 years has conducted a series of experimental programs to strengthen science teaching at the high school level.

Summer Institutes and Visiting Lecturers

For 3 years the National Science Foundation has sponsored a series of summer institutes attended by science teachers at both the high school and college level. The institutes normally ran for several weeks and the teachers attending them were given an opportunity to review recent developments in their respective fields of science under the guidance of leading scientists. The table below summarizes information on all institutes that have been held during this period.

NATIONAL SCIENCE FOUNDATION SUMMER INSTITUTES

Host Institution	*Science Area*	*Participants*
1953		
University of Colorado	Mathematics	College Teachers.
University of Minnesota	Physics	College Teachers.
1954		
University of Wyoming	Chemistry	College Teachers.
University of North Carolina	Mathematics	College Teachers.
University of Oregon	Mathematics	College Teachers.
University of Washington	Mathematics	High School Teachers.
1955		
University of Wyoming	Biology	College Teachers.
University of Minnesota	Chemistry	College Teachers.
Syracuse University	Chemistry	College Teachers.
Syracuse University	Chemistry	High School Teachers.
Oklahoma A & M College	Mathematics	College Teachers.
Oklahoma A & M College	Mathematics	High School Teachers.
Stanford University	Mathematics	College Teachers.
University of Wisconsin	Mathematics	High School and College Teachers.
Oak Ridge Institute of Nuclear Studies.	Physical Sciences	High School Teachers.
Pennsylvania State University	Physical Sciences	High School Teachers.
University of New Mexico	Physics	High School and College Teachers.

The response of the teachers attending the institutes has been enthusiastic and the Foundation plans to continue this experimental program. During the past year, however, a grant has been awarded to the Bureau of Social Science Research, American University, to attempt to

evaluate the effectiveness of summer institutes as a device for improving high school and college teaching of science.

The Foundation has also provided several grants on an experimental basis to enable outstanding scientists to visit groups of colleges and lecture on recent research developments.

Failure of Talented Youth to Continue Education

Fully half of the young people in the United States having the intellectual capacity to continue their education beyond high school do not do so. (Figure 5.) Many of these people undoubtedly have the potential ability to become leaders in industry, government, and the professions. Their lack of training prevents them at the outset from embarking upon careers consistent with their native ability. Whatever this may mean to the individual himself in terms of personal satisfaction and fulfillment, it certainly means an appalling loss to the Nation. Within recent years leaders in education, industry, and government have sought ways and means to salvage a higher proportion of this waste in human resources.

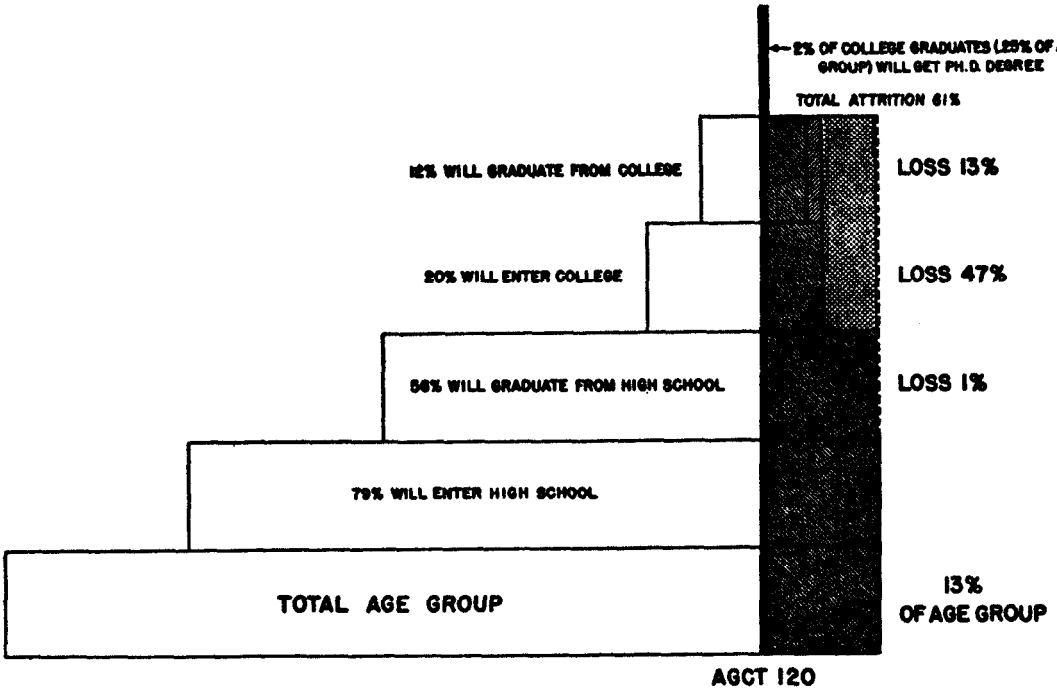

FIGURE 5. *Of all the members of an age-group with intelligence and scholastic ability equal to that of the average college graduate (I. Q. or AGCT 120), more than 60% failed to complete college. Only 2% of the college graduates, and .25% of the entire age-group will obtain a Doctor's degree.*

During the past year a cabinet level interdepartmental committee of the Federal Government, under the chairmanship of the director of the Office of Defense Mobilization, has attempted to gather available

information on the problem and to make recommendations for possible action. Clearly, the problem is not one that can be solved solely by action of the Federal Government. Education in the United States is almost entirely the responsibility of State and local governments and private groups and the social pressure required to improve or modify the educational system is generated in the citizenry itself.

The committee found that lack of finances was only in part responsible for the failure of many talented young people to continue their education. Lack of motivation was certainly a major factor. Many well-paying jobs were open to seniors graduating from high school. The value of additional education from a dollars and cents point-of-view was not immediately obvious to the graduate. In many localities a college education does not necessarily confer additional prestige upon its holder. On the contrary it tends to isolate the individual from his family and friends without at the same time providing him with ready access to other social groups.

Answers such as the above are plausible but nevertheless largely conjectural. There has been very little fact upon which to base either careful analyses of the problem or a sound program for encouraging a larger proportion of high ability young people to continue their education into college and beyond.

National Survey of High School Students

What factors are responsible for kindling a desire in high school graduates to enter or not to enter college? In order to get more information on this question the National Science Foundation entered into a contract with the Educational Testing Service, Princeton, New Jersey, to undertake a survey of the educational and vocational attitudes of 1955 high school seniors. The survey was designed to provide definitive information on a national scale of the post-high school interests of seniors, financial barriers to continued education, and the parental and other social factors which might be related to college going.

The 1955 graduating high school seniors from 5 percent of all public high schools in the United States were questioned. Each Senior student in the selected schools was asked to fill out a 30-minute questionnaire on his background and plans and interests relative to college, as well as to take a 15-minute test of academic aptitude. Fact sheets prefaced by the principals of the schools in the sample gave pertinent supplementary information about the school and community. In addition, comparative data were obtained for a smaller sample of high school

sophomores to see how attitudes change during the last 2 years of school.

The results reported below are based upon replies from 478 schools, with a total of 32,750 twelfth-year students. Since the scientific population of the future will be drawn largely from the high ability boys and girls, the responses of the high-scoring group were of particular interest to the Foundation. The top 30 percent of the students, known as "high-scoring," were assumed to have sufficient ability to do college work successfully.

Educational and Vocational Plans

Two questions dealt with post-high school plans of seniors and sophomores. The first asked: "What would you *really like* to do when you finish high school?" The second asked: "What do you think you *will* do when you finish high school?"

About half of the high scoring seniors, both boys and girls, would like to attend college immediately, while 79 percent of the boys and 69 percent of the girls express definite interest in college, now or later. The proportion of sophomores indicating similar interests is significantly lower. Part of the difference may result from drop-outs during the last 2 years, but there seems to be no doubt that interest in college increases from the tenth to the twelfth year in school.

The difference between the responses to the two questions suggests how finances may affect college going. Of the high scoring senior boys 47 percent state they will attend college immediately compared with 53 percent who would like to do so. Comparable figures for girls are 42 percent as against 50 percent. It will be noted that the higher the score on the ability test the larger the percentage of seniors planning to attend college.

Inquiries were made as to why students want to attend college. Seniors put greater emphasis upon vocational reasons than do sophomores. However, fewer sophomores answered the question, suggesting greater uncertainty as to the reason for a college education. Similar findings appear in comparison of what seniors and sophomores indicate they would like to study in college. Here again, many sophomores gave no response suggesting that many of them had not made up their minds.

The reasons given by high scoring seniors for not attending college defy simple analysis. About one out of eight definitely states that lack of adequate finances is the principal obstacle. Many other answers were given, however, some of them having economic implications, so that it is difficult to isolate the financial from the motivational factors.

Scholarship Assistance

A number of questions were asked concerning scholarship assistance to attend college. Students were asked: "Suppose that you would get a scholarship to go to college if you agreed to study a particular subject. The scholarship would be large enough to make it possible for you to attend a good college and you would have no need to worry about earning any part of your expenses. *But to get the scholarship you would have to agree to major in (or emphasize) some particular subject.*"

A surprisingly high proportion of those previously expressing no interest in college would apparently accept scholarships under the conditions stated. Logically, if there were no interest in college in these people, they would not be expected to accept a scholarship.

This inconsistency suggests several possibilities. Perhaps, the expressed lack of interest in college was a facade adopted to protect the respondents from admitting that they are not likely to be able to go to college. Perhaps, the offer of a "free ride" was too attractive to turn down. On the other hand, the fact that half of the high scoring boys expressing no interest in college stated that they would accept scholarships to study engineering and one quarter to study in the physical sciences suggests that lack of motivation for college might be replaced by positive interest if scholarship assistance were available.

It is also interesting to compare the response to the scholarship question with those previously given regarding subject of greatest interest. By contrasting what seniors say they would like to do with what they say they would do with the aid of scholarships, it is possible to assess to some extent the effect of financial pressure in diverting students from one field to another.

The responses indicate that if scholarships in the physical sciences were offered to high ability boys, they would attract 35 percent of those primarily interested in the social sciences, 27 percent of those primarily interested in business, and 26 percent of those interested in education. Scholarships in engineering would siphon off 72 percent of those interested in the physical sciences, 30 percent of those interested in the biological sciences, 46 percent of those interested in fine arts, and 34 percent of those interested in education. Scholarships in education, however, would attract only 18 percent of those primarily interested in physical science, 19 percent of those interested in engineering, and 34 percent of those interested in business.

High-scoring girls indicate less willingness to shift from nonscientific to scientific fields. It is worth noting, however, that one-third of the

high ability girls expressing interest in social science state they would leave that field to major in mathematics if a scholarship were available.

These figures must be interpreted with caution. What an adolescent says he will do and what he eventually does are often strikingly different. Undoubtedly, some respondents may have concluded that they would accept a scholarship to study in an area other than that of their primary interest and still devote most of their time to the field they like best. Moreover, many students might not have the ability or aptitude to obtain and keep a scholarship in a field outside their primary interest, despite their apparent willingness to accept it.

With due allowance for these precautions, however, it still appears that the offering of scholarships restricted to particular fields creates motivational forces of unequal intensity that tend to change the existing distribution of interest among secondary school graduates. The figures also indicate that commitment to some fields comes earlier than to others. More information on this point should be obtained in view of its implications in connection with recruitment for science and engineering at the high school level.

Social Factors

The survey gave more precise data than heretofore available on the relationship between parental occupation, income, and other social factors and college plans of talented high school seniors. About 95 percent of the children of professional parents expect to get to college sooner or later. For the business and technical groups the fraction drops to about 85 percent, falling to 65 percent for farm and labor groups.

Lack of motivation to attend college is much more evident among children whose fathers had little schooling than among those whose fathers graduated from college. The proportion of those planning to attend college immediately is higher among those who have friends also expecting to go to college than among those having few friends heading in that direction.

The size of school is also related to the plans for college attendance among high-scoring seniors. For schools having enrollments of from 1,000 to 1,499 students about 56 percent of the boys plan to attend college immediately. This is true of only 37 percent of the high-scoring boys from the smallest schools with enrollments of 99 students or less and of only 43 percent in the largest schools having enrollments of 1,500 students or more.

These findings may be related in part to the amount of vocational guidance available to the student, since the employment of professional guidance personnel is geared to size of school. It is noteworthy that more than one-fourth of the largest schools in the sample had no full-time guidance person, and over half of all schools reported no professional counselor on the staff, even on a part-time basis.

Conclusions

The survey permits estimates to be made of the number of youth of high ability in the United States who plan to go to college, who would like to go but will be prevented from doing so, and who have no motivation toward higher education. The United States Office of Education estimated a total of 1,265,000 seniors in public secondary schools in 1954–55. On the basis of the survey it would appear that about 6 percent of the high-scoring group, or 21,000 seniors, would really like to go to college but do not think they will be able to continue their education. Another 23,000 would like to go to college immediately but will have to defer college, for the time being, principally to go to work. About 6,000 plan to work full-time and will attempt to go to college at night.

On the basis of previous follow-up studies, it seems safe to say that at least 5,000 and at most 40,000 of those planning to go to college will not realize their plans.

Approximately 10 percent of the total secondary school population attend nonpublic schools. If it is assumed that similar proportions of talented students will be found in this group, it would appear that a total of from 60,000 to 100,000 seniors have the ability and the desire to go to college but will not do so. Presumably, if financial support were available, many of this group could be salvaged for higher education.

Finally, the survey indicates that about 50,000 high ability seniors in the United States have no interest in continuing their education. An additional 36,000 could not be classified because of failure to respond or because of the nature of the reply, but they are apparently not motivated toward college. If an allowance for nonpublic schools is added, there appear to be approximately 100,000 high ability seniors whose intellectual resources cannot be salvaged for higher education by simply offering scholarships.

Exchange of Scientific Information

The problem of managing the large volume of scientific information resulting from research becomes more acute each year. The Second Annual Report of the National Science Foundation for fiscal year 1952 gave as an example of the rapidly growing volume of scientific literature the increase in size of the *Physical Review* from about 2,000 pages annually during World War II to about 5,000 pages in 1951. This journal has continued to grow at the rate of about 700 pages a year so that in 1954 it contained almost 7,000 pages. It is so large now that the American Physical Society is considering the advisability of splitting the journal into two separate publications.

Another indication of the growth in the volume of scientific material is the rapid expansion of abstracting services that attempt to cover their fields comprehensively. For example, *Chemical Abstracts,* which attempts to cover all papers containing new knowledge in the field of chemistry, has about doubled in size since 1948. In that year, it contained abstracts of 43,000 papers and in 1954, 79,000 abstracts. In 1955, the number will undoubtedly go well over 80,000.

The scientific information problem has three major facets:

1. The form in which the literature originally appears.
2. The improvement of our bibliographic services and tools, and
3. The possibility that mechanization of our methods for searching the literature will eventually be required.

And in addition there is need to make more effective dissemination and use of foreign scientific information. Improved bibliographic services and the provision of translations of significant papers and reviews of foreign science will help to accomplish this objective.

Form in Which the Literature Appears

The form in which the literature appears is influenced by cost, by content, by the reading habits of users, and by the appearance of new methods of reproduction and processing. For more than 200 years,

the scientific journal has served as the principal channel of communication among scientists. Rising publication costs have caused the scientific societies to raise dues and subscriptions and occasionally to appeal to industry, research foundations, or government for help in meeting their publication deficits. The National Science Foundation for several years supported scientific publications on an emergency basis in order to tide them over difficult periods while they took steps to increase revenues and become self-supporting if at all possible.

Scientific publication, however, presents more than a financial problem. The sheer volume of many scientific journals is causing concern—although the journals are growing larger and larger the individual scientist does not have any more time for reading. It is necessary to study how to publish less without loss to science.

The Foundation will continue to consider requests from journals for emergency support, but in addition it is urging societies, and groups of societies in the same field, to look for some more permanent solution of their publishing difficulties and to undertake studies that will lead to greater understanding of the actual facts and the problems of scientific publication. Many societies have devoted a great deal of thought in the last few years to their publication problems, and some of them are planning studies and experiments with different forms of publication or distribution of information.

In order to provide reliable information about current scientific journals, the Science Division of the Library of Congress, with funds provided by the Foundation, prepared and published comprehensive lists of United States and Russian scientific serial publications and also a list of the world's biological serial publications. Each list contained about 3,000 entries giving complete bibliographical data about the publications and brief descriptions of their contents.

The Government has contributed in no small measure to the scientific information problem by issuing many thousands of scientific and technical reports annually. As a rule these reports are not covered by the widely used bibliographical tools of science; that is to say, they are outside the established channels of communication and may not come to the attention of many scientists who could make use of the information. In order to know whether a significant amount of important information remains permanently in the form of technical reports, the Foundation has supported a study in the Technical Information Division of the Library of Congress to determine to what extent information that appears first in the form of unclassified governments reports is subsequently published in the open literature. The questionnaires sent to

authors of some 1,500 reports have now been returned and the replies are being analyzed. A final report on this study should be available early in 1956.

Improvement of Bibliographic Tools

Many of the scientic abstracting and indexing publications have given good service to scientists for decades but even the best of them are now having difficulty keeping up with the tremendous volume of material. The publishers of *Chemical Abstracts* used to be very proud of the fact that they were able to issue an annual index to the journal within two or three months after the end of a year. Now the index does not appear until fall. This delay undoubtedly causes a great deal of additional work and inconvenience to chemists and librarians the world over. The American Chemical Society is fully aware of this problem and has a special committee studying methods of producing indexes promptly.

The indexes for *Biological Abstracts* some years ago were almost three years behind because of insufficient funds and reluctance to decrease coverage of the literature. Because the utility of an abstract journal is greatly impaired by lack of an index, the Foundation, in cooperation with the Office of Naval Research, the Atomic Energy Commission and the National Institutes of Health, has provided funds for up-dating the indexes for *Biological Abstracts.*

In addition, the Foundation has supported a thorough study of biological abstracting under the direction of Bentley Glass of Johns Hopkins University. The study had two parts: (1) A survey of the opinions and abstracting needs of biologists; and (2) a series of objective studies of the coverage of *Biological Abstracts* compared with the coverage of other services covering some of the same specialized fields of comprehensive subject bibliographies covering specific topics. The findings of this study and the resulting recommendations for increasing the effectiveness of *Biological Abstracts* may be helpful also to abstracting services in other fields of science. The results of the comparative studies of coverage clearly indicate the need for greater coordination of abstracting services.

Except for efforts to improve the coverage and the promptness of abstracting and indexes services and to coordinate their efforts in order to avoid undesirable duplication, it is difficult to know exactly what is needed in the way of improved bibliographic services because relatively little factual knowledge is available about the way in which scientists seek information and work with the literature. For this reason, the Foundation is supporting a study at the Department of Agriculture

of the uses made of information sources and bibliographic tools by laboratory scientists. The pilot study, directed by Ralph Shaw of Rutgers University, is being made in the Forest Products Laboratory at Madison, Wis., and is expected to produce information that will serve as a guide in designing more extensive studies of this type. When more precise knowledge is available about the way in which scientists work with the literature and the effectiveness and shortcomings of existing bibliographic tools and services, a sound basis will have been built on which to plan improved services.

Mechanization of Information Searching

Although many persons are convinced that machines can be used to advantage in searching our recorded knowledge and locating information on specific topics, as yet relatively little progress has been made toward this end. Dr. Vannevar Bush, who for many years has drawn attention to the need for the better use of information, said this about the problem in a recent address: [1]

> The progress of our civilization in peace time depends, and has always depended, not only on our current thoughts and findings, but on the skill and facility with which we create, store, interchange, consult, and utilize the whole record of our collective past experiences. We are making enormous strides in the development of methods for creating a record of what we learn—in printed words, by photography, or on a magnetic tape. We are also making strides in developing means for the transmission of ideas from one to another or from a central point to great audiences. But in one exceedingly important phase of the whole problem we are making little progress indeed. This is the phase of finding in the record the information that we need.

It seems reasonable to look forward to the day when machines will take much of the drudgery out of literature searching and help locate the more obscure items of information that may now escape notice. It must be borne in mind, however, that the task of organizing and coding material and entering it into a machine system is likely to be very expensive. This is not to say that such a system or systems if well designed might not save money in the long run by helping to avoid duplication in laboratory and library research. But it is absolutely essential that effective systems for organizing and retrieving information be developed. Probably no one would dispute the fact that at present

[1] "Communications—Where Do We Go from Here?" Founding Anniversary Meeting of the American Society of Mechanical Engineers, February 16, 1955, New York, New York.

our machine technology is far in advance of our ability to organize information for machine manipulation. Some fundamental research on methods of organizing information is called for and the Foundation is endeavoring to encourage and promote such research.

Language Studies

Fundamental research on language will produce knowledge that may be helpful in devising systems for mechanized information searching. Willard Gibbs noted many years ago that "Mathematics is a language." Its great advantage, of course, over other languages lies in the precision, uniformity and lack of ambiguity with which it symbolizes that portion of reality with which it is concerned. While the ordinary language of speech or literature is also a code or symbolization for reality it is by no means as precise, uniform, and unambiguous.

At the present time, lack of understanding of the basic nature of language and our inability to achieve linguistic precision may be the central problem in the exchange of information. During the past 2 or 3 years the Foundation has provided support for some preliminary studies related to this problem. Rudolph Carnap, University of Chicago, has been attempting to develop a statistical theory of language. This research is supported as research in mathematics, but it also has important implications in the field of scientific information.

L. Brillouin, Columbia University, is attempting to establish the concepts and theories of modern physics on the basis of the formal information theory developed during the past decade by Norbert Weiner, Claude Shannon, and others. The successful outcome of these studies may suggest how statistical information theory might serve as a foundation for other areas where the need for a firm theoretical foundation is far greater than in the case of physics.

Victor H. Yngve, of the Research Laboratory of Electronics, Massachusetts Institute of Technology, has received Foundation support for studies into the feasibility of translation of languages by machine. While the immediate goal of Dr. Yngve's work is of great current interest, the long-range goal might have still greater significance. His studies may have even greater significance as a contribution to basic linguistic theory.

Foreign Science Information

Because so few scientists in the United States can read Russian and also because many Russian scientific publications are not widely dis-

tributed in this country, there is a specific and acute need for translations of Russian scientific papers. The Foundation is supporting a project, administered by the American Institute of Physics, for the translation and publication of an English edition of the Russian *Journal of Experimental and Theoretical Physics*. The publication has begun with the first issue of 1955. The English edition will be issued bi-monthly and will be sold on a subscription basis. The Foundation has also made a grant to the American Mathematical Society for the continuation of its program of translating significant Russian papers on mathematics, a program which was begun several years ago with the support of the Office of Naval Research. Under the Foundation grant, the translations will be published in three volumes per year and sold by the society.

The extension of translating activities to other languages has begun with a grant to the Missouri Botanical Garden for an English translation of a Japanese reference work entitled *The Flora of Japan*.

Continuing support is being given to the Library of Congress for the operation of a Scientific Translations Center, which collects, records, and duplicates translations of Russian scientific papers from many different sources: Government agencies, scientific societies, universities, and industrial laboratories. The center publishes a monthly Bibliography of Translations from Russian Scientific and Technical Literature, which lists all the translations deposited with the center and also translations available from other sources such as commercial translating services.

In order to provide authoritative review articles on current developments in Russia in selected fields of science, the Foundation has made a grant to Annual Reviews, Inc., for the preparation and publication of review articles on nuclear science, physical chemistry, microbiology, plant physiology, and biochemistry. The reviews will be published as chapters in the annual review volumes covering these fields.

Support for Attendance at International Scientific Meetings

Direct personal communication among outstanding scientists of different countries stimulates thinking and promotes the exchange of scientific ideas and information in a way which cannot be done by any other means of communication. In order to encourage such personal contact, the Foundation has provided grants for partial payment of travel expenses to enable American scientists to participate in selected international and scientific meetings.

During the year, 132 scientists were given grants permitting them to attend 29 different international scientific meetings, such as the 14th

International Congress of Pure and Applied Chemistry at Zurich, the 9th General Assembly of the International Astronomical Union at Dublin, the 10th International Union of Geodesy and Geophysics at Rome, the International Symposium of the Biometrical Society at Campinas, Brazil, the International Symposium of Molecular Spectroscopy at Oxford, and the Symposium on Radiation Chemistry of Liquids at Paris. The grants have averaged about $580. This small figure indicates that the recipients must make substantial personal contributions in order to attend the meetings. In order to insure the maximum benefit to science and to the Nation, the international meetings to be supported by travel grants are carefully selected. The individual scientists who receive the grants are also carefully selected with the assistance of panels of consultants, scientific societies or the appropriate committees of the National Academy of Sciences—National Research Council.