PART I

Current Aspects of American Science

The Year in Review

Scientific activity in the United States during the past year has continued at a high rate. Among significant findings reported in all fields of science the following selected items may be considered representative:

The announcement by Marcel Schein, University of Chicago, and Bruno Rossi, Massachusetts Institute of Technology, of cosmic ray events of very high energy, suggestive of super protons or perhaps nuclei with negative charges. If corroborated by further research, these discoveries may lead to new concepts regarding the origin of cosmic rays and the constitution of the universe.

The first actual glimpse of the internal electrical structure of atomic nuclei was reported by Robert Hofstadter and colleagues of Stanford University. According to the laws of optics, in order to "see" or measure an object, the wave length of the radiation—whether light, X-rays, or electron beams—must be at least as short as the distances to be measured. Hofstadter, using ultrahigh energy electrons with wavelengths of the order of intranuclear distances found that the charge of the nucleus was not uniformly distributed throughout the nuclear volume.

The model of desoxyribonucleic acid—the basic material of which genes and viruses are made—proposed by J. D. Watson, California Institute of Technology, and F. H. C. Crick, Cambridge University. This model has proved helpful in attempts to explain such diverse biological actions as chromosome division and virus activity.

The complete synthesis of morphine, which has eluded organic chemists for decades, announced by M. D. Gates, University of Rochester.

James D. Ebert, Indiana University, continuing the work of Paul Weiss, implanted kidney, liver and spleen tissue in chick embryos and noted greatly increased rates of growth in the respective embryonic organs. Apparently, the growing organ can utilize specific organic components almost intact without first breaking them down into simpler building blocks. His experiments also revealed the effectiveness of the growth regulating mechanism. Although the growth of the treated organs for a time outstrips that of the rest of the embryo, the accelerated growth stops when it reaches the normal adult stage.

Further progress was reported in explaining physiological and psychological actions in terms of biochemistry or biophysics. George Wald, Harvard University, traced the chemical steps taken by the eye in adapting to light or darkness. W. S. McCulloch, Massachusetts Institute of Technology, W. H. Mosberg, Illinois State Hospital for Mental Diseases, and their colleagues, reported temporary relief for schizophrenia by injecting appropriate chemotherapeutic compounds directly into the brain. Wilder Penfield of McGill University, Montreal, and Maitland Baldwin and his associates at the National Institute of Neurology and Blindness have shown how memory responds to electric and mechanical stimulation.

The mass antipolio inoculation with the vaccine developed by J. E. Salk, University of Pittsburgh, was an outstanding development of research in the field of preventive medicine.

As in other recent years well over half of the support for scientific research was supplied by the Federal Government. The President issued an Executive order designed to strengthen and increase the effectiveness of Federal participation in scientific activities. In so doing he called particular attention to the importance of greater support for basic research.

He wrote:

> In 1940, the Federal Government spent about $100 million in supporting research and development. The budget which I have just transmitted to the Congress calls for expenditures for these purposes in the next fiscal year of over $2 billion. This is convincing evidence of the important role of science and technology in our national affairs * * * more than 90 percent of this Federal support is presently going into applied research and development. This is the practical application of basic knowledge to a variety of products and devices. However, only a small fraction of the Federal funds is being used to stimulate and support the vital basic research which makes possible our practical scientific progress. I believe strongly that this Nation must extend its support of research in basic science.

The United States took steps to join with more than 30 other nations in the International Geophysical Year (1957–58)—one of the largest and most significant international scientific undertakings ever attempted. Dozens of scientific groups and thousands of scientists throughout the world will engage in this concerted effort to observe and measure important natural phenomena associated with geophysics, meteorology, oceanography and upper atmosphere research.

The President's A-bank proposal for joint international participation in the development and use of atomic energy for peaceful purposes captured the imagination of the citizens of many nations.

The research support programs of the Defense Department research agencies, the Atomic Energy Commission, the National Institutes of Health, the Department of Agriculture, National Advisory Committee for Aeronautics, and the National Science Foundation continued at a vigorous pace.

The Foundation was well along in its overall survey of scientific activities and the likely future requirements for trained scientists and research facilities. For the third successive year the Foundation conducted a graduate fellowship program under which some 700 talented young scientists are provided support for graduate study. In addition many hundreds of graduate students receive assistance through the Federal research support programs.

Thus, outwardly at least, American science was thriving. Nevertheless, there was evidence of an underlying uneasiness on the part of many citizens about the aims and values of science and its role in a free society.

This in part stemmed from the increasingly esoteric and abstract nature of scientific thought, especially at the frontiers of knowledge. It was difficult for scientists to communicate their ideas not only to nonscientists but to colleagues in other scientific fields. Although he clearly saw the operational effectiveness of these ideas, the nonspecialist had no base in ordinary experience from which to gain understanding of present day scientific thought. In the absence of a clear understanding of what science is about, the average citizen more and more was required to accept or reject science uncritically and on faith.

The laws of nature take no sides on the question of how the power of science should be directed—whether toward good or evil. The control of such power rests with men and calls for ceaseless vigilance and firmness on the part of all men of good will. A generation that had witnessed two world wars and innumerable lesser crises felt natural resentment against the continuing stress and tension. Rightly or wrongly, some of the blame attached to science.

But although the laws of nature might be unbiased as to the ends to which they were put, scientists were not. They had responded loyally and with devotion to the urgent national call for their services. In so doing they set aside some of the traditional satisfactions to be gained from scientific pursuits. For the foreseeable future they would occupy a central place in the Nation's defense and technological development. They were in process of adjusting to their new status but it was a trying and critical experience.

Further uncertainty was felt by many citizens, scientist and nonscientist alike, in attempting to reconcile the demands of technological and military secrecy with basic democratic freedoms. L. V. Berkner at Ann Arbor described the point of view of many scientists on this conflict in the following terms:

> Scientific greatness always rises from diversity of thought, never from conformity. Since the security procedures that support technological secrecy inevitably put a premium on conformity, they tend to prevent our Nation's realization of the very greatness that we seek. Technological secrecy tends to obscure the essential dependence of democracy on diversity of thought and opinion. * * * The strength of democracy lies in the perspective and proportion that the diversity of public opinion provides for the guidance of our public officers. This guidance is now entirely lacking with respect to our most critical problem, because information is either restricted, or because public opinion is influenced by "leaks" to the press of information that supports some special interest or point of view. * * *
>
> But beyond its direct effect on the formulation of public policy, technological secrecy has an even greater impact on the public adjustment to the new environment produced by technology. As technology emerging from science becomes more and more a major part of our living fabrics, just so will its control become more and more a major factor in shaping our whole society and political

structure. Therefore, the decisions that direct the application of technology for man's benefit should not be reserved to any class, creed, political party, or individuals—whether they be scientists or churchmen, military strategists or statesmen, for the concept of "benefit" may be viewed differently by different groups. This responsibility for the application of technological development to man's benefit must rest with the whole of society, of which science is only one part, and in which each man, on the basis of his peculiar experience, partakes of the decision. For deep comprehension and intelligent action by society can be achieved only after all implications of scientific discovery are fully disclosed, explored and evaluated.

Perhaps the most hopeful note was found in the fact that so many thoughtful Americans, of every class and interest, were aware of these problems and had the will to face up to them.

National Science Policy

On March 17, 1954, President Eisenhower issued an Executive order concerning Government scientific research and the responsibilities of the National Science Foundation and other Federal agencies engaged in research and development. The text of the Order 10521 is given in Appendix V, p. 118.

The Executive order clarified and helped to define areas of interest of the several agencies with a view toward conservation of fiscal and manpower resources in the conduct of research. It made clear that agencies having operating missions depending upon research for their proper execution should continue to conduct and support basic research in areas closely related to their missions. At the same time, it stated that the National Science Foundation should be increasingly responsible for providing Federal support for general-purpose basic research.

The order called for the establishment of effective working arrangements between the Foundation and other agencies in arriving at mutually agreeable policies concerning the support of basic research. Each agency is charged with the responsibility for making continuous review and evaluation of its applied research and development programs with a view to maximizing efficiency and economy. Among the factors to be considered in such review are the status of basic research underlying development work, the relative priority of various development programs, project costs, and availability of manpower and facilities.

To the extent consistent with national security the order requires increased attention to the reporting and dissemination within the Federal Government of reports on the nature and progress of research projects undertaken by the various agencies. To facilitate this exchange of research information, the Foundation in cooperation with other agencies is directed to develop improved methods of classification and reporting. Other provisions of the order require the establishment of an inventory of major scientific facilities and equipment to facilitate the joint use and exchange of such items. This is under the primary supervision of the Interdepartmental Committee on Scientific Research and Development.

SURVEYS OF NATIONAL SCIENTIFIC ACTIVITIES

Several sections of the Executive order have to do with developing and encouraging the pursuit of an appropriate and effective national

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policy for the promotion of basic research and education in the sciences. This is of major concern to the National Science Foundation. In carrying out such responsibilities the Foundation is directed to recommend to the President policies for the Federal Government which will strengthen the national scientific effort and furnish guidance toward defining the proper role of the Federal Government in the conduct and support of scientific research.

During the past 2 years the Foundation has been engaged in making studies of the scientific resources of this country and of the manner in which they are being used to promote the national security, health, and economic welfare. This has involved the review and study of scientific research and training activities of the Government, industry, universities, and other public and private institutions. The order confirms the desirability and need for such studies.

The National Science Foundation Act of 1950 specifically authorizes and directs the Foundation to appraise the impact of research upon industrial development and upon the general welfare. The new order makes clear that this directive extends to the study of the effects upon educational institutions of Federal policies and administration of support programs for scientific research and development. In December the Foundation announced the appointment of an Advisory Committee on Government-University Relationships. It is the intention of the Committee to consider Federal policies and procedures which will promote general national research objectives and realization of Federal research needs while safeguarding the strength and independence of the Nation's institutions of learning.

By the close of the fiscal year, the Foundation had started several cooperative studies of Federal agencies, educational institutions, and industrial groups engaged in research and development.

RESEARCH AT EDUCATIONAL AND OTHER NONPROFIT INSTITUTIONS

During the year, an extended study was made of the type of information needed for analysis of scientific research and training activities at educational institutions. Questionnaires for obtaining such information were pretested at selected representative universities. Following the pretest a modified questionnaire-schedule was sent to over 400 universities and colleges which offer graduate study at least through the master's degree level.

The initial survey will provide statistics on the current enrollment of graduate students in the natural and social sciences, as well as in the humanities and most professional fields, and on the amount of financial support that is now available to graduate students in various fields.

Other segments of the study of nonprofit institutional research will be concerned with the analysis of sources of support for research at universities and colleges, the nature of such research, and the effect of research upon the teaching programs of the institutions. In order to define possible trends in research, case studies will be made of the research experience of some 30 selected institutions throughout the United States.

A separate project on the effects of outside research support on the development of an educational institution is being conducted at one leading university noted for its long and successful research experience. This analysis will cover research undertaken in the biological sciences department of the institution over the past 25 years. Among the factors to be considered are the relationship of research support to the professional development of individual investigators, the fate of research proposals that fail to attract nonuniversity support, the interplay of factors which influence the level and frequency of research support, and the influence of research support on education. This study will supplement the more general studies in appraising the impact of the type and quantity of support available for research upon scientific education and scientific productivity.

RESEARCH PROGRAMS OF FEDERAL AND STATE GOVERNMENTS

A second broad area of study of research activity in the United States is centered on current programs of Federal agencies in support of research in the natural and social sciences. The past year has been devoted to the development, with the advice and cooperation of the interested agencies, of a series of questionnaires to obtain comparable information on funds for research, scientific manpower resources, research programs, and related activities. At the present time the following information is being compiled:

Agency organization for science.—This is designed to develop a "map" of the organizational structure of units in Government performing scientific functions. It will eventually be reduced to an organizational directory of Government science for both Federal officials and private groups.

Personnel engaged in scientific activities.—This will provide information on the supply and distribution of scientific and supporting technical personnel in Government. The Government is the largest user of scientific and specialized personnel in the United States, either directly in its own laboratories or indirectly in industry or academic institutions working on Government contracts or grants.

Government scientific installations.—This in effect will be a descriptive inventory of Federal scientific installations, facilities, and other capital items for conduct of research and development. Under Executive Order 10521 the Interdepartmental Committee for Scientific Research and Development is directed to maintain a continuing inventory of large-scale research equipment owned and operated by Federal agencies.

Funds for scientific activities.—This will continue the fiscal analyses of Federal research and development activities of the type previously reported in the Foundation's published report series, *Federal Funds for Science.*

Preparation of a history of the activities of the Federal Government in science from 1789 to 1940 is being supported by the Foundation at the American Academy of Arts and Sciences. This historical account will supply important background information.

A survey of research activities of State governments is being done in two parts: (1) By the Bureau of the Census, Department of Commerce, and (2) by the Institute for Research in Social Science, University of North Carolina, Chapel Hill. The Census Bureau will analyze pertinent information now available in its extensive files and will determine in what respects additional investigations are necessary to study State-financed and State-controlled research activities throughout the country. The Institute at North Carolina will participate in the initial analysis and will conduct the followup investigations. Information will be gathered on research costs, manpower, research administration, and research content of State-supported programs.

RESEARCH ACTIVITIES OF INDUSTRY AND OTHER PRIVATE GROUPS

The National Science Foundation has started four studies of industrial and other private research activities by outside survey groups to round out its broad investigation of science in the United States. These studies, supported by the Foundation under contract, are as follows:

Survey of industrial research and development.—The preliminary phase of this study is being conducted for the Foundation by the Bureau of Labor Statistics, Department of Labor, under the direction of a steering committee composed of staff members of the two agencies. Plans were developed in consultation with the research committee of the National Association of Manufacturers, the Industrial Research Institute, and other industry groups. The study includes a review of available information from previous studies, a questionnaire survey of a carefully selected sample of about 12,000 companies in the United States, and intensive interviews with representatives of about 200 selected large corporations.

Estimates will be obtained on a nationwide basis of the amounts spent for the conduct of research by size of companies and by industry groups; of the source of these funds by major economic sectors; and of the amount spent by companies to purchase research conducted elsewhere, for example, in universities and research institutes.

The information will also permit the estimation by groups of companies, of ratios of research expenditures to capital expenditures, to sales, to research and development personnel, and to other relevant measures. In addition to dollar figures, the questionnaires will furnish in considerable detail information on the use of scientific and technical manpower in industrial research and development.

In the interviews an attempt will be made to ascertain the opinion of industrial leaders with respect to policies which might strengthen the scientific research effort of the United States. The interviews will also provide clues to specific bottlenecks faced by industry in planning its research. Some estimates may be obtained of the economic payoff of research.

Finally a historical analysis of selected companies will be carried out in an attempt to reconstruct the gross pattern of industry research over the past two or three decades. It is hoped that this will assist in the estimation of manpower and capital requirements that are likely to confront the Nation's economy in the near future.

Survey of research by trade associations and similar organizations.—This study is being conducted by the Battelle Memorial Institute, Columbus, Ohio. There are about 16,000 trade associations in the United States, of which 200 to 400 conduct or support research programs in the natural sciences. A somewhat larger number have research programs in economics and other social science fields. The study will also include other types of cooperative industrial research organizations and certain professional societies which conduct research programs, largely supported by industry.

Survey of research at nonprofit institutes and commercial laboratories.—This study is being conducted by the Maxwell Research Center, Syracuse University, Syracuse, N. Y. It is planned to explore the research programs of the 50 to 100 independent nonprofit research institutes and the estimated 250 to 400 commercial research laboratories in the United States. In many instances these organizations are concerned with research of interest to industry, but they differ from industrial laboratories in that the primary emphasis is upon research, and production, if any, is secondary.

Status of research in fermentation.—This study, undertaken as a case history in industry-government research relationships, is being conducted by the Roger Williams Technical and Economic Services, Inc., of New York. The field of fermentation was selected for such a pilot study for a number of reasons: (1) It involves both basic and applied research by industry, government, universities, and commercial laboratories; (2) it cuts across disciplinary lines, since both physical and biological research is required; (3) it is of interest to several important industries, including distilling, brewing, chemicals, food, and pharmaceuticals; and (4) the problem of security, such as would be encountered in the field of electronics, for example, is minimal.

RESEARCH PROJECT INFORMATION COORDINATION

The need for improved exchange of research information among Federal agencies has been stressed frequently. During the past year the Foundation has expanded its program of compiling and publishing unclassified lists of Federal research projects in various fields of science. The previously announced quarterly and semiannual lists of projects in psychology and the social sciences have been continued.

Preparation of the first annual list of extramural projects in the life sciences supported by Federal agencies has been completed and issued to the interested agencies for comment and suggestions for improving coverage in subsequent editions. The information on projects in the life sciences covers nearly 6,400 grants and contracts totaling almost $47 million for the calendar year 1952, or about 80 percent of the estimated Federal expenditures for research in biology, medicine, and agriculture for that year. The following seven Federal agencies having major research programs in the life sciences cooperated in the study: The Office of Naval Research, Office of Surgeon General of the Department of the Army, the Department of the Air Force, the Department of Agriculture, the Department of Health, Education, and Welfare, the Atomic Energy Commission, and the National Science Foundation. The analysis does not include research on human resources problems or psychology, nor does it include biological and medical research supported by the Atomic Energy Commission at its operating laboratories, such as the Oak Ridge, Brookhaven, and Argonne National Laboratories.

The Foundation is one of seven Federal agencies supporting the Biological Sciences Information Exchange, a cooperative enterprise administered by the Smithsonian Institution for the exchange of research information among scientific administrators of the contributing agencies.

Parallel activities in mathematics and the physical sciences are being carried on by means of compilations of projects in various fields and by informal liaison among program directors of the interested agencies.

International Geophysical Year

During 1957–58 for the third time in a century scientists of many countries will join in a critical examination of the ever-changing aspects of man's immediate physical environment.

The International Geophysical Year (IGY) is a major research undertaking in the earth sciences, including astrogeophysical measurements, meteorology, oceanography, glaciology, ionospheric physics, aurora and airglow, geomagnetism, cosmic rays, and rocket exploration of the upper atmosphere. The undertaking must be conducted on an international scale, for the problems are global in character. Each field of study requires observations and measurements on a worldwide basis. Moreover, these scientific fields are closely interrelated, so that maximum progress can be made only if the technical work in all fields is performed simultaneously.

Much effort has already gone into planning the program. Scientists from many countries have worked together in laying out the necessary scientific projects and activities, both on a national and international scale. In this sense, the IGY has already begun. Activity will increase during the next 2 years, culminating in intensive studies during calendar years 1957 and 1958. The years 1957–58 were selected for the observation period to take advantage of a period of maximum solar activity and of concurrent eclipses.

That geophysical problems could benefit from international cooperation was recognized in 1882–83 when the First Polar Year was launched, and again in 1932–33 during the Second Polar Year. These previous ventures were more limited in scope. Geographically, the areas of interest were restricted to regions about the North Pole, in contrast to the current worldwide program. Nevertheless, studies of the ionosphere during the Second Polar Year, by techniques then recently developed, gave rise to communications information that proved to be worth hundreds of millions of dollars.

INTERNATIONAL BACKGROUND

The proposal for the present international geophysical research effort originated in the International Council of Scientific Unions (ICSU), the central organization representing the several specialized international scientific unions. Toward the end of 1952, ICSU began planning for the IGY program. ICSU established a special committee for planning at an international level, and associated scientific groups in various nations were asked to set up national committees for planning and undertaking their national programs. The affiliated body in the United States is the National Academy of Sciences-National Research Council, which established a national committee for the preparation of the United States program.

As of November 1, 38 nations had signified that they would participate in the program:

Argentina
Australia
Austria
Belgium
Brazil
Burma
Canada
Czechoslovakia
Denmark
Finland
France
Germany, East
Germany, West
Greece
Iceland
India
Ireland
Israel
Italy
Japan
Mexico
Morocco
Netherlands
New Zealand
Norway
Pakistan
Peru
Philippines
Spain
Sweden
Switzerland
Thailand
Tunisia
Union of South Africa
Union of Soviet Socialist Republics
United Kingdom
United States
Yugoslavia

Details of the technical and fiscal plans of other nations during the International Geophysical Year were not available at the time of writing, but the final plans were to be formulated at a general meeting of the IGY Committee held in Rome in September 1954.

THE UNITED STATES PROGRAM

Many agencies and institutions assisted in planning the United States program. Within the Government, the program is of most immediate concern to the Departments of Commerce, Defense, State, and the National Science Foundation. In response to the request of the United States National Committee, the National Science Foundation has undertaken to coordinate various Federal interests. The Foundation will also handle the administrative and fiscal planning for the United States Government. Many universities, private foundations, observatories, and laboratories have specific interests. In the formulation of the program, several hundred scientists from Federal and private agencies and research institutions have contributed their services. Execution of this program will involve the continuing cooperation of all of these groups.

The United States program includes activities in several geographical regions of importance to this country: (1) The Arctic and sub-Arctic regions; (2) the middle latitudes of the Northern and Southern Hemispheres, including the United States, Central America, South America, and adjacent stretches of the Atlantic and Pacific Oceans; and (3) the Antarctic and sub-Antarctic regions. In each region the type of program to be pursued will depend on present geophysical activities in the region. Existing activities provide a substantial base for the total endeavor, but the proposed program will stress specific areas of research in geophysics for which existing programs are inadequate or lacking altogether. A more detailed summary of the United States program is given in Appendix VII, p. 123.

In many fields little additional activity need be carried on within the continental United States, since normal operations provide the necessary information. For example, the planned meteorology program calls for observations from only a few additional South American and Antarctic stations. Data from these regions, added to those gathered at existing Weather Bureau stations in the United States and the Arctic, will give adequate weather coverage for the Western Hemisphere. Similarly, the ionospheric, auroral, and geomagnetic programs stress the northern and southern latitudes. The planned Antarctic activity will require a major expedition.

In a letter to the Chairman of the National Science Board, President Eisenhower gave the International Geophysical Year strong endorsement calling particular attention to the value of scientific cooperation among nations. The President wrote:

> I am glad to support this undertaking. It is a striking example of the opportunities which exist for cooperative action among the peoples of the world. * * * Under especially favorable conditions, scientists of many nations will work together in extending man's knowledge of the universe. The findings of this research will be widely disseminated throughout the world, aiding in the further development of telecommunications, aviation, navigation, and weather forecasting. It is doubtful whether any single nation could undertake such a program. Acting in concert, each participating nation, contributing within its means, secures the benefits of the program. The United States has become strong through its diligence in expanding the frontiers of scientific knowledge. Our technology is built upon a solid foundation of basic scientific inquiry, which must be continuously enriched if we are to make further progress. The International Geophysical Year is a unique opportunity to advance science, while at the same time it holds the promise of greater technological gains both for ourselves and for other nations. I am sure that our participation in this far-reaching effort will very materially strengthen our bonds with the many

cooperating nations and make a constructive contribution toward the solution of mutual problems.

The budget request for support of the International Geophysical Year was submitted to the Congress in June 1954, and an expenditure of $2 million was authorized for the initial phase of the program. It is estimated that an additional $11 million will be required to complete the United States program.

Utilization and Training of American Scientists

THE INCREASE IN TECHNICALLY TRAINED PERSONNEL

In 1870, the population of the United States totaled nearly 40 million persons. Of every thousand persons in the population, 325 were gainfully employed. Only about 12,000 individuals in all, or 1 in 1,000 workers, were employed in science and technology. During the next three-quarters of a century these figures changed rapidly. By 1950 the population exceeded 150 million, and 400 persons out of every thousand were at that time in the labor force. The number of scientific and technical employed had passed the million mark, so that 1 in every 60 individuals in the labor force was a scientist, engineer, or other type of technologist (fig. 1).

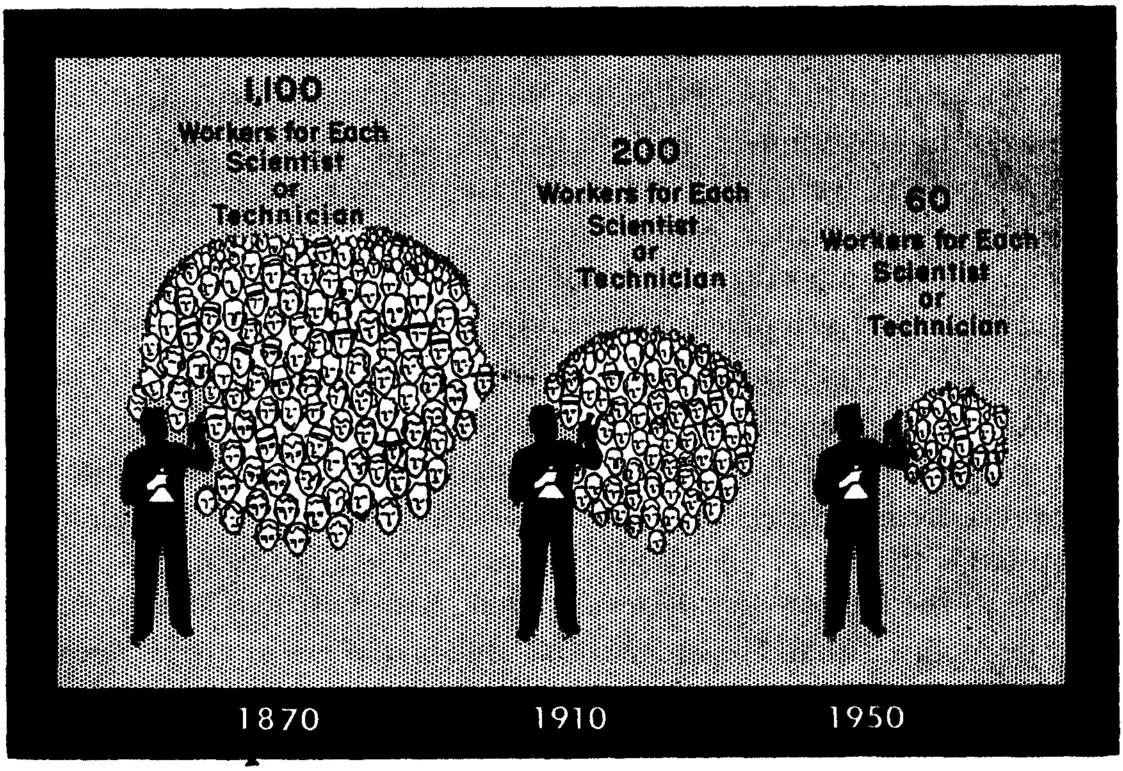


FIGURE 1. *Ratio of scientific and technical workers to total labor force in 1870, 1910 and 1950.*

Another indication of the trend toward technology is seen in the changing ratio of farm to nonfarm workers in the labor force. In 1820, some 72 percent of the labor force was classified as agricultural workers; by 1870 this proportion had fallen to 53 percent; and in 1950 less than 12 percent was so classified.

The term "scientists and engineers" is limited here to those who have at least a bachelor's degree, or its equivalent in professional experience, and who are employed in recognized branches of the natural sciences, engineering, or mathematics. By 1953, the population of scientists and engineers meeting this definition was estimated at 400,000 to 500,000 engineers and 200,000 scientists. About half of the scientists were chemists, a fourth were biologists or agricultural scientists, and the remaining fourth were earth scientists, physicists, mathematicians, and other scientific specialists.

According to the 1950 Census of Population, about 24 percent of the engineers in the United States were in civil engineering, 21 percent in mechanical engineering, and 20 percent in electrical engineering. The remaining 35 percent were distributed among chemical, industrial, aeronautical, mining and metallurgical engineering, and other engineering fields.

UTILIZATION OF SCIENTISTS AND ENGINEERS

In 1951, the Bureau of Labor Statistics estimated that about 48 percent of the scientists in the United States were employed in private industry, 26 percent in Government, and 26 percent in education. Of the engineers, 75 percent were employed in private industry, 22 percent in Government and 3 percent in education.

In 1951 the proportion of scientists actually engaged in research, as contrasted with development work and other professional activities, was highest (58 percent) in geology, which includes field exploration, and lowest (13 percent) in psychology. Nearly half of the physicists and chemists listed research as their primary activity. Eighty percent of the mathematicians reported principal professional activity as teaching, as contrasted with only 11 percent of chemists and geologists.

In 1953 the Research and Development Board of the Department of Defense reported that 17 percent of scientists and engineers in research and development were employed in Federal Government, 68 percent in private industry, and 15 percent in educational and other nonprofit institutions.

Although figures are available on the number of college graduates receiving degrees in science, less is known about the number who actually enter scientific professions after graduation. The National Science Foundation has obtained some information on this point from a study of persons graduating from college in June 1951 (fig. 2).

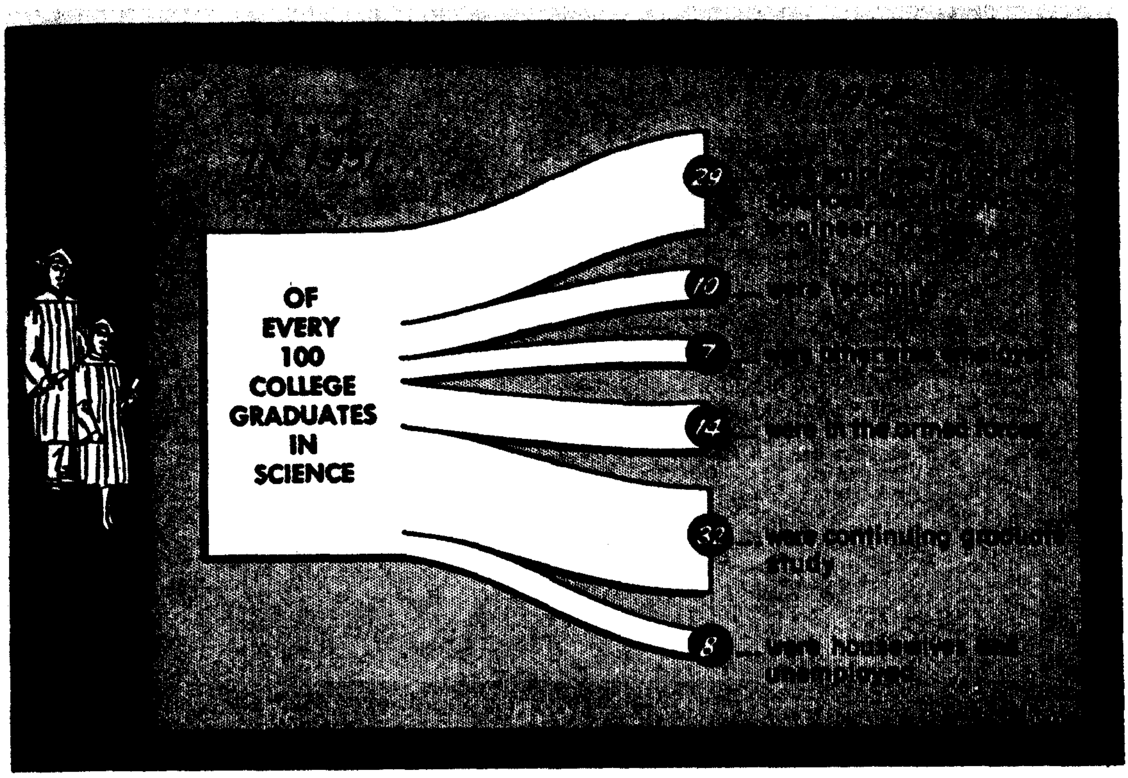


FIGURE 2. *Employment status of 1951 college graduates in science, 1 year following graduation.*

Approximately 1 year after graduation, 32 percent of the science graduates were continuing their education in graduate studies—40 percent in science, 45 percent in health fields including medicine, and the remainder in other fields. Fourteen percent of the total were in the Armed Forces, another 46 percent were professionally employed, and the remaining 8 percent were mainly women graduates who had married and become housewives. Of those professionally employed, 46 percent were working in the natural sciences, 21 percent in education, 15 percent in business and commerce, 10 percent in engineering, 6 percent in health fields, and 3 percent in occupations not elsewhere classified.

UNIVERSITY OUTPUT OF SCIENTISTS

The Commission on Human Resources and Advanced Training estimates that about 44,000 of the 200,000 scientists have doctors' degrees. Of this number about 55 percent are in physical sciences, 39 percent in agricultural and biological sciences, and 6 percent in the earth sciences.

Since 1900, the number of doctoral degrees granted annually in science by American universities has approximately doubled every 10 years. In 1900, 102 degrees were reported, and 4,631 in 1953. This increase, however, conceals a serious loss in the output of science doctorates during the years 1942–49. The low point of recent years was reached at 833 in 1945. Figure 3 shows the number of such degrees granted since 1920.

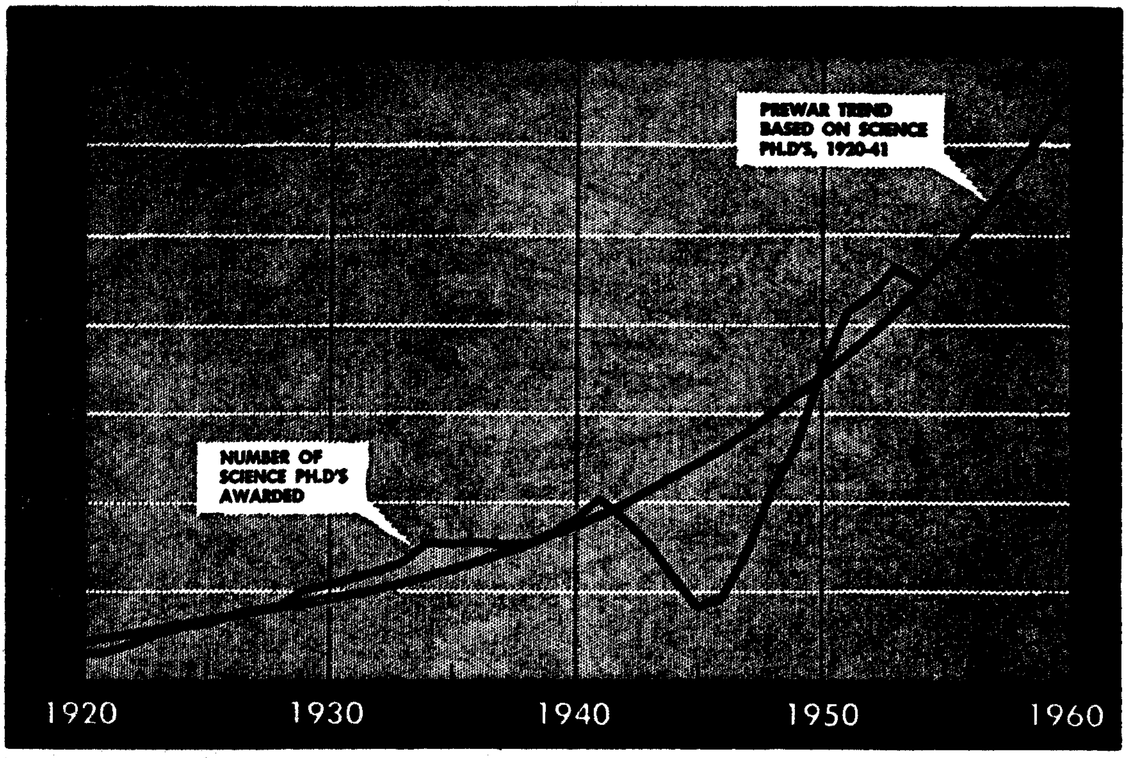


FIGURE 3. *Ph. D. degrees in science awarded in the United States, 1920–54, with prewar trend through 1960.*

The loss of science doctorates during 1942–49 is attributable in large part to military requirements which sharply reduced the college student population in both graduate and undergraduate training. A secondary factor, operating importantly during at least part of the period, was the great number of employment opportunities which made graduate study less attractive. The loss of science doctorates during this period may be estimated at about 9,000 on the basis of the prewar trend.

The downward trend in bachelors' degrees awarded in science and lower undergraduate enrollments of recent years will be followed by a smaller number of doctorates in 1954 and the next few years, or until the youth of the higher birthrate years of the 1940's appear in the graduate schools. There is no present indication that the loss of 1942–49 will be made up.

The highpoint of bachelors' degrees awarded in science and engineering occurred in 1950 largely as the result of the GI bill and the return to the colleges of the youth whose education was interrupted by the war. In that year, 57,000 bachelors' degrees in science and 52,000 in engineering were reported. By 1953, bachelors' degrees in science numbered 34,000 and in engineering 24,000. The low point was probably reached in 1954. Thereafter, the larger first-year college classes of the past few years should result in increased numbers of science graduates. Significant increases are in prospect for the early 1960's.

SHORTAGES OF SCIENCE TEACHERS

Little that is definitive can be said on the present requirements and shortages of scientists and engineers. The Committee on Manpower Resources for National Security of the Office of Defense Mobilization in its review of the situation in 1953 pointed to current shortages in engineering, to needs for advanced degree holders in the physical sciences, in medicine, and in teaching. Shortages in engineering and physical science fields are shown by recruiting difficulties and the increase in entrance salaries. The shortage of qualified science teachers in the secondary schools is well known. The shortage of teachers may be expected to extend to the colleges as the student population bulge advances to that point.

Enrollments in elementary schools in the United States were estimated at about 18 million in 1919–20. There was a slight increase during the next 30 years to about 20 million in 1949–50. The high birthrates of the war and postwar years have led the Commission on Human Resources and Advanced Training to estimate that elementary school enrollments will reach nearly 32 million by 1964–65.

The increase in secondary school enrollments will be proportionately greater. In 1919–20 there were an estimated 2.5 million students in high school, compared with 7 million in 1949–50 and an estimate of 12.7 million in 1964–65.

According to information in the Biennial Survey of Education in the United States, 1948–50, the Office of Education reports that the student-teacher ratio in colleges was 14 to 1 in 1950 as contrasted to 18 to 1 in secondary schools and 33 to 1 in the elementary schools. In order to maintain a reasonable student-teacher ratio in the secondary schools many thousands of newly trained teachers are needed each year to provide for the increasing enrollments and to replace those leaving teaching. The National Education Association estimates the need for new high school science teachers over the next decade as increasing from 7,700 per year in 1954–55 to about 10,000 per year in 1965–66.

While high school enrollments go steadily upward, the proportion of college graduates who qualify to teach high school subjects continues to decrease. The situation is particularly critical in the case of graduates qualifying to teach high school science and mathematics. Between 1950 and 1954, the total number of bachelors' degrees granted dropped by 34 percent. During this same period, according to the National Education Association, the number of college graduates meeting certification requirements to teach in high school dropped 42 percent, and the number qualified to teach mathematics and science dropped 51 and 56 percent, respectively.

More serious still is the fact that many college graduates who qualify to teach high-school science subjects actually find employment in other fields. A recent study of 1953 college graduates in teacher preparation programs showed that only 40 percent of those qualified to teach science and mathematics were actually teaching in November 1953. These percentages compare with 70 percent for home economics, 62 percent for English, and 53 percent for commercial subjects.

LOSS OF POTENTIAL SCIENTIFIC AND TECHNICAL PERSONNEL

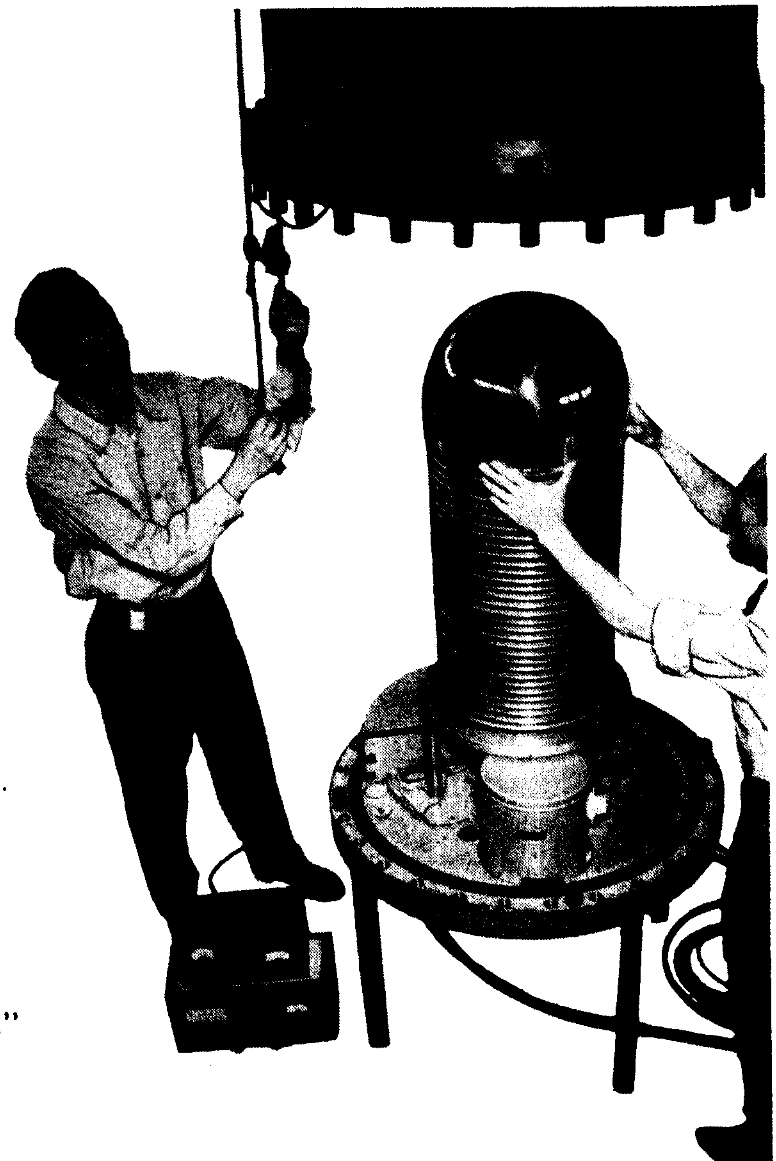
It is generally agreed that successful pursuit of a professional career in science requires a high level of mental ability. The Commission on Human Resources and Advanced Training has attempted to relate the distribution of intelligence in a population group to levels of education. The resulting data show the average ability rating of high school graduates to be about 110 and of college graduates to be about 120, in comparison with 100 for the general population of the same age group.

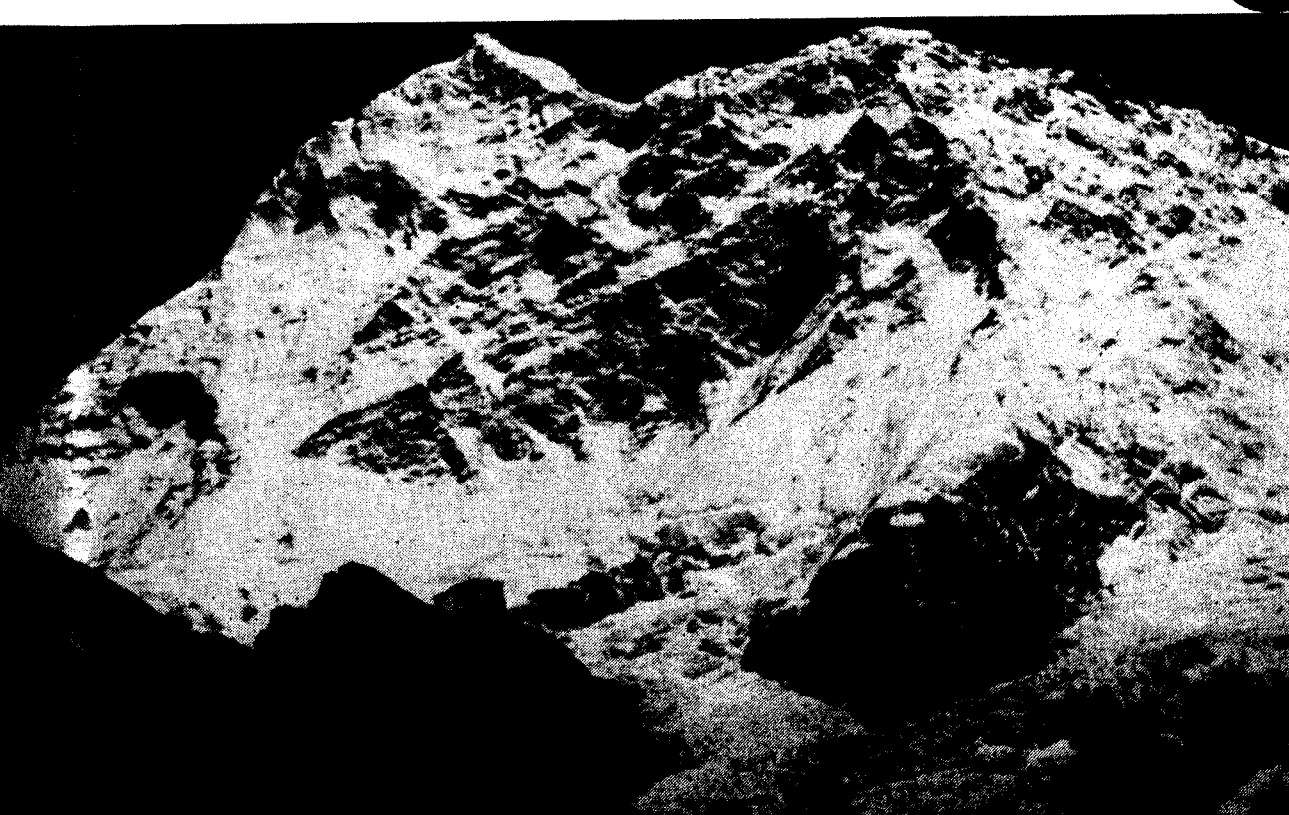
About 13 percent or 1 out of 8 of an age group possesses a rating of 120 or more, equivalent to that of the average college graduate. This is the group from which intellectual leadership not only in science but in all fields must be sought. Presumably, this relatively small group contains most of the individuals who are capable of benefiting from advanced training and who, in turn, will be best able to benefit society as a result of such training. The extent to which this group continues its formal education is a measure of our success in training up to our potential manpower resources.

Nearly all of this potentially productive group now finishes high school, with only about 1 percent loss reported by the Commission. However, 47 percent fail to continue formal education beyond this point, and another 13 percent drop out before completing college. Thus, about 60 percent of the group with the greatest potential fail to complete a college education. Only 2 percent of all college graduates, or one quarter of 1 percent of the total age group, continue their education through the Ph.D. level.

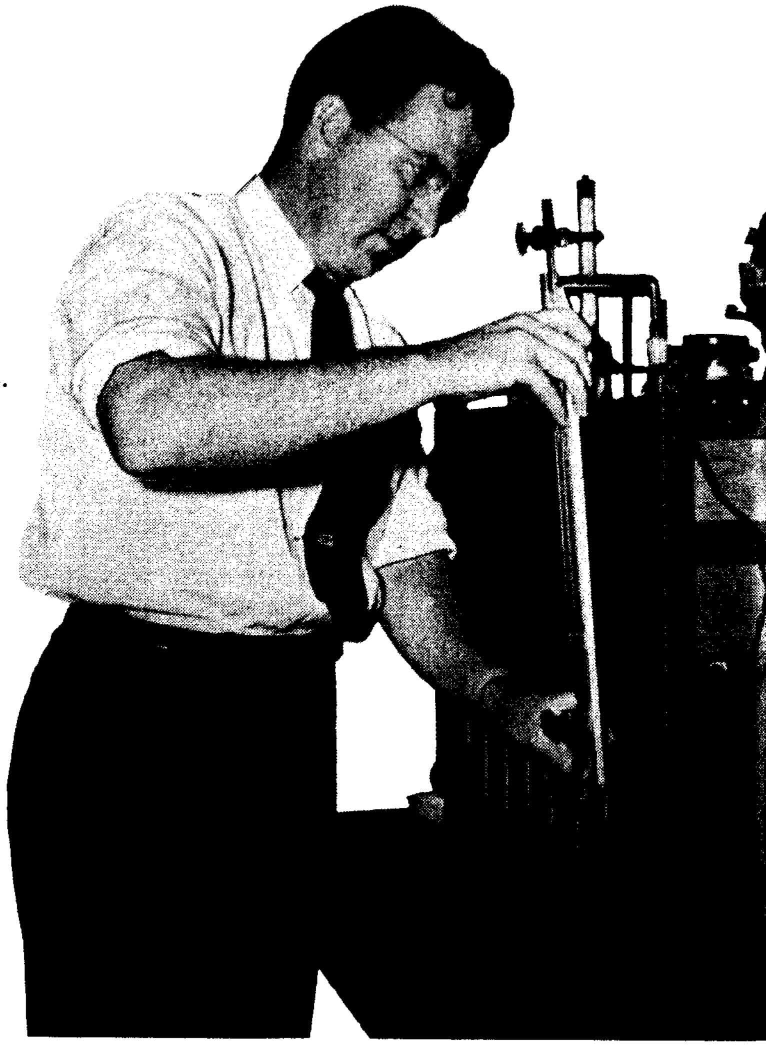
Economic and cultural factors have an important bearing on the failure of large numbers of the more talented youth to continue their education. The high cost of a college education, a traditional independence from family support at about college age, competing interests in employment, early marriages, and lack of interest and knowledge of opportunities available to college graduates are other important fac-

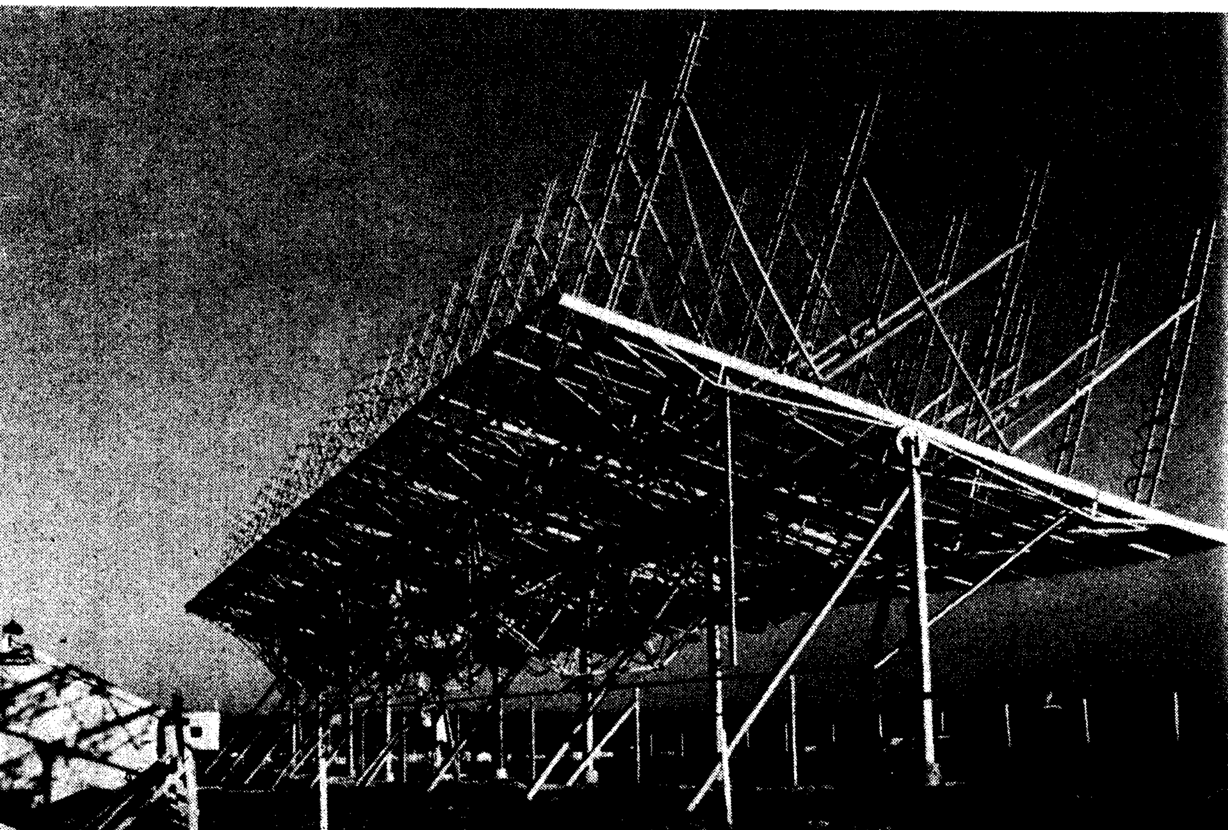
Graduate assistants (right) at Massachusetts Institute of Technology, adjust terminal of 2-million-volt Van de Graaf accelerator, used to study electron emission from metals under high-energy bombardment. John G. Trump directs research. Makalu (below) world's 4th highest peak, rises to 27,790 feet near Nepal-Tibet border. California-Himalayan Expedition in April 1954 reached 23,000 feet, highest point yet attained on Makalu's frigid, wind-swept slopes. NSF support enabled Nello Pace, University of California physiologist, to study human body changes at high altitudes. Lawrence Swan, biologist on 10-man team, found native spiders at 20,000 feet, "the highest animal level in the world."





Daniel J. O'Kane (right),
microbiologist,
at the University of Pennsylvania,
is studying the enzymes
that produces energy from food.
The Warburg respirometer
measures small gas changes
from "breathing" of microorganisms.
John D. Kraus (below),
of Ohio State University,
is shown with an unusual type
of radio telescope.
It has 96 helical (corkscrew)
beam antennas mounted on
a pivoted 160-foot steel frame.
The antenna picks up weak radio
waves from celestial objects.
The Ohio State radio telescope
has located over 200 spots
of radiation in the sky.
Most of these "radio stars"
are not associated with
any known visible object.
Kraus is now making a radio map
of all sky visible from Columbus.





tors. A positive decision to attend college is related to the socio-economic status and such additional factors as parental education, books in the home, and the counsel of teachers and friends.

There are no simple solutions to the problem of increasing our potential of highly trained scientific and technical manpower. They may include greater public support of education in order to reduce the financial burden of attending college, at least in those fields where policy dictates that increases are essential. The motivation to undertake science training can be increased by stressing the national importance and the personal satisfactions and rewards of careers in science and technology.

A summary of the Foundation's efforts to increase the Nation's competence by encouraging policies to increase the quality and number of young people trained in science is given in later sections of this report.

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Research in Colleges

A conference on physics research in colleges held at Amherst College in May 1953 (See *Third Annual Report,* p. 36) was the first of a series of conferences sponsored by the Foundation on the subject of research in colleges, as distinguished from universities. During the past year conferences of this type were held on research in geology, Beloit College, October 1953; biology, Bryn Mawr College, April 1954; astronomy, Swarthmore College, April 1954; and chemistry, Washington and Lee University, May 1954.

The conferences were called to consider problems associated with the conduct of research in colleges or small university departments, to assess the value of research as an adjunct to teaching in such institutions, and to determine the desirability of increasing the research activities in the normal undergraduate schedule.

The participating institutions were selected so as to represent various regions and types of institutions. Altogether, 92 institutions were represented, of which 63 may be classified as strictly liberal arts colleges. (See Appendix VI, p. 120.) The average attendance at the conferences was about 30. Some colleges were represented at more than one meeting.

THE PLACE OF RESEARCH IN THE COLLEGES

The participants noted that many colleges, although operating under stringent financial limitations which preclude research programs, are sending students on to careers as scientists. It was generally felt that undue pressure to undertake research might unbalance the programs of these institutions and should be avoided. On the other hand there was general agreement that carefully conceived plans of research aid, administered with appreciation of the special role of colleges in our educational system, could further enhance the service they render.

Although the majority of the participants were active in research, it was clearly the consensus of opinion that the primary function of the liberal arts college is teaching. If not overemphasized, research was considered a desirable activity for the college teacher and essential in realizing most completely the fundamental aims of the college. It was generally felt that a scientist engaged in research, even on a small scale, is likely thereby to be better equipped to present his subject in dynamic fashion. Excellent teaching has clearly been shown as one of the best means to stimulate undergraduates to enter careers in science.

The conference delegates agreed that student participation in research can be highly effective in motivating the students toward careers in science. Furthermore, the experience produces mental maturity of value for all students, including those who do not enter research careers. Several conference participants pointed out that the greater freedom from pressures and the simplicity of administration in small institutions provide an environment suited for creative work in basic science. While the total output of research in the small colleges cannot be expected to approach that of the universities, many notable investigations have been and are being carried out in smaller institutions.

UNDERGRADUATE PARTICIPATION IN RESEARCH

Undergraduate participation in research was considered at all the meetings, but it was the special topic of the conference on chemistry. Undergraduate participation is carried out under a variety of curricular devices, such as honors work, special study programs, and paid assistance in faculty research. The conferees felt that in general research experience tends to develop enthusiasm among students. As one delegate stated: "The student becomes alive when he finds he can produce." Other values noted included the added stimulation to faculty research and the help in selecting students fitted for graduate work.

Undergraduate participation in research creates certain administrative problems, such as increasing the amount of time expended by the instructor. Moreover, a research-minded faculty is essential in carrying out such a program. In geology and biology, where the summer is a peculiarly suitable and often the only possible time for certain kinds of research, scholarships covering travel and other expenses may be required.

CONCLUSIONS AND RECOMMENDATIONS

Conference recommendations for encouraging research were necessarily related to the differing needs of the various scientific fields and to local institutional situations that may interfere with the conduct of research. The major difficulties appear to be (1) inadequate faculty time because of heavy teaching schedules and administrative and other duties, and (2) inadequate salaries. The conferees recognized that the basic responsibility for removing these difficulties lies with the colleges.

This is particularly true in regard to relieving the teaching load, but some help may properly be given by outside agencies to provide for assistants or partial salary for additional personnel, thus permitting the institution to schedule more research time for an able investigator.

Low salaries militate against the use of summers for carrying out research, as it is frequently necessary for a faculty member to seek supplementary employment during the summer. This situation may be met by providing summer salaries so that competent scientists may undertake or continue research activities. In geology and biology, where much field work is carried out, assistance may be provided for attendance at summer stations or laboratories. In the physical sciences, there are analogous opportunities for summer attendance at universities, participation in research programs at astronomical observatories, exchange of staff members between large and small institutions, and leaves of absence.

The National Science Foundation has experimented along these lines by approving grants to research stations which in turn provide aid to college teachers. The summer institute or conference, which brings otherwise isolated teachers in small colleges in contact with recent scientific developments, has also proved successful.

It was noted that frequently a college may be unable to supply scientific instruments. The conferees felt that small grants of $100 or less might be of real help in furnishing research supplies and small pieces of equipment in such cases.

In discussing research support from Federal agencies or private foundations the conferees generally agreed that a proportion of the total available research funds should be reserved for research at small colleges. Moreover, it was felt that the point of view of the college teacher should be considered by the panels and project review boards which advise agencies in the distribution of research funds. In support of this position several conference participants cited the record of the Carnegie Foundation for the Advancement of Teaching during its 5-year program operating in the Southeast from 1948 through 1952. Grants to colleges made under this program appear to have been extraordinarily successful in stimulating research as well as in revitalizing teaching.

There was some discussion of appropriate procedures for awarding small grants. Although no definite administrative device was recommended, it seemed clear that one of the major requirements of such a program was an intimate knowledge of existing local problems.