The First Annual Report

of the

NATIONAL SCIENCE FOUNDATION

1950–51

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LETTER OF TRANSMITTAL

WASHINGTON 25, D. C.
November 1, 1951.

MY DEAR MR. PRESIDENT: I have the honor to transmit herewith the Annual Report for 1950–51 of the National Science Foundation for submission to the Congress as required by the National Science Foundation Act of 1950.

Respectfully,

ALAN T. WATERMAN,
Director, National Science Foundation.

The Honorable
The President of the United States

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FOREWORD

The establishment of the National Science Foundation by act of Congress on May 10, 1950, broke new ground. The American people, through their elected representatives, decided that fundamental, scientific research was of so great national importance as to warrant the expenditure of Federal funds in its support. They further decided that a new type of Government agency should be brought into being to insure the wise expenditure of the money. The ultimate power to disburse the funds made available each year by Congress was lodged in a Board composed of citizens appointed by the President and confirmed by the Senate. The Director of the Foundation, likewise appointed by the President and confirmed by the Senate, is the chief executive officer who, with his staff, will implement the decisions of the National Science Board within the framework established by the congressional appropriations. The present Board, which has been in existence about a year, is composed of men and women from all sections of the country and includes those who can speak with authority on all the major divisions of science.

The plans presented to Congress last spring for the first few years' operation of the new agency were the result of the lengthy deliberations of the National Science Board. As the Chairman of the Board for the year 1951, I have had the privilege of presiding over the numerous meetings that have been held and feel certain that I speak for the Board when I assure the President and Congress that what has been proposed represents the carefully considered opinion of all the members.

If the Congress will each year provide sufficient funds to enable the Director and his staff to carry out the program we have laid down, I have no doubt that over the years this new way of expending taxpayers' money will prove to have been a wise departure from the usual pattern. As time goes on, Congress will come to have confidence in the widely representative Board of citizens and look to this Board for the policy decisions affecting research in the natural sciences.

I use the words "over the years" advisedly for no one should expect to be able to assess in a short interval of time the value of money spent on scientific investigations. Even in the field of applied science, research is in the nature of a long-term investment; when it comes to raising the level of research work in the basic sciences, one must be prepared for a considerable "time lag" before the consequences of increased budgets are clearly discernible. Applied research is like drilling for oil when you know where the oil is. Fundamental research is like prospecting for oil in a hitherto unexplored country.

Of course, no one can draw a sharp line between basic and applied research and the Foundation will support many investigations that might be classed in the one area or the other. Indeed, speaking for myself and not for the Board, I venture to suggest that we might do well to discard altogether the phrases "applied research" and "fundamental research." In their place I should put the words "programmatic research" and "uncommitted research," for there is a fairly clear distinction between a research program aimed at a specific goal and an uncommitted exploration of a wide area of man's ignorance. It would be safe to say that all so-called applied research is programmatic but so, too, is much that is often labeled fundamental. Both types of research are of the utmost importance—important for advancing industry, public health, national defense, and extending the boundaries of knowledge, but today in the United States it is the uncommitted investigator who stands in the greatest need of public support. He needs not only more money for his equipment and for helping hands but more public recognition of the significance of his work, for he is the scientific pioneer, the man who turns the unexpected corner, the laboratory man whose experiments mark the opening of a new era or the theorist whose ideas are so fruitful as to be revolutionary. By and large the United States has not yet produced its share of such scientific pioneers as compared with Europe. One of the purposes of the National Science Foundation is surely to right this balance and provide in every section of the country educational and research facilities which will assist the development of such men.

In the advance of science and its application to many practical problems, there is no substitute for first-class men. Ten second-rate scientists or engineers cannot do the work of one who is in the first rank. Therefore, if the aims of Congress as set forth in the National Science Foundation Act are to be fulfilled, there must be all over the United States intensive effort to discover latent scientific talent and provide for its adequate development. This means strengthening many institutions which have not yet developed their full potentialities as scientific centers, it means assisting promising young men and women who have completed their college education but require postgraduate training in order to become leaders in science and engineering. To this end a fellowship program has been placed high on the list of priorities by the National Science Board. Again, given time, the expenditure of public funds in this enterprise, I feel certain, will prove to have been a most advantageous investment by the American people.

The first annual report of the Foundation which follows is by necessity a report of progress in formulating plans. It will be several years before concrete accomplishments can be listed, but measured solely in terms of a contribution to national defense in a period of lengthy, partial mobilization, I, for one, have no question but that the money will be well spent. The relations of science to war are so well known as to require no elaboration but what is often little realized is the relation of highly trained scientific talent to the progress of the technological armament race to which a divided world is now committed. Until such time as disarmament becomes a reality, the free nations must be deeply concerned with finding and developing scientific pioneers, for on their efforts we must rely as much for increasing national security in a war-torn decade as for industrial progress in periods of peace.

JAMES B. CONANT
Chairman, National Science Board

ANNUAL REPORT, 1950–51

Penicillin, the proximity fuze, the atom bomb, among a host of other scientific contributions to American victory in the Second World War, brought home to many citizens the value of scientific research. In the continuing crisis after the war, there were few who opposed the proposition that sustained Federal support of science and research was essential to the defense and welfare of the United States.

By the National Science Foundation Act of 1950 the Congress established the National Science Foundation "to promote the progress of science; to advance the national health, prosperity, and welfare; to secure the national defense; and for other purposes." The President approved the act on May 10, 1950.

THE NATIONAL SCIENCE BOARD

The 24 members of the National Science Board, appointed by the President on November 2, 1950, are persons eminent in the fields of the basic sciences, medical science, engineering, agriculture, education and public affairs, and they represent all areas of the Nation. A list of members of the Board is given in Appendix I, page 23.

At its initial meeting, called by the President on December 12, 1950, and held at the White House, the Board elected James B. Conant, president of Harvard University, chairman, and Edwin B. Fred, president of the University of Wisconsin, vice chairman. In accordance with the National Science Foundation Act, the Board appointed an Executive Committee of nine members under the chairmanship of Detlev W. Bronk, president of The Johns Hopkins University. Subsequent meetings of the Board have been held at approximately monthly intervals.

THE OFFICE OF THE DIRECTOR

On April 6, 1951, the President appointed Alan T. Waterman, formerly deputy chief and chief scientist of the Office of Naval Research, as Director of the Foundation. The Director immediately established the plan of organization envisaged by the act and began recruiting the necessary staff. C. E. Sunderlin, formerly scientific director of the Office of Naval Research, London, was appointed Deputy Director.

Programs for the development of a national science policy, the support of research and the training and registration of scientific manpower are administered by four divisions—the Division of Medical Research, the Division of Mathematical, Physical and Engineering Sciences, the Division of Biological Sciences, and the Division of Scientific Personnel and Education—each headed by an Assistant Director of the Foundation. The Director's staff also includes a General Counsel and an Assistant Director for Administration, whose functions include the direction of Offices for Scientific Information, Finance, and Administration. Names and titles of the principal staff members are given in Appendix II, page 25.

By the end of the fiscal year, progress had been made in staffing the organization with trained and capable personnel and in formulating the research and fellowship programs to be undertaken by the Foundation.

FUNCTIONS OF THE FOUNDATION

In describing the functions of the Foundation, the Congress made clear its intent as to the type of scientific work to be supported. Among other things, the Foundation is authorized and directed—

- to develop a national policy for the promotion of basic research and education in the sciences;
- to support basic scientific research and to appraise the impact of research upon industrial development and the general welfare;
- at the request of the Secretary of Defense, to support specific defense research activities;
- to award scholarships and graduate fellowships in the sciences;
- to foster the exchange of scientific information;
- to maintain a register of scientific and technical personnel and to serve as a central clearinghouse for such personnel;
- to evaluate scientific research undertaken by Federal agencies and to correlate the Foundation's research programs with other such programs;
- to cooperate in international scientific research activities.

The Act states that in exercising the above authority, "it shall be one of the objectives of the Foundation to strengthen basic research and education in the sciences."

BASIC RESEARCH

Basic, fundamental, or pure research, historically and traditionally, has been regarded generally as an adjunct of culture and civilization. Like painting, music, and philosophy, natural science was supported by sovereigns and wealthy patrons, and the scientist, like the artist, was thought of as an ornament of the court. In a later age, when parliaments replaced kings, official support of all the arts and sciences declined, and basic research was carried on largely by educational institutions and academies of higher learning. Only within recent years have industry and government learned that basic research is the pacemaker for technical progress and, hence, merits sustained financial support.

Basic science has been honored over the years for its own sake. Its aims have been the advancing of the frontiers of knowledge and the collection of basic information—in many cases guided solely by the curiosity and personal interests of the individual worker.

At first glance this lack of aim and unconcern with practical matters suggest that financial support for basic research, whether academic, industrial, or Federal, is not justifiable in times of grave national peril. A review of the centuries-long advance of scientific thought, however, shows that its greatest source of strength lies in the freedom of the scientist to go beyond the known, where a fresh look at the world is forced upon him and where his best guide may be his own unchecked imagination.

American military men have learned this and they point to the risk implicit in the German policy at the start of World War II. After their initial successes, the Nazis withdrew their support from research and felt that all of their resources should go to produce existing weapons. Research funds were cut to the bone about 1940. Long-term research was stopped. Two years later they learned their error. But then it was too late.

By way of contrast, Irving Langmuir, American Nobel prize winner and industrial scientist, reported that Soviet Russia carried on large-scale basic research all through the war.

Basic research has to do primarily with the discovery of new facts about nature and with finding, testing, and developing general principles. The discovery of radioactivity is an example of the discovery of a new fact and the statement and verification of the law of gravity an example of a general scientific principle. Both types of scientific discoveries require imaginative minds of a very special type. It takes imagination to recognize a new fact in the first place, and it takes imagination to organize a mass of such facts into a meaningful pattern. These patterns which are called the laws or principles of science are the basic instruments through which man has mastered the material world in which he lives.

The results of basic research are used by applied scientists, inventors, and engineers in many practical problems. The war-time contributions of science stand out as spectacular examples of how principles revealed in basic research were put to work. The preeminence of the American electronics industry, the growth of our chemical plants, the phenomenal development of agriculture in the United States stem from exploitation of the fruits of basic research.

Alfred P. Sloan, Jr., chairman of the board of the General Motors Corp., has compared research to mining. Our mastery of science and invention and our ability to put our know-how to work on the industrial assembly line account for our present world economic leadership, according to Mr. Sloan. "To insure a continuous flow of this skill and know-how we must," he writes in *Colliers,* "insure an expanding reservoir of what I call 'fundamental knowledge.' I might compare this to the ore in the ground. To accomplish any constructive purpose, ore must be extracted and refined. But first it must be discovered. Just so with fundamental knowledge. Its discovery starts in the academic area as pure research. Then it passes through the stage of applied research into engineering and ultimately reaches the assembly line and the consumer."

ELECTRONICS—AN EXAMPLE OF BASIC RESEARCH

The Greeks discovered both electricity and magnetism. Thales of Miletus (600 B. C.) knew that a piece of amber, when rubbed, would attract fragments of straw or feathers, and our word "electricity" is derived from the Greek *elektron,* amber. Certain iron ores found in the district of Magnesia on the Aegean Sea, were likewise found to attract fragments of iron. From these so-called magnesian stones come the words, "magnet" and "magnetism."

Despite these observation, however, the Greeks apparently learned no important basic information about electricity and magnetism. Not until 1819 did the Danish Hans Christian Oersted observe that a moving electric charge sets up a magnetic field, and thus establish a relation between the two. In 1831 the Englishman, Michael Faraday, found by starting a current in one electrical circuit that an instantaneous electric current is set up in an adjacent circuit. This was the pioneer experiment in wireless communication, since the two circuits were insulated from each other.

During the next half century a host of experimenters, led by Faraday, continued research in electromagnetic phenomena. Moreover, each advance in basic knowledge led to practical application. The earliest dynamos to generate electricity were built and the first electric motor. The telegraph and telephone were invented.

In the 1860's an English mathematical physicist, James Clerk Maxwell, subjected the ideas of Oersted and Faraday to mathematical analysis. His equations showed that the electromagnetic field around a moving charge or magnet changes with the motion. The change does not take place instantaneously, however. It takes time, and the effect moves outward from the source in a wave-like pattern. Maxwell's theory thus predicted electromagnetic waves. In 1887 Heinrich Hertz in Germany was able to produce and detect the type of waves predicted by Maxwell.

If waves of electromagnetic energy move through space, why not use them to carry signals? Within seven years after Hertz first observed the Maxwellian waves, an Italian physicist, G. Marconi, was trying to devise transmitting and receiving apparatus for such signals. By 1901 Marconi had successfully sent wireless signals across the Atlantic Ocean, laying the foundation for radio communication. In the 1920's scientists also learned that very short electromagnetic waves are reflected by objects in their path like light from a mirror or the echo of a sound. This basic fact led to radar during World War II and to other uses such as the proximity fuze.

Meanwhile, other investigators were interested in the nature of electricity itself. Maxwell's equations said nothing about this. They simply showed how electrical and magnetic forces are related and how they travel through space. By use of an evacuated glass tube devised by William Crookes, J. J. Thomson proved that the passage of an electric current between electrodes in the tube was due to extremely small particles each carrying a small unit of negative electricity. These particles, now well known as electrons, are universally found in matter. They are present in all atoms, and an electric current in a wire is nothing more nor less than a stream of electrons through the metal. Further basic research on the behavior of electrons showed that they could be released from matter by several methods, by heating, for example, or by letting light fall upon the surface, as in a photoelectric cell, or by bombardment by other electrons.

As these facts became known, scientists saw that electron currents and electron tubes could be turned into highly sensitive devices for detection of electromagnetic waves. While the first tube of this type was developed by J. A. Fleming in England in 1904, the original electron vacuum tube for radio was made by the American, Lee DeForest. World War I brought extraordinary developments in the use of electron tubes for communications, and shortly after the war commercial radio began.

Thus starting with the discovery of a few simple facts science has made its remarkable progress largely through basic research—one discovery leading to another until our knowledge of the field made possible applications for the benefit of mankind. In the course of this accumulation of basic scientific knowledge, men of inventive or applied turns of mind brought to the world devices of great practical importance for our welfare and our civilization, and when needed, for our military defense.

The impressive point is that the discovery of the electron and the applications of this discovery, which today represents a multibillion dollar industry, came out of the physicist's attempt to understand the riddle of the nature of matter.

Basic research concerning the atom gave new insight into this great riddle. For still deeper insight into the nature of matter it is necessary to probe into the nucleus of the atom. To date study of the atomic nucleus has yielded a bewildering array of subnuclear particles—protons, neutrons, and many types of mesons. Although physicists have only begun to understand the nature and composition of the atomic nucleus, it is highly significant that from this study has already come one of the most impressive phenomena known to man, atomic fission. As these riddles are solved by basic research, man's knowledge of and control of his world will increase.

CASE HISTORIES IN BIOLOGY AND MEDICINE

Biology and medicine provide excellent case histories of the scientific method—the way in which the facts of nature are first observed, then turned into theory, and eventually applied.

Although bacteria had been postulated by the ancients, and actually seen by Leeuwenhoek in 1675, bacteriology only became a science with the work of Louis Pasteur and Robert Koch in the mid-nineteenth century. Pasteur's finding that certain fermentations were caused by yeasts and bacteria led him to the germ theory of disease, which in turn started a revolution in medicine. Almost at once antiseptic surgery, the purification of water, and the pasteurization of foods and milk became widely used methods for preventing disease.

Vaccination, immunization, and inoculation were rationalized by the germ theory. It guided Paul Ehrlich's long search for a drug to combat syphilis and recently led to Alexander Fleming's discovery of penicillin. Many infectious diseases have been controlled or wiped out by methods based on the germ theory.

Yet, the germ theory could not be applied in all cases. It failed to explain some ailments: diabetes, cancer, pellagra, arthritis, anemia, and others.

With the development of a knowledge of nutrition and the preparation of chemically pure foods, it was found that animals could not grow on fats, carbohydrates, and proteins alone. Other factors, vitamins, were then discovered to be needed to maintain proper growth and health. In turn some "diseases" like pellagra became recognized as deficiency conditions. They were not caused by bacteria at all but by something lacking in the diet.

In 1901 Takamine isolated adrenalin—the first known hormone—a product of a ductless gland. Since then diabetes, goiter, and even arthritis have been shown to be related to such substances and controlled by their use.

Hemophilia, the bleeder's disease, became better understood through a study of inheritance and the application of basic genetics. Conversely genetics has ruled out congenital syphilis and Mongolism as being truly heritable.

The cell theory, which leads to understanding of both the architecture of the body and its functions, was first suggested by botanists who observed plant cells. Yet it underlies inheritance, reproduction, and growth both normal and cancerous. Cancers are "cells gone wild." The natural controls on growth in such cells are out of order.

Thus much of modern medicine rests on five basic biological theories—germ theory and the theories of nutrition, hormones, genetics, and cells. For many years no one saw a connection between these. But recently biologists have learned that they are related. All of these older theories may be understood better in terms of a newer study—enzyme chemistry.

Enzymes are complex proteins which start and carry on such processes as digestion, respiration, growth, and muscle and nerve action. Some enzymes are found outside of cells, but more often they are found within. Since enzymes are in a sense living chemicals their role in the body as control and activating mechanisms may be at least partly explained in terms of chemistry.

Bacteria, hormones, and antibiotics have been shown to inhibit or alter enzyme action. Many vitamins are incorporated into enzymes.

The genes or hereditary units are either themselves enzymes or produce them. Enzyme chemistry is thus basic to understanding of biology and medicine, and by extension to such related applied fields as farming, forestry, pharmaceutics, and many others. There is reason to expect that further study in this field will yield startling results in better understanding and control of living processes.

RESEARCH—GAMBLE AND INVESTMENT

Science is highly competitive, but the competition is in ideas. Every idea must compete against all other ideas in the market place of science. No one can tell in advance which idea will stand up under severe testing in the laboratory or in practice. "Research is a gamble at best," writes a thoughtful editor on the *New York Times*. "But just as good poker players win consistently, year in and year out, so good research laboratories consistently produce results."

One large American corporation, E. I. du Pont de Nemours & Co., has told its stockholders how it turns this research gamble into sound business investment. "As in games of chance, the problem really is to spread the company's research risks over a great many possible winners, while retaining sufficient reserve in funds and manpower to increase the stakes when the deal looks good. * * * In the end, the winning project must more than make up for all the losses or the entire game must be abandoned. * * *

"Comparisons with games of chance, however, can be carried only so far in describing the risks of research. In the former, a mathematician with a slide rule can figure the odds ahead of time. Not so in research. There the odds are set by a combination of factors: The wisdom of management, the inventive genius of the scientists, the dollars and facilities available for research.

"There's no advance guarantee, then, that 1 in 20, or even 1 in 40 projects will pay off. Rather, the test of successful research is management's ability to fashion odds under which winnings will exceed losses by a profitable margin."

This company has found that it invests about $4 in research for every dollar spent on successful projects. The good idea pays not only for the whole research program, but for development costs and plant and equipment to produce the new goods on which the company's continuing welfare depends.

Another view about basic research is expressed by C. G. Suits, vice president and director of research, General Electric Co. The unexpected byways of research, he points out, often prove of far greater importance than the original objecitves. In truly exploratory science it is extremely difficult to plan final results with precision. The real planning goes into the choice of people with insight, imagination, and skill, and into the choice of a field for their efforts which will challenge genius.

THE DWINDLING TIME-LAG

In the more leisurely days of the last century and up to the time of the First World War, there was often a long delay between the end of a basic research study and the report of the results or between the report and use of the findings. One well-known example involves the work of Gregor Mendel, father of modern genetics. His study of inheritance was published in 1866 but did not become generally known until nearly 40 years later. Since then great advances have been made in genetics theory through the efforts of many workers.

Hybrid corn introduced just before the last war is one practical use for this basic work. During the four war years replacement of common types of corn by hybrid corn is said to have increased the value of the corn crop 2 billion dollars. Prior to the introduction of hybrid corn, the Department of Agriculture spent about 5 million dollars in applied research and development work. But as L. J. Stadler, field crop authority at the University of Missouri, points out, this return came about not only by the 5 million dollars' worth of made-to-order research, but by discoveries in basic science which were wholly incidental and which could not have been made to order.

It would be rash to say that, had Mendel's work been brought to the attention of the world right after publication, hybrid corn would have been used four decades sooner. Today, however, so long a time-lag between an important basic finding and its use is rare indeed. In many fields the lag has disappeared altogether.

Bradley Dewey, an industrialist and former president of the American Chemical Society, said in 1945 that in the field of aerodynamics, fact-hungry engineers were lined up back of the scientists waiting for facts and laws that govern flight at supersonic speeds.

Again in 1949, Harry P. Hammond, dean of the school of engineering, Pennsylvania State College, found that the Air Force was stalled because of lack of knowledge of the upper atmosphere.

Studies of the use of scientific literature by physicists and chemists also show the shortness of the lag. Fussler found that in the case of papers published by chemists in 1939, half of the literature cited as source and reference material was less than 6 years old; three-fourths of it less than 14 years old. The physicists were treading still closer on the heels of previous work. Half of the literature cited by physicists was less than 4 years old, and three-fourths of it less than 8 years old.

Leaders of industry have vigorously called attention to the fact that applied research is rapidly overtaking basic research, and that the situation is critical. R. J. Dearborn, chairman of the Patent Committee of the National Association of Manufacturers, stated that industry recognizes that this country faces a serious need for more funds for basic research, and that by 1945 industrial research had grown about tenfold since World War I, while basic scientific research had not kept pace.

EFFECTS OF WORLD WAR II ON BASIC RESEARCH

The war intensified a situation already critical in 1940. The atomic scientists in particular have been acutely aware of how the war interfered not only with the normal output of basic research work, but in the production of new young scientists able to carry on basic work after the war. J. Robert Oppenheimer, wartime director of the Los Alamos Scientific Laboratory, and now director of the Institute for Advanced Study, Princeton, N. J., has testified that "we learned a lot during the war."

"But," he continued, "the things we learned are not very important. The real things were learned in 1890 and 1905 and 1920, in every year leading up to the war, and we took this tree with a lot of ripe fruit on it and shook it hard and out came radar and atomic bombs. * * * The whole spirit was one of frantic and rather ruthless exploitation of the known; it was not that of the sober, modest attempt to penetrate the unknown."

Henry D. Smyth, author of the Smyth report and present member of the Atomic Energy Commission has said flatly that there were no great advances in basic science during the war. On the contrary, the war years, he said, have been "a period of almost complete stagnation and this means that the fountainhead of all our future scientific developments has run dry."

In still more serious vein, Robert P. Patterson, former Secretary of War, said: "The security of our Nation depends upon the maintenance of our present leadership in scientific research and development. That is the inescapable lesson of the war we have just won, at a cost of more that a million American casualties.

"A nation that lags in the laboratory will not only have no chance of victory in a future war, but it is extremely unlikely that it will survive at all, so terrible in their destructiveness are the weapons we can foresee even on the basis of our present knowledge. * * * If we would keep the peace we must keep our defenses strong, and the laboratories of America have now become part of our first line of defense."

SOURCES OF BASIC RESEARCH

The leading agricultural, economic, industrial, and military position of the United States springs in large part from the technological talent of the American people. Our real genius as a Nation has been the power to convert scientific knowledge into practical utility. Evidence of this is found on every hand, in farming, in industry, in business, in public health, and, during two World Wars, in our military power. It is fundamental to our high standard of living.

Until comparatively recently and except in a few outstanding cases, the United States has not led other nations in fundamental research. Most of the basic knowledge came to us as a heritage from the accumulated findings of science all over the world.

An indication of the extent to which science is international may be found in an analysis of the nationality of scientists awarded the Nobel prize. During the first 20 years of this award, 1901–20, a total of 43 awards were made in the physical sciences. Of these 15 went to Germany, 26 to 7 other European nations, and the remaining 2 to Americans. For the same years, of 17 awards made in medicine and physiology, 4 went to Germany and the remaining 13 were divided among 9 European countries. No awards in medicine were made to Americans during this period.

In the years 1921–49 a total of 60 awards were made in the physical sciences of which 14 went to Germany and an equal number to the United States, 30 were split among 10 other European nations, and the remaining 2 went to Asiatic countries. In medicine and physiology 38 awards were made during these years. Both the United States with 9 awards and England with 7 passed Germany with 5, and 14 were split among 9 other European countries and the remainder went to other Western Hemisphere countries.

In the last 30 years a considerable number of American scientists have received Nobel prizes, awarded primarily for outstanding work in basic research. The fact remains that three out of four awards in science have gone to scientists outside the United States. This country is by no means self-sufficient with respect to scientific talent.

While the war and its aftermath seriously hindered basic research activities in the United States, the effect in most countries, particularly on the European continent, was shattering. Research had nearly come to a standstill. Since the war, the research scientists of certain of the western countries—notably in the United Kingdom, western Germany, the Lowlands, and Scandinavia—have shown a remarkable recovery. Nevertheless, the United States has a greater responsibility than ever before to carry its full share in the advancement of basic scientific knowledge.

THE PRESENT EMERGENCY

The most immediate problem before the Foundation, and one that has been considered at length by the Board and the Director, is the relation of the present emergency to the support of basic research. There is no question that the Foundation's programs in basic science will, in the long run, be a major contribution to the Nation's military and technological strength. However, it seems worthwhile in this report to state the point of view from which the Foundation is planning its program. This may be summarized as follows:

> *Since both the degree and the duration of the present emergency are uncertain, it is clear that the United States must—*
>
> *a. with all dispatch, put itself into what the military call "operational readiness," and*
>
> *b. take the necessary steps to maintain itself in this state of readiness for an extended period, perhaps for many years.*
>
> *This should be done with the realization that at any time the emergency may turn into a crisis.*
>
> *In respect to science, our national policy requires that urgent military uses of science should be expedited, where these uses may be put to practice in a short time, say 2 or 3 years. Clearly, this should be done with all the care that can be spent on an emergency problem. The United States certainly cannot undertake all possible scientific applications in a limited period and hope to complete them in time for operational use. There must be careful selection as to the practical uses which are both feasible and of high priority.*
>
> *This country also must remain in scientific readiness over a long period of years. This will require the utmost effort to strengthen our scientific progress and maintain that strength at the highest possible level. In this second phase, the United States must keep the initiative, scientifically speaking, in as direct a sense as it intends to keep the initiative with respect to the effectiveness of its military forces. It is here that the program of basic research to be supported by the National Science Foundation can be most effective.*

A NATIONAL SCIENCE POLICY

The development and formulation of a national science policy will take time. At the outset it must be approached with care and thoroughness.

Among the questions which need to be answered in developing a national policy in basic research and education in the sciences are the following:

- What is the total financial support now being provided for scientific research?
- What is the distribution of this support among the three major sources—Government, industry, and educational institutions?
- What amount of financial support can and should be provided and what is the most desirable distribution from among the available sources of support?
- What is the division of research effort among the various natural sciences?
- What areas need greater emphasis and what less?
- What means can be developed to shorten the period between discovery and practical application?
- What are the present and future needs for trained scientific manpower?
- What is the impact of Government support of research programs on the educational process in universities and colleges?
- What is the effect of Federal research programs on the financial stability of universities?

A national science policy will stem from many sources and embrace the ideas of diverse groups and individuals. A sound policy, however, must rest on a sound foundation of fact. Developing such a body of fact is one of the chief tasks of the Foundation.

NEED FOR A CURRENT SURVEY OF RESEARCH EXPENDITURES

The National Science Foundation was established at a time when unprecedented sums of money were being spent for scientific research and development. This fact points up the great emphasis placed on applied research and development in contrast to—and perhaps at the expense of—basic research.

No up-to-date assessment of the national research and development situation is at hand. The latest over-all survey of the country's scientific resources was made by the President's Scientific Research Board in

1947 for the Steelman report, *Science and Public Policy.* Some of the conclusions are now obsolete because of the Korean war. In addition, as the report points out, much of the statistical material came from the earlier Bush report, *Science—the Endless Frontier.* The best present estimates of sums being spent for research and development are largely based on these studies and are of limited use as guides to current planning.

The Steelman report points out that there are many definitions of research as well as of its components—basic research, applied research, development, and so on, which makes analysis very difficult. There are also wide differences in accounting practices for costs and overhead charged to research and development.

Among its first tasks the National Science Foundation plans to make a thorough review of the present national pattern of research and development. As soon as practicable, the Foundation will review in the main fields of science the total effort, its breakdown in terms of funds and manpower and the state of the art to show in what areas additional work is needed.

PRESENT ESTIMATES OF RESEARCH AND DEVELOPMENT EXPENDITURES

Within the limits of the present data, some general conclusions may be reached as to the extent of the present national effort in research and development. The United States Bureau of the Budget annually compiles figures for Federal expenditures in research and development, and the Research and Development Board, Department of Defense, has for several years estimated the total national expenditures for research and development. The National Research Council has also estimated the approximate level of industrial research in the United States for 1950.

On the whole, the orders of magnitude of the figures supplied by these agencies are in agreement. It appears that the Nation is currently spending about 2½ billion dollars a year for all research and development activities, of which the Federal Government supplies between 60 and 70 percent, while the universities supply about 5 percent. While industry provides 25 to 35 percent of the funds for research and development, nearly two-thirds of the entire amount is actually spent in industrial laboratories and facilities. Slightly more than 10 percent of the work is done at the universities.

Tables showing estimates of research and development expenditures since 1940 are given in appendices VI–VII, p. 30. Research costs, like all other costs, have risen sharply over the decade, so that the research dollar in 1951 is quite different from the 1940 research dollar. This fact must be considered in making historical comparisons.

When research and development costs are lumped together, the lion's share, of course, comes under the heading of development, which includes such items as design, engineering, and production of prototype models. For this reason it is impossible to isolate the year-to-year changes in research expenditures.

Both the Research and Development Board and the National Research Council based their estimates on research costs. By sampling methods the Board found the average costs per research worker, engineer, and scientist in industrial laboratories, universities, and the Federal Government. These figures were then extended to the total number of personnel working in research and development. The Council used a similar method in reaching its total for industry, but used base cost figures provided by the chemical industry.

BASIC RESEARCH EXPENDITURES

In the national total for research and development, the smallest share, dollar-wise, goes to the universities. Since most basic research is carried on in the universities, it is clear that the smallest portion of financial support is given to basic research. Nor is the total sum earmarked for research and development in the universities all spent for basic research. In response to the demands of the Defense Department, many universities are doing applied research and development work.

One professional group, the Engineering College Research Council, has studied the effect of the trend toward applied research and development in the universities.

It found that one-fifth of the college research effort is in the field of physics and nearly one-half in the three areas of physics, chemistry, and electronics. Another 25 percent of the defense research work is in aeronautical and electrical engineering, mathematics, and the earth sciences. Chemical engineering, food technology, ceramics, astronomy, industrial engineering, marine engineering, petroleum and fuels engineering, and mining engineering together account for less than 10 percent.

While the Council does not feel that applied work has yet hampered basic research in the colleges and universities, continuing pressure upon the universities for defense research without compensating support for basic research could easily upset the present balance.

MORE AND BETTER MEN AND FACILITIES

The availability of research and development contract funds has many beneficial effects upon academic institutions. Contract funds may make it possible to attract more competent researchers, as well as to provide facilities and equipment not otherwise available on the normal academic budget. Benefits of this kind, however, have shown a tendency to be concentrated in a relatively few institutions. A Research and Development Board study of contracts written for fiscal years 1948, 1949, and 1950 reveals that 11 schools accounted for about half of all sums obligated in these years, while 65 institutions accounted for nine-tenths of the obligations.

More and more institutions are receiving research and development contracts or grants, but there still exists a large research and development potential, particularly in the smaller schools, which is not now being used by Government agencies supporting research and development.

The Engineering College Research Council found a similar concentration of industrial research. The metropolitan areas of New York, Chicago, and Philadelphia alone account for more than a third of industrial laboratories and research workers.

WIDER GEOGRAPHICAL AND INSTITUTIONAL SUPPORT

The National Science Foundation proposes to support basic research on as broad a geographic and institutional basis as possible. In the small institutions, many of which are operating on meager budgets, relatively small sums of money may make it possible to retain the services of an unusually competent research investigator, for example, who could form the nucleus for a new and useful center of research. In other cases colleges may be able to strengthen their research programs materially by the purchase of a few hundred dollars worth of needed equipment.

A recent study by H. B. Goodrich and R. H. Knapp of the origins of American Ph. D. degrees in science affirms the importance of the small college as a source of the Nation's scientific manpower. They found that the small liberal arts colleges are the most productive source of students who go on to take advanced scientific training. Of the 50 institutions that turn out the largest proportion of scientists per 1,000 graduates, 39 were small liberal arts colleges. Only three large universities were among this group. Actually, as the authors mention, this comparison is not quite fair to the larger schools. The total number of graduates of small schools receiving doctors' degrees in science is only 25 percent greater than the number from large universites. These studies do point, however, to the desirability of the Foundation's providing support to competent men regardless of the size of the institutions to which they may be attached.

SCIENTIFIC MANPOWER

Robert E. Wilson, Chairman of the Board, Standard Oil Co. (Indiana) and Chairman of the Research Committee of the National Association of Manufacturers, is one of many industrial leaders who have called attention to the present critical shortage in trained scientists and engineers. Mr. Wilson adds that "this shortage is certain to grow more serious over the next few years and to seriously hamper our war effort."

Lawrence P. Lessing writing in *Fortune* carries the thought further: "Billions may be poured into mere brawn and steel, or into mere applied research on weapons, but unless these are animated by a rising stream of basic science and technical brains they will come to nothing."

In closing his article Lessing quotes an editorial from *Chemical and Engineering News:* "The fast approaching bottleneck of too few scientists and technologists can well be the most efficient weapon possessed by Stalin and the Politburo."

Since the training of young scientists is of such crucial importance, the National Science Foundation has determined that a graduate fellowship program should be the first order of business. First emphasis will be given to fellowships rather than scholarships, because the completion of graduate work will have the most immediate effects upon the national supply of trained manpower.

NEED FOR BETTER MANPOWER DATA

Good, current, over-all information on scientific manpower in the United States is urgently needed for sound future planning and especially for mobilization planning.

The National Science Foundation shares the task of compiling better manpower data under the Act which directs it to "maintain a register of scientific and technical personnel and in other ways provide a central clearinghouse for information covering all scientific and technical personnel in the United States, including its Territories and possessions."

The work of the present National Scientific Register now maintained in the Office of Education, Federal Security Agency, is covered in appendix V, p. 29. The National Scientific Register has been supported by the National Security Resources Board. The Foundation is taking over its support in fiscal 1952.

In the case of scientific manpower the same problems of definition arise that are common to other aspects of the Nation's research and development situation. According to the National Research Council, "there is no definition of 'research and development' which is suitable for personnel classification and job assignment and other laboratory administration; and many companies do not know how much they budgeted for scientific research in any year. The question of what—or who—is a research man, is hardly confined to industry, but it becomes almost unanswerable there."

NUMBER OF TRAINED SCIENTISTS AND ENGINEERS

The Research and Development Board estimates that 130,000 engineers and scientists in the United States are engaged in research and development. About 55 percent of these work in industrial laboratories, about 25 percent in universities and nonprofit institutions, and the remaining 20 percent in Federal and State facilities.

Eric A. Walker, former executive secretary, Research and Development Board, reports that the military research budget alone requires 54,000 research scientists and engineers, or 47 percent of the total, in the United States. In 1952 the projected plans of the Defense Department, the Atomic Energy Commission, and the National Advisory Committee for Aeronautics may take up to 70 percent of the research manpower supply.

The extent to which the defense program will continue to drain the national supply of scientific manpower emphasizes the need for the training program in science planned by the National Science Foundation. Not only must defense needs be met and adequate teaching staffs maintained but sufficient personnel must be available to carry on basic research.

SHORTAGES EXIST IN SPECIFIC FIELDS

More or less severe manpower shortages are noted in most scientific and specialized fields. The demand varies from field to field depending upon the degree of mobilization. It also varies between those who have completed their undergraduate training and those at the graduate level. In meteorology, for example, an adequate supply of qualified weather officers seems to be in reserve, whereas the demand for research meteorologists has not been met.

In certain fields the supply is limited by the facilities available for training. The Committee on Specialized Personnel, Office of Defense Mobilization, reports oceanography as an example. In 1950 only three doctorates were awarded in physical oceanography, and the shortage in this field, of special importance to the Navy, cannot be overcome until new training facilities are set up.

In almost every field, the percentage of women holding advanced degrees is very small, usually less than 5 percent of the total. The attrition rate among women scientists is high. Many withdraw from professional life after marriage. However, women graduates provide a potential source of scientific talent that can be utilized more fully.

The demand for scientific personnel for teaching purposes fluctuates to some extent with enrollments. Enrollments are expected to climb after the effect of the low birth rates of the depression years has passed.

Under conditions of cold war economy, the over-all need for trained personnel is perhaps greater than it would be under full-scale mobilization. This results from a "guns *and* butter" economy in which the country attempts to keep the civilian economy as nearly normal as possible, while at the same time it carries the burden of a huge defense program. Under full mobilization much civilian production would be curtailed or suspended, releasing trained personnel for the war effort.

BETTER UTILIZATION OF SCIENTIFIC MANPOWER

The training of new scientists is one answer to the problem. The next most useful step is to utilize to a greater degree the available supply of trained personnel. This means wider distribution of the defense effort to use existing facilities and personnel, not now being fully used.

The National Research Council finds that more than half of the industrial scientists and engineers are located in five States—New York, New Jersey, Pennsylvania, Illinois, and Ohio. California is the only other State having comparable research activities. Following its survey of university research potential, the Engineering College Research Council reports that our defense research in colleges and universities could be increased by more than 60 percent, without reducing the present level of nondefense research.

The director of the Office of Defense Mobilization has called upon all State, county, and municipal governments and private institutions to cooperate in utilizing to the fullest extent possible the entire engineering talent of the Nation. Under this program engineering personnel in noncritical positions will be encouraged to transfer to posts where their services are more urgently needed. Inventories of available personnel are being set up for this program.

The greater use of women will be urged, especially in positions normally filled by draft-eligible males. Competent personnel will be asked to remain on the job beyond the normal age of retirement. Specialized on-the-job training will be given to develop specialized and technical skills at the subprofessional level. Review of jobs often reveals duties that can be performed by clerks and other less highly trained workers, thus freeing a larger portion of the time of scientists and engineers.

The Director of the National Science Foundation is a member of the Scientific Advisory Committee appointed by the President and of the Committee on Specialized Personnel, Defense Manpower Commission, Office of Defense Mobilization. He also consults with the office of the Defense Manpower Administrator, Department of Labor. He is a member of the Interdepartmental Committee on Scientific Research and Development, which is acutely aware of scientific manpower problems of the Federal Government. Through these groups the National Science Foundation participates in the major programs designed to ease the critical shortage of scientific manpower. As its staff and programs develop, the Foundation will be increasingly taking on a greater share of this work.

SCIENTIFIC INFORMATION

In a sense, scientific information is both the beginning and the end product of research. Faced with a new research problem, an investigator normally makes a careful search of the literature to determine what has been done in the field and to make sure that his proposed work has not already been done. On the other hand, the end product of research normally consists of a report of the results.

Scientific progress is cumulative. One individual builds on the findings of other individuals or groups; his work in turn becomes modified or augmented by still others. The faster and more freely information passes from scientist to scientist, the faster science progresses. When this intellectual exchange is hampered, science as a whole declines. Ready exchange of information, then, can be called the circulatory system of a healthy and vigorous scientific body.

Serious problems exist in the dissemination of scientific information both internally in the United States and in obtaining for American scientists the benefit of scientific information developed in foreign countries. Publication of research papers in the learned journals is now subject to delays up to several years. Technical difficulties in abstracting published articles and in distributing abstracts among scientists further delay the proper correlation of research activities throughout the world.

Efficient dissemination of scientific information guarantees against wasted effort. No scientist will knowingly undertake study already adequately covered. His professional standing depends upon his capacity for sound and original work, and he risks that standing by duplicating the work of others. A free flow of information among working scientists provides the best insurance against duplication and overlap in research.

SCIENTIFIC INFORMATION PROBLEMS

Scientists exchange information by publication of their scientific findings and by informal exchange, especially at scientific meetings.

With respect to the publication of information, it is necessary to insure that all worthwhile findings are published and to insure that published materials are readily made available in usable form to scientists needing them.

Here, also, the Foundation must make a thorough survey and analysis of all phases of the production and distribution of scientific literature in the United States. Such a survey will determine:

- In which areas publication facilities are lacking or inadequate.
- Where gaps exist in the major collections of scientific literature and what can be done to close these gaps.
- The factors which contribute to a lag in publication of research results.

The Foundation will also sponsor research to develop new techniques for the quick and economical dissemination of scientific information. This research will be designed to improve existing methods of abstracting information, to study the use of mechanical and electronic means for compiling bibliographies and other reference materials, to encourage more rapid ways of preparing and processing reports and other units of scientific literature, and to design better methods for making these units of scientific literature available to scientists.

APPENDIX I

MEMBERSHIP OF THE NATIONAL SCIENCE BOARD

Terms Expire May 10, 1952

SOPHIE D. ABERLE, Special Research Director, University of New Mexico, Albuquerque, N. M.

ROBERT P. BARNES, Head, Department of Chemistry, Howard University, Washington, D. C.

CHESTER I. BARNARD,* President, Rockefeller Foundation, New York, N. Y.

DETLEV W. BRONK,* *Chairman of the Executive Committee of the Board,* President, The Johns Hopkins University, Baltimore, Md.

GERTY T. CORI, Professor of Biological Chemistry, School of Medicine, Washington University, St. Louis, Mo.

CHARLES DOLLARD, President, Carnegie Corp. of New York, New York, N. Y.

ROBERT F. LOEB,* Bard Professor of Medicine, College of Physicians and Surgeons, Columbia University, New York, N. Y.

ANDREY A. POTTER, Dean of Engineering, Purdue University, Lafayette, Ind.

Terms Expire May 10, 1954

LEE A. DUBRIDGE,* President, California Institute of Technology, Pasadena, Calif.

DONALD H. MCLAUGHLIN, President, Homestake Mining Co., San Francisco, Calif.

GEORGE W. MERCK,[1] President, Merck & Co., New York, N. Y.

JOSEPH C. MORRIS,* Head of Physics Department and Vice President, Tulane University, New Orleans, La.

HAROLD MARSTON MORSE, Professor of Mathematics, The Institute for Advanced Study, Princeton, N. J.

JAMES A. REYNIERS, Director, LOBUND Institute, University of Notre Dame, South Bend, Ind.

ELVIN C. STAKMAN,* Chief, Division of Plant Pathology and Botany, University of Minnesota, St. Paul, Minn.

PATRICK H. YANCEY, S. J., Professor of Biology, Spring Hill College, Spring Hill, Ala.

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*Member of the Executive Committee.

[1] Appointed September 1951 to fill vacancy created by death of Edward L. Moreland, Jackson & Moreland, Boston, Mass.

Terms Expire May 10, 1956

James B. Conant,* *Chairman of the Board,* President, Harvard University, Cambridge, Mass.

John W. Davis, President, West Virginia State College, Institute, W. Va.

Edwin B. Fred,* *Vice Chairman of the Board,* President, University of Wisconsin, Madison, Wis.

Paul M. Gross,* Vice President and Dean of the Graduate School of Arts and Sciences, Duke University, Durham, N. C.

George D. Humphrey, President, The University of Wyoming, Laramie, Wyo.

O. W. Hyman, Dean of Medical School and Vice President, University of Tennessee, Memphis, Tenn.

Frederick A. Middlebush, President, University of Missouri, Columbia, Mo.

Earl P. Stevenson,[2] President, Arthur D. Little, Inc., Cambridge, Mass.

Ex Officio Member

Alan T. Waterman,* Director, National Science Foundation, Washington, D. C.

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*Member of the Executive Committee.

[2] Appointed September 1951 to fill vacancy created by resignation of Charles E. Wilson, director, Office of Defense Mobilization.

APPENDIX II

Principal Staff of the Office of the Director

Director	Alan T. Waterman.
Deputy Director	C. E. Sunderlin.
Assistant Director for:	
Medical Research	John Field (Acting).
Mathematical, Physical, and Engineering Sciences	Paul Klopsteg.
Biological Sciences	John Field.
Scientific Personnel and Education	Harry C. Kelly.
Administration	Wilson F. Harwood.
General Counsel	William A. W. Krebs, Jr.
Chief, Scientific Information Office	Robert Tumbleson.
Comptroller	Charles G. Gant.
Executive Secretary, National Science Board	Lloyd M. Trefethen.

APPENDIX III

FINANCIAL REPORT FOR FISCAL YEAR 1951

In September 1950, the Congress appropriated $225,000 to the Foundation for the fiscal year 1951, ending June 30, 1951, to cover the cost of establishing the Foundation but not for support of program activities authorized in the act. The Foundation obligated $152,951 of the $225,000 appropriated as shown on the table which follows.

OBLIGATIONS INCURRED FOR FISCAL YEAR 1951

Amount appropriated			$225,000
Amounts obligated by the Foundation through June 30, 1951:			
For support of the Interdepartmental Committee on Scientific Research and Development			26,101
For study of the graduate population in colleges and universities			11,440
For operating costs of the Foundation:			
Expenses of the Board:			
Compensation	$8,750		
Travel	10,971		
		$19,721	
Expenses of the Director and Staff:			
Personal services	30,468		
Travel	2,955		
Purchase of equipment	53,840		
Other costs	8,426		
		95,689	
			115,410
Total amount obligated			152,951
Unobligated balance			72,049

Under its act, the Foundation is authorized to receive and use funds donated to it provided such funds are made available without restriction other than that they be used in furtherance of one or more of the general purposes of the Foundation. During fiscal year 1951, the Foundation received a donation in the amount of $512 from the Committee Supporting the Bush Report. These funds have been covered into a trust account established on the books of the Treasury for this purpose. As of June 30, 1951, no disbursements had been made from this account.

APPENDIX IV

INTERDEPARTMENTAL COMMITTEE ON SCIENTIFIC RESEARCH AND DEVELOPMENT

The Interdepartmental Committee on Scientific Research and Development was created by the President (Executive Order 9912, December 12, 1947). It is made up of members from the Department of Agriculture, Interior, Commerce, State, Defense, Army, Navy, Air Force, the Federal Security Agency, the Atomic Energy Commission, the National Advisory Committee for Aeronautics, the Veterans' Administration, the Smithsonian Institution, and the National Science Foundation.

Under the terms of the Executive Order, the Committee is directed to:

1. Recommend steps to make the research and development programs of the Federal Government most effective in the promotion of the national welfare.
2. Study or propose studies and recommend changes in administrative policies and procedures, including personnel policies, designed to increase the efficiency of the Federal research and development program.
3. Study and report upon current policies and Federal administrative practices relating to Federal support for research, such as grants and contracts for basic research.
4. Obtain the advice of persons not employed by the Federal Government with respect to matters of concern to the committee.
5. Encourage collaboration among Federal agencies engaged in related scientific research and development.
6. Propose means by which information relating to the status and results of scientific research ad development undertaken or supported by Federal agencies can be most effectively disseminated.
7. Perform such other duties as shall be prescribed from time to time by the President.

The first chairman of the Committee was Alexander Wetmore, secretary of the Smithsonian Institution. In accordance with the policy for the rotation of personnel recommended by the President's Scientific Research Board in its final report, Wetmore was succeeded by Lawrence R. Hafstad, director of the Reactor Development Division, Atomic Energy Commission, who was appointed in February 1949. The current chairman, appointed January 1, 1951, is Hugh Dryden, director, National Advisory Committee for Aeronautics. Eugene W. Scott has served as executive secretary of the Committee since June 1, 1949.

The Committee during its early meetings decided to take up certain studies of research operations common to, and of major importance to research groups in various Federal departments. To date the Committee has been concerned with problems relating to scientific personnel, selective service, budgetary procedures, grants and research contracts, and scientific information.

Beginning with fiscal year 1951 the National Science Foundation took over support of the Interdepartmental Committee.

APPENDIX V

THE NATIONAL SCIENTIFIC REGISTER

In early 1950, the National Security Resources Board determined that a national register of scientists should be compiled and maintained. As a result the present National Scientific Register was set up as an interim project in the Office of Education, Federal Security Agency, in June 1950. Funds to carry on the initial operation were supplied by the National Security Resources Board. James C. O'Brien was appointed director. The National Science Foundation is supporting the project in fiscal 1952.

The register is concerned primarily with:

1. development of an up-to-date inventory of individual scientists, for use in the event of all-out war;
2. providing the basis for analytical studies of the characteristics of the scientific population for planning purposes;
3. assistance in the development of related research projects in the field of scientific personnel.

No effort has been made to use the Register for placement of personnel but during the current emergency it has proved valuable to the Office of Defense Mobilization in the preparation of estimates of current manpower needs.

To date the National Scientific Register has confined registration to the natural and engineering sciences, and mathematics. The registration program is conducted as a joint effort between the Register and organized science in America, represented by the principal professional and scientific societies and councils. Committees of experts, representing the various sciences, collaborated in developing technical coding and classification structures for these sciences.

In the first year of operation, initial questionnaires have been distributed in the natural and physical sciences, with returns from approximately 150,000 scientists; coding and analysis of questionnaires in the fields of physics and chemistry have been completed; punch-card files in physics and chemistry are ready for use; and plans have been made for obtaining information about members of some branches of engineering.

Statistical analysis of data is done in cooperation with the Bureau of Labor Statistics and other groups. The first volume of findings, *Research and Development Personnel in Industrial Laboratories—1950,* was published in May 1951.

APPENDIX VI

ESTIMATED RESEARCH AND DEVELOPMENT EXPENDITURES IN THE UNITED STATES, 1941–52

[In millions of dollars]

Year	Total	Source of funds		Use of funds by type of institution		
		Other	Federal	Industrial	University	Federal
1941	800	560	240	520	80	200
1942	930	590	340	600	90	240
1943	1, 050	420	630	650	100	300
1944	1, 200	430	770	700	110	390
1945	1, 300	420	880	750	120	430
1946	1, 490	830	660	890	130	470
1947	1, 810	1, 020	790	1, 120	170	520
1948	2, 060	1, 140	920	1, 290	200	570
1949	2, 080	1, 030	1, 050	1, 310	220	550
1950	2, 240	1, 200	1, 040	1, 430	240	570
1951	2, 590	1, 280	1, 310	1, 630	260	700
1952	2, 930	1, 290	1, 640	1, 820	280	830

Source: Research and Development Board, Department of Defense.

APPENDIX VII

FEDERAL EXPENDITURES FOR RESEARCH AND DEVELOPMENT—FISCAL YEARS 1940–50

[In millions of dollars]

	1940	1941	1942	1943	1944	1945	1946	1947	1948	1949	1950
Atomic Energy Commission	....	....	....	....	....	....	....	31. 0	84. 0	111. 0	121. 1
Federal Security Agency: Public Health Service	2. 8	3. 0	3. 2	3. 2	3. 3	3. 4	3. 5	10. 1	19. 6	21. 9	32. 1
National Advisory Committee for Aeronautics	2. 2	2. 6	5. 0	9. 8	18. 4	24. 1	23. 7	26. 5	29. 8	37. 9	42. 5
Office of Scientific Research and Development	....	5. 3	11. 0	52. 2	86. 8	114. 5	36. 8	5. 6	. 9	....	....
Departure of Agriculture	28. 4	27. 5	28. 5	29. 4	30. 5	32. 0	35. 0	37. 3	40. 7	48. 0	50. 6
Department of Commerce	3. 3	3. 1	3. 2	5. 2	5. 2	5. 0	5. 0	4. 3	6. 2	10. 0	10. 0
Department of Defense:											
Department of the Air Force	8. 7	100. 4	83. 8	115. 6	110. 2	136. 0	121. 0	152. 4	187. 3	212. 4	193. 4
Department of the Army	3. 8	18. 7	68. 4	149. 0	161. 3	134. 0	114. 0	93. 6	113. 2	124. 0	108. 8
Department of the Navy	13. 9	24. 6	58. 9	130. 5	176. 6	243. 0	183. 0	269. 3	233. 7	270. 5	237. 4
Total, military functions	(26. 4)	(143. 7)	(211. 1)	(395. 1)	(448. 1)	(513. 0)	(418. 0)	(515. 3)	(534. 2)	(606. 9)	(539. 6)
Department of the Interior	7. 9	9. 5	13. 5	17. 0	20. 7	18. 0	17. 0	16. 5	19. 1	28. 3	27. 7
Other agencies	2. 4	2. 4	3. 4	12. 2	32. 6	20. 0	11. 0	9. 9	27. 5	29. 7	16. 0
Total, comparable items	73. 4	197. 1	278. 9	524. 1	645. 6	730. 0	550. 0	656. 5	762. 0	893. 7	839. 6
Indirect costs, all agencies[1]	(*)	(*)	(*)	(*)	(*)	(*)	(*)	(*)	158. 4	161. 8	199. 7
Construction of facilities, all agencies	(*)	(*)	(*)	(*)	(*)	(*)	(*)	53. 7	62. 0	115. 9	149. 6
Manhattan Engineer District, total expenditures	....	....	....	77. 0	730. 0	859. 0	366. 0	186. 0	....	....	....
Grand total	(*)	(*)	(*)	(*)	(*)	(*)	(*)	(*)	982. 4	1, 171. 4	1, 188. 9

Source: Bureau of the Budget.

[1] Indirect costs for Department of Defense are included only in part.

*Not available.

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