plies education. The war proved the necessity of a population with a good scientific background, from the research scientist to the operator of scientific equipment in the field. We learned many new methods and developed many teaching aids which should be used in our peacetime education. Our continued interest in the field of education is basic to the advancement of science.

At one time many scientists looked to European schools for their postgraduate study. Postgraduate study for research workers, educators, and all scientists who work in creative fields is a necessity. Since many of the past foreign facilities are no longer open to us, I would like to point out a new approach. Let us look to the research laboratories of industries, privately endowed institutions, government, and schools for our future postgraduate work. The shops, the mines, the hospitals, and the hundreds of progressive organizations in our own country offer unlimited possibilities for advanced study. The exchange of men between the various activities of our economy will do much to advance science.

The Universe, including our earth and most of biology, was here and working long before man was here or conscious of the world around him. Science to me is the process by which we can, by cooperation, work to understand the process of Nature. The scientists should be open-minded students sitting in the great classrooms of Nature, listening to her lectures, and using this information to benefit their fellow men. We are still in the kindergarten and should not let our present accomplishments prevent us from seeing how little we really do know and what great opportunities there are for advancement. Here is a limitless field. How can we best use it?

A National Science Foundation?

Philip N. Powers

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A CONTROVERSY DEVELOPED AROUND science legislative proposals in the last Congress—a controversy which remained unresolved in spite of compromise and which eventually blocked, for better or for worse, the passage of any of the rival proposals for the Federal support of science. Since then, decisions of a sort have been made on most of the issues originally at stake, and it seems time to take stock of those decisions, to give objective consideration to their wisdom, and to make necessary and appropriate recommendations to the new Congress.

The main issues at stake were:

(1) Shall we have Federal subsidy of basic research?

(2) Shall we have Federal scholarships and fellowships as a means of developing scientific talent?

(3) Granting the need for a National Science Foundation to do these things, shall it be administered by a part-time Board or a single administrator?

(4) Shall this proposed Foundation be asked to coordinate all federally-supported research?

(5) Shall private profit be allowed from patents on discoveries made with public funds?

(6) Shall support be given to basic research in the social as well as the natural sciences?

With the passage of time, these issues are being partially resolved in one way or another as follows:

(1) We now *have* Federal subsidy of basic research on a fairly large scale through the Office of Naval Research in the Navy Department, as well as several of the Bureaus, and through various organizations within the War Department.

(2) We *do not have* Federal scholarships and fellowships (except in a few isolated instances).

(3) The Federal support of basic research is being *administered* by Naval officers, by Army officers, and on a smaller scale by officials in other branches of the Government.

(4) The *coordination* of all research supported by the Army and Navy is to be achieved through a newly-established Joint Army and Navy Research and Development Board under the chairmanship of Vannevar Bush.

(5) There are *no restrictions on patents* of discoveries made while using naval funds except to reserve to the Government a free, nonexclusive license. The policy of the Army is not so clear, but tends to be more restrictive.

(6) Financial support *is being given* for basic research in social as well as natural science.

These issues have given rise to new issues which will again be resolved in one way or another. The important question is whether they will be resolved on the basis of considered opinions of scientists, educators, and others, or whether the whole matter will simply be

[1] The views expressed in this article are personal and not official.

left to resolve itself or perhaps be left to the Army and the Navy to decide in the way that seems best to them.

This present state of affairs cannot be fully understood without giving some consideration to recent events and the conflicting interests which were evident. In chronological order, the outstanding developments during the last two years are believed to be as follows:

November 1944

President Roosevelt addressed four questions to Vannevar Bush relating to: (a) making wartime developments in science known to the world, (b) continuing the "war of science against disease," (c) Federal aid for research activities in public and private organizations, and (d) the discovery and development of scientific talent.

July 1945

Having received the reports of four separate committees, each appointed to study one of the questions, Dr. Bush replied to the President with his now famous report entitled "Science, the Endless Frontier."

Senator Warren Magnuson, of Washington, introduced into the Senate a bill (S. 1285) embodying the principal recommendations of the Bush Report: a part-time Board of scientists to administer a program for the support of basic research in the natural sciences, including medicine, and for the grant of scholarships and fellowships.

Senator Harley Kilgore offered a rival bill (S. 1297), which agreed in (a) its support for basic research in the natural sciences, and in (b) provisions for scholarships and fellowships, but disagreed in its provisions for (c) a single administrator instead of a part-time Board, (d) the coordination of all Federal research, (e) restricting patents on discoveries made with government funds, and (f) the inclusion of the social sciences.[2]

September

In the President's message to Congress, the basic policies of the Kilgore Bill were endorsed.

October–November

Hearings were held before a Subcommittee of the Senate Committee on Military Affairs. Approximately 100 witnesses testified in favor of:[3]

(1) A National Science Foundation	99%
(2) Scholarships and Fellowships	100%[4]
(3) Administration by a	
(a) Single administrator	23%
(b) Some type of board	37%
(4) (a) Some sort of coordination of all Federal research, as opposed to	21%
(b) No coordination	1%
(5) Patent provisions being	
(a) Included	24%
(b) Excluded	23%
(6) The social sciences being	
(a) Included	45%
(b) Excluded, but supported by some other agency	9%

[2] This latter provision did not appear in the original Kilgore Bill but was introduced in a revised version in October 1945.

[3] See "Analytical Summary of Testimony," given in Subcommittee Monograph No. 5 in December 1945. The complete testimony occupies 1,210 pages in a series of six interesting documents entitled, "Hearings on Science Legislation (S. 1297 and Related Bills)," Government Printing Office, 1946.

[4] In the "Analytical Summary of Testimony" it merely states: "The witnesses agreed that there should be a Government financial-aid program for the development of scientific talent," and "There was indeed no opposition."

November

Dr. Isaiah Bowman wrote to President Truman in behalf of the "Committee Supporting the Bush Report."

December

President Truman replied to Dr. Bowman, reaffirming his views as expressed to Congress in September.

On the basis of the testimony, a revised bill, S. 1720, was introduced by Senator Kilgore and others. The Board was strengthened, the patent phraseology was modified, the social sciences were still included, and provisions for a register of scientific and technical personnel and for international cooperation were added.

Under the leadership of H. C. Urey and Harlow Shapley, a "Committee for a National Science Foundation" was formed and issued a statement generally endorsing S. 1720, though not naming it specifically.

January 1946

Senators Thomas, Kilgore, and Magnuson discussed controversial issues with Drs. Bush and Bowman in an effort to revise S. 1720 so that it would be acceptable to all concerned.

February

Under the leadership of Senator Saltonstall, representatives of the Committee Supporting the Bush Report, the Committee for a National Science Foundation, and the American Association for the Advancement of Science met with Senators Kilgore and Magnuson and reached complete accord on a new bill.

This compromise bill, S. 1850, was introduced on 21 February by Senators Kilgore, Magnuson, Johnson, Pepper, Fulbright, Saltonstall, Thomas, and Ferguson.

March

S. 1850 was favorably reported out of the Military Affairs Committee.

April

The Committee Supporting the Bush Report endorsed S. 1850 in a letter to the President and the Congress.

The Council of the AAAS endorsed S. 1850 by a vote of 230 to 10. In behalf of the AAAS, its president, James B. Conant, requested Senators to support S. 1850.

The National Association of Manufacturers announced its opposition to S. 1850.

May

Rep. Wilbur D. Mills introduced H.R. 6448, a bill to establish a Science Foundation along the lines of the original Magnuson Bill. This bill was referred to the Subcommittee on Public Health of the Interstate and Foreign Commerce Committee. Hearings were arranged without inviting or notifying representatives of the Committee for a National Science Foundation or the AAAS. Among those who learned of the hearings and testified in favor of the Mills Bill were representatives of the National Association of Manufacturers, the Committee Supporting the Bush Report, and Dr. Bush.

June

A statement endorsing S. 1850, over the signatures of James B. Conant, George F. Zook, Morris Fishbein, Thomas P. Cooper, Isaiah Bowman, Boris Bakhmeteff, Arthur A. Hauck, Willard A. Givens, and Harlow Shap-

ley, was printed in the *Congressional Record* on 25 June (p. A3929).

July

With its social science provisions stricken from it, S. 1850 passed the Senate by a vote of 48 to 18 and was referred to the House. It died in the Interstate and Foreign Commerce Committee.

The above facts suggest that a National Science Foundation might have been established if there had been sufficient unanimity of opinion among scientists. The breakdown of the compromise agreement, as evidenced by the introduction of, and support for, the Mills Bill, appears to have been an insuperable stumbling block to the passage of any bill. It therefore seems safe to say that in the future *there will be no Science Foundation of any sort without the wholehearted backing of all major groups of scientists.*

There have been some other significant events which help to determine the present state of affairs:

In May 1946 a bill was introduced into the House "To establish an Office of Naval Research. . . .; to plan, foster, and encourage scientific research. . . .; to provide within the Department of the Navy a single office, which, by contract and otherwise, shall . . . obtain, coordinate, and make available to . . . the Navy, world-wide scientific information and the necessary services for conducting specialized and imaginative research; to establish a Naval Research Advisory Committee. . . ." This bill was subsequently passed and, when signed by the President in August, became Public Law 588. Vice Admiral Harold G. Bowen, who had been Chief of the Office of Research and Inventions since its establishment by the Secretary of the Navy in May 1945, now became the first Chief of Naval Research. On 1 November he was retired and was succeeded by Rear Admiral Paul F. Lee.

In May 1946, as part of a War Department reorganization, a new division of the General Staff, G-6, was created to have "primary War Department interest in the application of national scientific resources to the solution of military problems," to advise the Secretary of War and the Chief of Staff on "all War Department matters relating to research and development," to have "over-all War Department responsibility for the initiation, allocation, coordination, and progress of research and development programs," and for other purposes. Maj. Gen. H. S. Aurand was appointed Director of Research and Development.

For the support of *basic* research in universities and industrial laboratories this year, the Office of Naval Research, together with the Naval Bureaus of Aeronautics, Ordnance, and Ships, have about $70,000,000, and the War Department has about the same amount.[5] These figures may be compared with the estimates in the Bush Report for the expenditures of a National Science Foundation during the first year and increasing to a stable level at about the fifth year:

Activity	Millions of dollars	
	First year	Fifth year
Division of Medical Research	$ 5.0	$ 20.0
Division of Natural Sciences	10.0	50.0
Division of National Defense	10.0	20.0
Division of Scientific Personnel and Education	7.0	29.0
Division of Publications and Scientific Collaboration	.5	1.0
Administration	1.0	2.5
	33.5	122.5

From "Science, the Endless Frontier," by Vannevar Bush (p. 33).

Finally, in October, the President established by Executive Order a Scientific Research Board under the chairmanship of Reconversion Director John R. Steelman and composed of the Secretaries of Agriculture, Commerce, Interior, Navy, and War, the Federal Loan, Federal Security, and Federal Works Administrators, the chairmen of the Federal Communications Commission, the Tennessee Valley Authority, the National Advisory Committee for Aeronautics, and the director of the Office of Scientific Research and Development. The Reconversion Director is directed to prepare a report of "(1) his findings with respect to the Federal research program and his recommendations for providing coordination and improved efficiency therein; and (2) his findings with respect to non-Federal research, development and training activities, a statement of the interrelationship of Federal and non-Federal research and development, and his recommendations for planning, administering and staffing Federal research programs to insure that the scientific personnel, training and research facilities of the Nation are used most effectively in the national interest."[6] It is to be noted that this Board has no function except to gather facts and report them to the President.

Coming back now to some of the original purposes of the proposed legislation, it is clear that, although the basic issues remain, new questions have come into focus and must be examined.

The Discovery and Development of Scientific Talent

In a sense, this is the central problem, for without

[5] Figures gathered by the Bureau of the Budget show that for all government research and development work (excluding the Manhattan Engineer District and research in social science) there was appropriated for this fiscal year approximately $712,000,000. This includes about $272,000,000 for the Navy Department and $327,000,000 for the War Department. Carried over from last year, but also available, there was $316,000,000 for the Navy, [illegible],000,000 for the Army, and $67,000,000 for the rest of the Federal Government. Much of this year's appropriation will, of course, not be spent this year, but merely be obligated for expenditure another year.

[6] Executive Order 9791, 17 October 1946.

adequately trained personnel resources, no amount of funds from the Government or from any other source will produce progress in science. On the other hand, well-trained scientists, with an urge to seek new knowledge, will work on in spite of serious handicaps resulting from lack of equipment and funds. This is not to suggest that the equipment is not needed—on the contrary, essential equipment is becoming more elaborate than ever—but it is to point out that the essential ingredient of scientific work is the highly trained human mind.

During and since the war, American policy has tended to ignore this fact. Scientific brainpower has been exploited without regard to its replenishment. We are now faced with an unprecedented scarcity of scientific personnel—the inevitable result of our failure to continue the education of scientists during the war, and this in the face of a rapidly increasing demand for scientific work.

The discovery and development of scientific talent involves not only the problem of demand far exceeding supply but also the over-all status, in quality and diversity of qualifications as well as quantity, of the Nation's scientific manpower resources. We need to know how these resources are presently utilized and the prospect for their continuous development and improvement. It is to be hoped that Steelman's new Scientific Research Board will soon provide much of this information. The magnitude of the problem of discovering and developing scientific talent will then be more clear.

In the Bush Report, the Moe Committee[7] calculated that the normal prewar flow of scientists cannot possibly be regained before 1955 and that during this period an accumulated deficit of at least 16,000 scientists with Doctors' degrees is inevitable. They also reported that in the past the selection of students entering colleges and universities has been primarily on the basis of economic status and not on the basis of talent. It seemed clear that the majority of our ablest high school graduates have been denied college training because of lack of funds and have therefore had no opportunity to become scientists or, for that matter, to enter any of the other professions.

More recently, a committee of the Society for the Promotion of Engineering Education has reported[8] on "The Outlook in the Demands for and Supply of Engineering Graduates." Considering engineers only, their most optimistic figures indicate a cumulative deficit increasing from 25,500 this year to 37,805 in 1949 and then decreasing until the deficit vanishes in 1952.

The need for Federal scholarships and fellowships as well as for other means of developing scientific talent is evidently clear and well established. When testifying on the Kilgore and Magnuson Bills, James B. Conant stated that "those sections which deal with scholarships and fellowships . . . are by far the most important parts of the bill . . . for there is no use considering ways and means of spending money on research unless first-rate men are available to do the work."

With the failure of S. 1850, we still have no organized program in this country for the development of scientific talent. To be sure, there are a few scholarships and fellowships available from private sources, but there are not enough of them. The G. I. Bill will help, but it remains to be seen whether a significant contribution to the development of scientific talent will result. It must be remembered that the training of a scientist to do original work usually requires at least six or seven years.

Our program for the national defense is already handicapped by the shortage of scientists. This is a matter of deep concern to leaders within the Army and Navy who have been given ambitious assignments for the development of novel weapons. Because of this concern, in other parts of the Government as well as in Army and Navy, much-needed programs[9, 10] are under way for improving the employment status of scientists in the Government. The Government hopes thereby to compete more successfully for the ablest available scientists.

As a means of encouraging the development of scientific talent, the Office of Naval Research is also sponsoring an incentive program among high school students. In cooperation with Science Service, outstanding boys interested in the sciences are selected and rewarded with cruises on Navy ships and planes. They are given every opportunity to see the results of scientific research as applied, developed, and used by the Navy. No special effort is made to interest them in the Navy, but every effort is made to stimulate and maintain their interest and enthusiasm in scientific pursuits.

The Army and Navy have no authority to grant the scholarships and fellowships[11] which are needed, but

[7] To assist in answering President Roosevelt's question, "Can an effective program be proposed for discovering and developing scientific talent in American youth so that the continuing future of scientific research in this country may be assured on a level comparable to what has been done during the war?" Dr. Bush appointed a committee under the chairmanship of Henry Allen Moe, secretary-general of the John Simon Guggenheim Memorial Foundation.

[8] In *Journal of Engineering Education*, September 1946, p. 25.

[9] See M. H. Trytten on "The Advisory Committee on Scientific Personnel," *Science*, 1946, **103**, 437.

[10] See Philip N. Powers on "The Science Training Group in the Washington Area," *Science*, 1946, **104**, 477.

[11] Some of the research contracts with universities have indirectly provided the equivalent of fellowships, however.

it is of interest to note the recently announced Holloway Plan. Financial support is provided for superior college students, enrolling in any one of a large number of selected colleges, who wish to become naval officers. There are sufficient funds available on a competitive basis so that approximately the top 5 per cent of the Nation's high school graduates now have an opportunity to receive tuition plus $50 per month while in college and then become regular naval officers for at least one and a half to three years. This is an excellent way to ensure the quality of our future Navy, but it makes it more than ever essential that, for this same top 5 per cent, *similar opportunities to go to college be offered to those who prefer to enter the scientific as well as the other professions.*

Federal Support for Basic Research

American science can take little pride in its past performance of basic research.[12] We have, to be sure, been pre-eminent in the application of fundamental knowledge to practical problems, but a large proportion of the original discoveries were made abroad. The numbers of Nobel prizes awarded in this country compared with those awarded abroad offer some indication of the extent to which we have been dependent on foreign scientists for the discovery of fundamental knowledge. In the fields of physics, chemistry, medicine, and physiology the ratio is approximately 1 to 6. Were it not for the internationalism of science, our American science might have been badly off indeed.

During the war years, very little basic research was done anywhere. Instead, there has been extensive exploitation of fundamental knowledge gained before the war. Scientific work has been out of balance and will become increasingly hampered unless the flow of fundamental knowledge is resumed. This is a challenge to American science to see whether it has sufficiently matured to assume its proper role in the world. There are indications that this is not yet to be the case, but we have an unprecedented opportunity. Many of the outstanding European scientists have come to this country, and we are one of the few countries having the wealth to provide the elaborate equipment frequently needed for atomic age research.

The need for encouragement of basic research was one of the primary inspirations of S. 1850. But there was some disagreement about the desirability of asking the Government to provide such encouragement, and considerable dispute about how public funds for basic research should be administered.

While this dispute was going on, the Army and the Navy, well aware of the necessity for the support of basic research to preserve national security, embarked on programs of their own without waiting for the establishment of a National Science Foundation. The Navy took the lead with its Office of Research and Inventions and its request for legislation for a permanent Office of Naval Research. As a consequence, we have large-scale Federal Support for basic research after all, and we may ask how it is working out.

Shall we be thankful that the military stepped in to do a job that we have been otherwise unable to accomplish? Is the job being done in a way which can be wholeheartedly endorsed and approved by American scientists? How have last year's disputes over administration, patents, and social sciences been resolved? To attempt full answers to these questions would be to anticipate the report of the Steelman Scientific Research Board without the necessary facts to do so. It is highly appropriate to comment at this point, however, that the administration of funds through the Office of Naval Research has thus far been widely acclaimed. The Navy has exhibited a remarkably clear understanding of the necessity for freedom of scientific research. For example, Capt. R. D. Conrad, director of ONR's Planning Division, recently remarked:[13] "It is the responsibility of all of us to be vigilant that Government aid to research shall be in the true spirit of science, whether the funds are administered by the present Government Departments or by a National Science Foundation of the future."

There are other questions: *Should Congress establish within the War Department a counterpart to the Office of Naval Research? Assuming that funds are being administered "in the true spirit of science," can we expect this state of affairs to continue? Is it proper for military funds to be used for research which has no specific military objective?* With respect to the last question, Capt. Conrad also stated: "The responsibilities of the Navy for the national security justify the expenditure of naval funds for [basic] research. . . ."; and on another occasion:[14] "It will be a long time before a National Science Foundation can be enacted into law, staffed, supplied with funds and opened for business. In this critical interval, the Armed Services are providing the support so essential to science." Also, Capt. M. J. Lawrence, the Assistant Chief of ONR, stated:[15] "The Navy is in favor of the proposed National Science Foundation and we feel that if and when such an agency is set up it will certainly take over some of the [basic research] programs now being sponsored by us."

[12] See K. T. Compton on "Science and National Policy," *Scientific Monthly*, August 1946, p. 125.

[13] Navy Day address at the University of Illinois, 27 October 1946.

[14] In an address read for Capt. Conrad by Cdr. P. K. Wells before the Commonwealth Club of California in San Francisco on 6 December 1946.

[15] Before the Indiana Academy of Science in Terre Haute on 18 October 1946.

For the time being, American science is apparently receiving more support for basic research than ever before. We have part of a National Science Foundation after all, and we are gaining experience[16] which will be invaluable in further planning for a permanent Foundation. At this point it must be remembered, however, that the easiest thing for Congress to do is nothing. The Army, as well as the Navy, has officially[17] supported a National Science Foundation, and if scientists, educators, and others throughout the country fail to support this view, thereby failing to assume responsibility for encouraging the promotion of science for peaceful purposes, then there is another question to be faced: *Is the primary end of free American science to be the national defense—free because of the necessity of fundamental discoveries leading to novel weapons of war?*

[16] For example, with admittedly less than a year's experience in contracting for basic research, the Office of Naval Research has not had a single patentable discovery brought to its attention. This suggests that last year's controversy over patents was all out of proportion to its importance. Indeed, this is not surprising because the fundamental knowledge resulting from basic research is rarely patentable.

[17] Except for the patent provisions, S. 1850 was supported by the War and Navy Departments in letters to the Chairman of the Senate Committee on Military Affairs during April 1946.

Technical Papers

The Role of the Liver in Guanidoacetic Acid Metabolism in Man

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The experimental production of pathologic changes in the liver of rats, rabbits, and dogs by the restriction of dietary methyl (*1*) groups suggests that a study of methylation processes in patients with cirrhosis may yield information of value. Najjar, *et al.* (*7*) claim that there is a reduction of the excretion of N^1 methylnicotinamide (F2) in patients with liver disease after the administration of nicotinamide. However, Perlzweig and Huff (*8*) have shown that the excretion of F2 is the resultant of two or more metabolic reactions involving nicotinamide, methylation, and the conversion of F2 to products the natures of which are unknown. McKibbin, *et al.* (*6*) were unable to demonstrate decreased excretion of F2 in dogs after the production of fatty livers by a choline-free diet.

It is probable that this problem could be approached more directly by studying the methylation of guanidoacetic acid to creatine. It is now presumed that guanidoacetic acid is synthesized in the kidney from arginine and glycine (*2, 3*), and that its methylation to creatine occurs in the liver with methionine, or with the system of choline + homocystine (*5*) acting as methyl donors. Creatinine containing a deuteriomethyl group has been isolated from normal human urine after the administration of methionine containing a deuteriomethyl group (*9*).

From the observations of Block and Schoenheimer (*2*) the conclusion is drawn that approximately 2 per cent of the creatine depot of the rat undergoes daily turnover. This value corresponds well with the amount of creatinine excreted in the urine per day. It was also demonstrated that, as far as is known, there is but a single pathway in the metabolism of guanidoacetic acid, namely, its conversion to creatine and thence to creatinine. Therefore, if it is assumed that in man the amount of creatinine excreted daily is replaced in the body by an equimolar amount of creatine, synthesized from equimolar amounts of guanidoacetic acid and methyl groups, a quantitative estimation of the urinary excretion of guanidoacetic acid and total creatinine should be informative in determining the extent of this transmethylation reaction. This process has the significant advantage that the transformation of guanidoacetic acid to creatine normally reaches 95 per cent of completion in man, *i.e.* the amount of guanidoacetic acid in the urine is equal to approximately 5 per cent of the sum of the total amount of creatinine + guanidoacetic acid (see below). Therefore, small deficiencies in the conversion of guanidoacetic acid to creatine should be reflected by relatively large increases in the excretion of guanidoacetic acid in the urine.

We have found in 15 determinations (*4*) on 8 men that the ratio $\frac{\text{mg. guanidoacetic acid}}{\text{mg. total creatinine + guanidoacetic acid mg.}}$ (guanidoacetic acid index) in the urine of normal male adults on an unrestricted diet is in the range 0.03–0.05, with an average value of 0.043 + 0.006. The excretion of guanidoacetic acid by the normal female

[1] The authors are very grateful for the aid given by Mrs. Gloria K. Peacock.