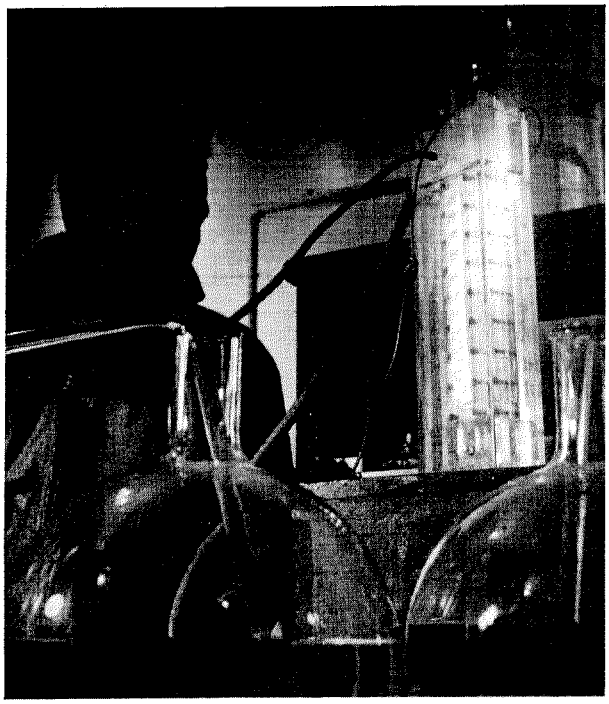

An invitation—and a warning—to private industry to come to the aid of basic research.

by LINUS PAULING

Chemistry and the World of Today

WHAT can I say under the title "Chemistry and the World of Today?" I can say anything, discuss any feature of modern life, because every aspect of the world today—even politics and international relations—is affected by chemistry.

Everyone has experienced in his daily life the effects of the discovery and development of a new fiber, nylon. We all have seen the revolution that has taken place in medical treatment through the discovery and extensive use of penicillin and other powerful antibiotics. During the last decade the world has been changed in a very significant way by the atomic bomb, which was constructed through the joint efforts of physicists, chemists, and engineers.

Only recently, during the war years, when we began using up in practical applications our backlog of new basic discoveries, did it become clear to me that, although all scientists make their contributions to scientific progress, modern life is really based on *fundamental science,* on *pure research,* and that the nature of the world today has been determined, and the nature of the world of the future will be determined, by the work, and especially the ideas, the imagination, of a small number of people—the "impractical scientists," mainly university professors, who strive to add to our body of knowledge in every way, rather than to solve certain practical problems that obviously need solution.

I am not minimizing the importance of developmental research and of industrial application of new discoveries; but am instead pointing out that the direction in which progress occurs is in fact determined by the basic discoveries that are made, and that accordingly it is the progress of pure science that determines what the nature of the world will be a generation later.

It is clear that the synthesis of nylon resulted from the early researches on the structure of natural fibres, and that the application of penicillin in medicine would have been impossible except for the original, accidental discovery of penicillin, by Professor Fleming. The clearest example of the determinative part that is played by research in pure science is probably that of the controlled release of atomic energy.

There has, of course, been a tendency to attribute to the physicists alone the development of atomic bombs and atomic power plants, but it is my feeling that chemistry should have a large part of the credit. For example, neptunium, the first of the trans-uranium elements to be discovered, was discovered by Professor Edwin McMillan and Dr. P. H. Abelson. Although Edwin McMillan is professor of physics at the University of

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California, his first research was carried out in chemistry, under my direction, and I have a strong feeling that his work along these lines has been strikingly effective because he has a sound knowledge of chemistry as well as physics.

Let us consider the steps that were involved in the development of this new part of our civilization, the manufacture of atomic bombs and production of power from the atomic nucleus. First, there was the discovery of something really new, both the observation of new natural phenomena and the inspiration of new ideas. Becquerel observed that a rock (containing radium, as was found later) could fog a photographic plate through black paper. Einstein, just *thinking* about the nature of the physical world, saw with the inner vision of his great intellect that a simplified picture of the world could be formulated, and that this picture led to the conclusion that matter and energy are interrelated: scientists then knew how great the amount of energy was that could be released by the destruction of matter. The positron was discovered, by Carl Anderson, who wasn't looking for it. The neutron was discovered. The phenomenon of the fission of atomic nuclei was discovered. The transuranium elements were discovered.

All of this foundation for the development of the atomic bomb and atomic power plants is a part of fundamental research—the search for unpredictable results, the effort to add to man's body of knowledge in any significant way. Becquerel could not lay plans to discover radioactivity—no one in the world had had imagination wild enough, bold enough, to predict or suspect that atoms could explode. Nobody, not even Einstein himself, could *plan* to discover the theory of relativity. No bank would have lent money to Chadwick to subsidize his search for the neutron—twenty years ago investment in atomic energy would have been called a preposterous idea by everybody. But it is these basic discoveries that determined the direction in which developmental research and subsequent practical application could be carried out.

A Monopoly of the Universities

Fundamental research is carried out almost entirely in universities, by university professors, and to a smaller extent in private or governmental laboratories and, as a minor activity, in industrial laboratories. It is carried out by men and women whose temperament, ability, and training are such as to fit them for this unusual activity—that of looking for new knowledge without concern about its immediate use in the solution of practical problems—and the environment in universities seems to be especially well suited to this activity.

I believe that we all recognize that progress will cease unless new fundamental discoveries are made, and that the rate of progress is determined by the amount of fundamental research that is carried on. Two years ago the President's Committee on Scientific Research emphasized the importance for the security and welfare of the nation of carrying on basic scientific research on an expanded scale. The recommendation was made that a National Science Foundation be established, and that federal funds amounting to 250 million dollars per year by 1957 be appropriated for the support of basic scientific research, *mainly in the universities of the nation.*

Three years ago, in delivering the first Remsen Memorial Lecture, the distinguished Chairman of the Board of Directors of the American Chemical Society, Professor Roger Adams, discussed the importance of federal support *and* scientific research. He mentioned that there was controversy about the nature of the administration of the proposed Science Foundation—that the Kilgore Bill presented a plan for a politically controlled organization, and the Magnuson Bill proposed that the control and distribution of funds be *left in the hands of the* scientists. He mentioned the compromise bill that was under discussion—but let me quote from his talk:

"Even though the organization of the proposed National Research Foundation under the compromise bill resembles that which Hitler decreed for the Kaiser Wilhelm Geseleschaft after 26 years of extraordinarily successful operation by scientists, American scientists are supporting the bill as probably the best to be hoped for with our democratic government. They recognize that the necessity of a foundation in this country to support scientific research and the training of scientists is of utmost importance to the health, security, and welfare of the nation. They have faith that the present President of the United States or a successor will not allow political influences to prejudice his appointments or decisions.

The British and Russian Systems

"In Great Britain, the government allocates a liberal amount of money for scientific research and development. These funds are administered by a small committee of distinguished scientists with full authority to distribute them to the best of their ability for the benefit of science and the British people.

"In Russia, all reports emanating from that country are to the effect that the government is supporting a very extensive program in fundamental research. But the Russian scientists have their troubles. A few quotations from an address by P. L. Kapitza, the world-renowned Russian physicist and engineer, delivered before the Soviet Academy of Sciences in 1943 on 'The Institute of Physics' of which he is the director, deserve repeating.

"He said: 'The organization of *science in our country* must be more systematic and conscious of its aims than it is in capitalistic countries where it is rather left to chance and has a spontaneous character.' *His institute* had a complicated financial system which he strenuously opposed and which was finally changed. He stated: 'In my debates with officials of the Commissariat of Finance on their so-called "schematic system" of accounting, I wrote them the following: "When you look at a painting of Rembrandt, are you interested in the question how much Rembrandt paid for his brushes and canvas? Why, when you consider a scientific job, do you want to know the cost of apparatus or the material used in it?" If a scientific job has produced considerable results, its value is not comparable with the material expenditure on it. The money cost of scientific work is not comparable with its cultural value. I asked, "How much would the Peoples' Commissariat for Finance have considered allotting to Isaac Newton for his work which led to the discovery of gravity?" The Commissariat objected tirelessly. Our discussions went on for over six months and I think I could not have won unless the Council of Commissars had come to my aid.' In commenting on these statements *the director of another* Russian institute remarked, 'An everlasting war has to be waged with "bookkeeping."' It appears that the accounting systems required by the Russian and United States governments are not far different. . . .

"Progress in applied science depends upon advances in fundamental science. The power of science in the United States will be no more effective than the quality of our teachers and students who create the background for future industrial discoveries. Once again I quote

In the absence of a National Science Foundation, research like Prof. Badger's studies of molecular spectroscopy related to molecular structure is subsidized by Navy.

Kapitza who pleaded for recognition of fundamental science and its importance—he said, 'We, however, are often apt to judge scientific achievements only by their practical results and consequently it appears as if the person who picked the apple had done the main job, while in actual fact, the apple was created by the person who planted the tree.'

"The strength of a country has depended in the past on its possessions—in earlier days on land, its control of transportation and waterways, or its supply of raw materials, but today a nation's strength will lie largely in the quality of its science and scientists. Government must support the work of scientists but not control it in such a way as to hamper development or to direct it into military channels. . . ."

Now it is 1949. Three years have gone by since Professor Adams delivered this Remsen address, four years since the National Science Foundation was strongly recommended to the President in the Bush Report, two years since the recommendation was repeated, still more strongly, in the Steelman Report—and there is still no National Science Foundation. Can we say that the members of the Congress alone are to blame for this situation? Are not we ourselves, the members of the American Chemical Society, also to be blamed? Should we not have done something more than to send a representative to a hearing of a Congressional committee, to send a letter or two written by the Board of Directors? I myself feel that we *should* have done something more, and that we should now do something more, in order to make clear to the people of the nation that the scientists themselves believe the statements that they make about the importance of basic research.

The objection might be raised that it is not proper for the American Chemical Society to take part in political activities. I do not believe that this objection is a valid one.

It seems to me that under our Charter we have not only the right but the duty to educate the people of the nation, including the members of the Congress, about the questions that are discussed in the Bush Report and the Steelman Report. The American Medical Association, in some respects a sister organization to the American Chemical Society, is now taking a vigorous part in the discussion of the federal compulsory health insurance plan proposed by Federal Security Administrator Oscar Ewing and endorsed by the President of the United States.

President Truman, in his message to the Congress on January 5, said "We must spare no effort to raise the general level of health in this country. In a nation as rich as ours it is a shocking fact that tens of millions lack adequate medical care. We are short of doctors, hospitals, and nurses. We must remedy these shortages. Moreover, we need, and we must have without further delay, a system of prepaid medical insurance which will enable every American to afford good medical care."

The American Medical Association's campaign against this proposal involves a program of public education to promote advancement of health under our present voluntary system. The program of public education is costing several million dollars, raised by assessments of $25 per man on the membership of the AMA.

Clem Whitaker, one of the two publicists who are the directors of the National Education Campaign of the American Medical Association, has described the purpose of the campaign in the following way: "American medicine, in its campaign against compulsory health insurance, cannot afford to fight alone. This must be a campaign to arouse and alert the American people in every walk of life, until it generates a great public crusade and a fundamental fight for freedom. We need the help of every American who honestly believes in the American way of life—and our campaign must be geared to get that help. Any other plan of action, in view of the drift toward socialism and despotism all over the world, would invite disaster."

In mentioning the American Medical Association and its National Education Campaign I hope that I do not give the impression that I myself am sympathetic to its aims. As an individual, I feel that a system of socialized medicine in the United States may well be desirable, and that at any rate it needs serious consideration. I find it difficult to understand why this nation, which prides itself on being the richest nation in the world, should be inferior to Sweden and other small nations in the standards of health and medical care of its people.

Call to Action

However, that is aside from the point. What I want to emphasize is that the American Medical Association is taking significant action on a question relating to federal legislation, and that there is, in my opinion, no reason why the American Chemical Society should not put on a strong program of public education about the overwhelming importance of federal support of scientific research, as advocated in the Bush Report and the Steelman Report.

It is true that there is danger in having basic scientific research in our universities supported exclusively or predominantly by the Federal Government—the danger of bureaucratic control of the universities and of scientific research. In the absence of a National Science Foundation, the Public Health Service and the Armed Forces, especially the Department of the Navy, have been subsidizing pure research in our universities, because of the recognition of the very great need of the nation for work in this field. Many scientists, such as President DuBridge of the California Institute of Technology, have recognized the danger in predominant support of research by the Armed Forces. A similar danger would of course apply to some extent to federal support through a National Science Foundation, amounting to 250 million dollars a year. We recognize that there is this danger, and yet we see that the need to

carry on basic research on the proposed scale exists, and must be met. What can be done in this situation?

I feel that there is a way in which the threat of complete domination of basic scientific research by the Federal Government can be met, and I suggest that the American Chemical Society give serious consideration to an active program of education along this line, as well as for the National Science Foundation.

The way in which the people of the United States can avoid the danger of federal domination of research in the universities of the nation is by the provision of a comparable sum of money for support of research from other sources.

Private-Enterprise Research Fund

I have in mind the formation of a foundation, like the Nutrition Foundation, which will collect funds from the industrial corporations of our great nation and will distribute these funds among our universities and pure research institutes. I suggest that, in order to be effective, this private enterprise fund for pure research be of considerable magnitude, amounting to 75 million dollars per year by 1957.

I have reached the figure 75 million dollars per year by considering what sum would be effective as protection against the danger of a Federal subsidy of research in pure science of 250 million dollars per year and what sum would be reasonable in comparison with the sums expended by industry for developmental scientific research.

A private-enterprise research fund of 75 million dollars per year would be just 20 percent of the proposed Federal subsidy; a smaller fraction could not be expected to have a significant effect in averting the dangers of bureaucratic domination. The funds expended in research by industry in 1947 have been estimated at 450 million dollars, and the extrapolation in the Steelman Report indicates that this sum will be increased to 750 million dollars by 1957.

Accordingly my proposal is that a sum be provided by industry for research in pure science in our universities equal to 10 percent of that expended for developmental research. I believe that this fraction is reasonable, considering that the sum proposed for expenditure by the Federal Government in support of pure research in the universities would amount to 25 percent of the Federal budget for research in its own departments.

Insurance for Industry

We must not consider that support by the nation's industrial corporations of the proposed Research Foundation would come under the heading of charity. Dr. F. R. Bichowsky in his book on industrial research has stated that industrial research should be considered by our corporations as insurance—insurance that the corporations will have new products to manufacture in the future. In the same way, I would say that the proposed support of pure research should be considered as insurance—insurance that the research departments of the corporations will have basic knowledge that will permit them, in the future, to pursue their own insurance activities.

I do not believe that the sum of 75 million dollars per year is an unreasonable one, in comparison with either the profits or the gross income of the industrial corporations of the nation. The figure 20 billion dollars has been quoted as the annual profits of our industrial corporations. Seventy-five million dollars is only 0.375 percent of the profits—surely not a large fraction to pay for insurance. I do not know what the annual gross income of our industrial corporations is, but it must be of the order of 100 billion dollars. Seventy-five million dollars is 0.075 percent of this gross annual income—surely a very small amount to expend on insuring an improved product for the next generation.

Where the Need Is Greatest

In the distribution of the funds under the control of this Research Foundation I would hope that the private institutions of the nation would be especially favored. The effects of the great increase in the cost of living—and the cost of carrying on research—during the past ten years have been in some degree alleviated in our State-supported universities by a great increase in the annual appropriations of the State legislatures. The privately controlled and privately supported universities have, however, not had a corresponding increase in the earnings from their endowments and in new gifts.

There is in my opinion an especially crucial situation in our private universities in that the size of the professorial staffs in chemistry and other sciences has not increased proportionately to the number of undergraduate and graduate students. Although the undergraduate students as well as graduate students in our universities have doubled in the last decade, the number of faculty members has increased by only about 25 percent on the average, and by a smaller fraction in the privately supported universities.

Overloading the Professors

At Harvard University there were twelve members of the Chemistry Department in 1939; today this number has increased to thirteen. In 1939 there were fourteen members of the professorial staff of the Division of Chemistry and Chemical Engineering in the California Institute of Technology, and now there are only sixteen, although the number of post-doctorate research fellows working in the Division has increased during the decade from sixteen to forty and there has been a corresponding increase in the number of graduate students.

The expected consequences of such a deficiency in the professorial staffs are serious. The professors, because of the overload of teaching, may not find it possible to keep even with the advance of scientific knowledge. The students whom they train may come to the end of their period of training already somewhat behind the times; the universities would then be producing an unsatisfactorily trained group of men to carry out scientific work in the coming decades.

This situation emphasizes the fact that, in order to be effective, the funds distributed by the proposed Research Foundation should be given to the universities essentially without restrictions as to the way in which the money may be expended, and the Research Foundation should be set up in such a way that there is assurance that the funds will continue to be available year after year.

I hope that the members of the Boards of Directors of our industrial corporations, in justice to our American system of private enterprise, will see that they have the opportunity to help to avert the danger that they forsee by themselves providing a more significant part of the support of pure research in our universities and research institutes. I believe that we, as individuals, and the American Chemical Society, as a corporation, have the duty to work vigorously both for a National Science Foundation to implement the recommendations in the Bush Report and the Steelman Report and for a great Research Foundation subsidized by industry.