

SCIENCE and the GOVERNMENT

The following address by the President of the National Academy of Sciences was presented on October 3, 1963, as part of the program of the Sixth Annual Meeting of the Corporate Associates of the American Institute of Physics at the Rockefeller Institute in New York.

By Frederick Seitz

ABOUT four centuries ago, our ancestors in Europe brought back into sharp focus a method of reasoning about the material world—namely science—which the Greeks had used on and off to some advantage for nearly a millennium, first in their own Aegean culture and then in the Greek culture that blossomed both in Egypt and under the Romans. The reawakening in Renaissance Europe, which occurred after several centuries of critical probing of the Greek manuscripts following the Crusades, was heralded by men such as Bacon and Descartes, who acted as sentinels along the highway which the new dynamic civilization of the West was traversing in the new age. These men realized that the coupling of the scientific method to the peculiar institutions of the new Europe, with its spirit of liberalism, its scholarship, and its devotion to technology for both adventure and conserving labor, could open a vast new universe of knowledge and power to man. It is interesting to note in passing that the brilliant young Descartes was optimistic enough to believe that the entire scientific revolution could come into golden fruition in his own lifetime as a result of his own efforts. He plunged into his life's work with this goal in mind. Actually, the golden age of science that Bacon and Descartes foresaw has not been reached until this century. In fact, science passed through two stages before reaching the one we are now witnessing, in which technological progress is very directly related to scientific discoveries.

In its first active stage, science was mainly of intellectual and inspirational value, although it was by no means completely divorced from the everyday world of technology. Most good scientists hoped their work would prove useful. There was, however, the more primary desire to gain strength in a general sense through more precise knowledge of the world. During this stage, well before the industrial revolution, it was supported by the enlightened aristocracy with intellectual leanings as

an exciting adventure of the mind which could, incidentally, help man understand nature better in ways which could, among other things, be useful. The main effect of this stage was to produce that mutation of outlook toward the universe about us that has made us as uniquely different from the typical citizen of the ancient world as the latter was from his cave-dwelling forebears. One need only note that Aristarchus' proposal of the third century B.C. that the earth was a rotating sphere moving about a central sun was not at all acceptable to the Ptolemaic civilization. There is no evidence that it was even a matter of serious public debate.

Perhaps one can characterize the first conscious phase of Western science in the Renaissance by saying that it gave man a new and fresh view of the universe which he had been observing and musing upon since our species first achieved its unique ability to speculate. In principle, the new view was in consonance with the view of the Greek scientists upon which it actually was founded, but it went very much further in tying conjecture and experiment together in a quantitative way. Moreover, European Renaissance society was, for reasons which are still not clearly understood, more prepared than any previous society to accept the results of scientific reasoning and to extend them with enthusiasm. Through these new revelations, man began to see himself in different perspective. Among other things, he gained from this both in arrogance and in modesty. His ability to cooperate with nature was extended, but he learned that his sphere of activity was a minute part of the world.

The second phase of the evolution of Western science occurred when systematic investigations began to turn up major areas of the universe whose quality and range could not be suspected from everyday observations but which could be used at least with limited or partial success by a combination of common sense and trial-and-error Edisonian methods in the world of the industrial revolution. In a sense, this phase began when the microscope and the telescope revealed their respective domains in the sixteenth and seventeenth

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centuries; however, the period did not get under way in earnest until the last century with the discovery of the wave nature of light, the periodic nature of the chemical elements, the full unfolding of electromagnetic phenomena, the discovery of the electron, the atom, and of natural radioactivity. In retrospect, it is remarkable how much use was made of this new information by Edisonian methods which employed only the most rudimentary theoretical knowledge—the admixture of limited inspiration and much patient labor that proved so successful in the hands of the great inventors of the last century. In this second phase of the development of science, the scientist was highly important for generating new basic knowledge; however, his direct participation in technology was not yet an absolute necessity for technological progress. Nevertheless, his activities began to receive the attention of those individuals who provided the driving force for the industrial age.

The third turning point in the evolution of science occurred in the first half of the present century. In it, the direct participation of the scientist became indispensable for the advance of many of the most revolutionary and profitable phases of technology, such as those involving the production and use of chemicals, communications, and energy conversion. In one or two generations, the individual with a PhD training in science, or its equivalent, has taken over highly important parts of the leadership in technology because an appreciation of the basic scientific principles and a direct knowledge of the techniques of sophisticated research have become necessary for most major technological advances.

A significant trend in this third phase of science has been the accelerated pace of investment of wealth in research and development because of its practical consequences, particularly since 1940. As is well known to all of you, the expenditures for research, development, testing, and evaluation have undergone an essentially geometrical increase since 1940, with a doubling time of approximately four years, and have now reached a point where the total annual expenditure is nearly three percent of the gross national product. About seventy percent of this expenditure is derived from governmental funds. Although an appreciable fraction of this investment, in the vicinity of 10 percent, has gone into undirected basic research, the underlying incentive for the support of research within present-day society has been the desire to accelerate the practical consequences of science and engineering, whether for commerce, defense, health, or educa-

tion. The practical rewards have been staggeringly great and no reasonable person believes that the present over-all investment of three percent per annum is not advantageous.

Will there be a fourth phase in the evolution of science in the near future, characterized by a qualitative change in its role in society either in relation to technology or otherwise? If so, I believe the new phase will be associated with an enhanced level of broad public interest in the support of science and its technology which transcends the purely practical, although it will involve practical considerations in part. The new phase will be based on the combination of a number of motivations meaningful to the average man, such as pride, competition, sportsmanship, amusement, curiosity, as well as the purely practical. The public support of the space program clearly has some aspects of such nonpractical motivation along with the practical ones. One can conceive of many other programs of a similar type which could involve a total annual investment in research, development, testing, and evaluation of the order of a quarter or even half of the gross national product, that is, about ten times as much as at present.

At first sight, such a proposal may seem completely preposterous. One must realize, however, that we are living in highly revolutionary times in which many of the parameters affecting the course of life are varying radically. I see no reason to believe that science and technology will be supported in a major way only for pragmatic reasons in the future. In the course of my own lifetime, for example, the fraction of the labor force needed to tend the farms has dropped by a factor of about five to less than 10 percent. It is true that some of the labor released has been used in industries which help to mechanize the farms; however, such industry serves far broader purposes in society as a whole, so that the trade-off carries with it a great lightening of the burden of feeding our population. It is not difficult to conceive of circumstances in which the fraction of the labor required for the other vital needs such as shelter, clothing, medicine, transportation, and the like will drop by comparable factors and leave a potentially large part of our economy free for services of choice to be made either on an individual or a public basis. It is entirely conceivable that, in such a framework, vast public-sponsored programs involving science and technology and accounting for a quarter or half our economy would become the order of the day, being justified by a combination of interests and incentives not rigidly practical. I find no difficulty

in imagining a transition to such a state of affairs by the end of the century, even though one cannot predict it with any certainty.

It is much more difficult to imagine the effects of such a vast popularization of science and its products upon the course of basic science itself. My own guess is that if such a transition in public support occurs, it will imply the emotional participation of the membership of the public at large in a broad sense. Although the point of view of the public would presumably be undergoing a continuous upgrading through an increase in general education, the goals, as understood by the public, would have to be somewhat popular. This could mean that relatively superficial scientific results would receive much more attention and support than profound ones because they would be easier to dramatize. Such a trend, carried out on a large scale, could be disastrous to the most creative aspects of science, that is, to those which have given us great generalizations in the past. Beyond noting this danger, it seems difficult to say more at the present time. Probably the good scientist would thrive through the transition, as he has thrived through the changes brought on by the industrial age.

Let us return to the present day, recognizing that we are still in phase three in the sequence I have listed, that is, the phase in which the pragmatic aspects of science are of uppermost interest to society at large. It is still much too early to decide whether or not we may also be in the early stages of the transition to stage four which I have just described.

The over-all magnitude of the support of research, development, testing, and evaluation in the United States, now being of the order of three percent of the gross national product, is sufficiently great that one cannot expect it to go on doubling every five years much longer if the innovation it leads to is regarded primarily from a pragmatic viewpoint and under the present cold war conditions. There is nothing uniquely magical about three percent of the gross national product; however, it is sufficiently close to the normal return on investments that one has a feeling it is close to the maximum that one can expect on the average when one is judging RDT&E on the basis of practical affairs in the absence of a shooting war or a similar, widely appreciated emergency. Presumably, in accordance with the present philosophy, one may expect this fraction to begin to level off in the coming few years. Thereafter, the absolute amount of money spent per year on RDT&E presumably would grow at a rate nearer

the rate of growth of the gross national product, that is, below five percent per annum rather than at the rate of fifteen or twenty percent per annum, as in the past. As it has been pointed out many times, continued geometrical growth of the support of RDT&E, at the rate it has enjoyed since the end of the war, would mean that it would absorb the entire national product in another twenty or twenty-five years unless the gross national product grows at a far greater rate than we have any reason to expect from analysis of the past. In one sense, the pattern of support affecting research has reached something in the nature of a watershed or climax and promises to lock into a less dramatic mode of growth.

It is not easy to state with great precision just what fraction of the over-all support of RDT&E goes into good basic science at present because there is a substantial degree of arbitrariness in the definitions used. Different means of accounting place the fraction somewhere between five and ten percent, that is, at about 0.2 percent of the gross national product.

One great question facing those concerned with basic science at the present time is related to the ultimate level which the annual investment in basic science will reach. Will it continue to be a relatively fixed fraction of the over-all expenditure for RDT&E and hence level off in the near future from an average growth rate of about fifteen or twenty percent per annum to one nearer the average growth of the national economy, that is, two or three percent per year, or will it continue to surge upward for another decade or so until it represents an expenditure nearer a quarter of the total expenditure for RDT&E, basic research profiting principally at the expense of testing and evaluation?

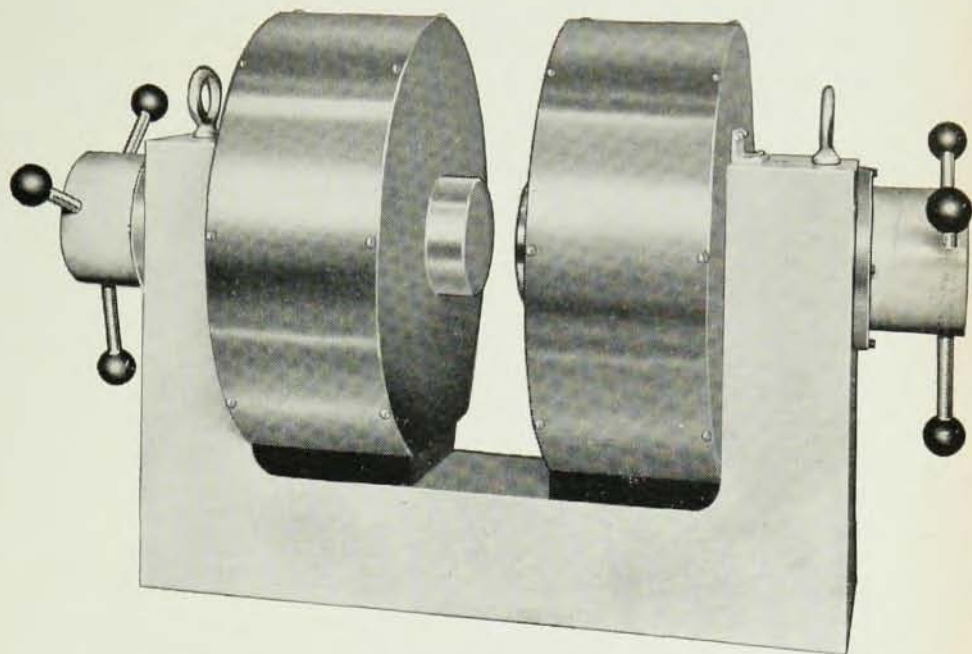
Whatever else may be said, I feel personally that there are two very strong reasons for increasing the budget for basic research by a factor between two and four in the coming decade, even at the expense of testing and evaluation, that is, of increasing the fraction of RDT&E devoted to basic research to a value nearer a quarter. First, there is general agreement that we could and should double the number of individuals receiving the most advanced type of training in science and technology during the coming decade, because our technology depends in an ever increasing way upon the most advanced concepts. The rapid increase in our population, particularly of the segment in the student years, assures us that we will have the human material with which to work in the next

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decade. Second, as research becomes more sophisticated it requires more complex logistic support to be effective. Thus the cost per investigator, both inside and outside the university, can profitably rise between five and ten percent per year on this score alone.

Once the rate of growth of the support for basic research bends over to conform to a curve more nearly in line with the average rate of growth of our gross national product, that is, of the order of about three percent per annum, there will be a very radical change in certain aspects of the administration of science within the federal government, for it will be necessary to take a much harder look at the way in which the funds are distributed, with regard to individuals, institutions, and fields, than has hitherto been the case. Up to this point and since the war, many individual scientists and many laboratories, particularly those in universities, have regarded a situation in which their research budgets increase about fifteen percent per year as the normal healthy one. Indeed, this point of view has worked to the advantage of society thus far. A growth rate near six or eight percent has been viewed to be so austere as to permit one to do no more than hold the line, whereas a growth rate near three percent per year, the average annual growth rate of the gross national product, has been associated with stagnation and decay in the over-all pattern that now prevails. It is interesting to note in passing that the budgets of many industrial laboratories which do not derive their support from the government are growing at a rate less than ten percent per year at present.

Once the growth curve of funds for basic science bends over, as would inevitably seem to be the case at some time within the coming five or ten years, hopefully near the end but perhaps near the beginning, we shall face many crucial questions. In the physical sciences, for example, shall we support high-energy physics, or the earth sciences, or scientific exploration of the planets at the rate the scientists in each of these three fields deem is proper, granting that we do not have funds sufficient to support all at the optimum rate for each but assuming we have enough to support at least one? Along the same lines, we will have to decide whether the biological sciences should be supported at an optimum rate and leave the physical sciences behind or vice versa, or whether funds should be shared about equally as is the case at present. Then too, there will be the question of the extent to which we should support the relatively independent university investigator who plays such

an enormous role in training the coming generation of scientists and engineers. Should he be cut back so that a few great centers can continue to grow at the rate of fifteen percent per annum, or should the situation be inverted? Still further, will it be wise to concentrate those funds which do go to universities in a few well-established institutions, or should some preference go to emerging campuses which do not yet have reputations? What about geographic distribution, recognizing that the flow of money has a profound influence on the flow of people, including those with managerial talent? These will be hard and bitter issues to face, but face them we must. As in all human affairs, the process of decision will involve emotion as well as logic. In fact, it may be very difficult to separate the two.

Who will make these decisions and in what atmosphere? In the last fifteen years we have evolved a group of capable scientific contract administrators who are distributed through the various federal agencies and act on individual proposals with relative freedom. They have played an enormously important role in promoting the funds that have been made available for science, by focusing on the needs in a logical and dramatic way, and in directing expenditures. Moreover, they have worked to a high degree in concert because the atmosphere in Washington has been conducive to discussions across agency boundaries at the scientific administrator level. How will these individuals, who have developed their standards of action and judgment in a period of rapid expansion of funds for basic science, be able to withstand the shift to a new, slower pattern of over-all growth? Will they be able to preserve balance and objectivity through all of this, or will they be overwhelmed by emotional factors when they must make hard choices among individuals, programs, and institutions, when so much of a complex nature is at stake? Will it become necessary for "judicial" committees to establish rather explicit policies which prescribe the actions of the contract administrators? Does this mean, for example, that structures such as the Office of Science and Technology will assume powers in the future beyond anything we have had since the war? It seems almost certain that a large part of the great debate of the future concerning the support of basic science will center about the new limitations we must inevitably face and how we will adjust to them. Only a truly remarkable up-surge in the rate of growth of our gross national product would circumvent the need for this.