BASIC RESEARCH AND NATIONAL SECURITY

6 October 1955

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BASIC RESEARCH AND NATIONAL SECURITY

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DR. REICHLEY: This morning we begin our General Lecture Program as indicated in the recently distributed announcement. The first series in this program is concerned with Research and Development and will consist of about five lectures spread throughout the next two months.

Today we will hear about the most fundamental kind of research--basic research--the study and investigation to find new truths and to gain a better understanding of the laws of nature. Such study, we know, has great meaning for national security. The discovery of electromagnetic waves and their characteristics by teachers of physics led eventually to radio, radar, proximity fuses, and other uses important to the military services. Studies in the nature of the atom and of radioactivity provided the basic work that resulted in the atomic bomb. Many other subjects investigated in the academic environment of ivy-covered towers have led to changes in industry and war.

To tell us about basic research and its importance to national security, we have called on an outstanding, experienced scientist, Dr. Raymond Seeger, Acting Assistant Director of the National Science Foundation. It gives me pleasure to welcome Dr. Seeger to the Industrial College. Dr. Seeger.

DR. SEEGER: Dr. Reichley, General Calhoun, and those of you who, like me, have to be here. I was very much impressed in reading the scope of topics that I might cover. As a matter of fact, I thought: If this is true, I must get over there to hear what this fellow has to say. I am certain that I don't have the answers. I hear that some of you people do have the questions, however.

One of the great issues today is the relation of man to science. I have deliberately used the phrase man and science, rather than science and man, to suggest that man himself is the key to the problem. I shall stress only the scientific aspect of this relationship today although I am quite sensitive to the human significance.

One phase of the issue may be stated thus: Is science inherently individualistic? If so, personal freedom is a primary requisite for

each scientist. Or, Is science essentially social? Then Government planning is a fundamental necessity for all science.

The present emphasis all over the world seems to be on the social importance of science, arising probably from the prominent place it occupies in the economic structure of modern society (cf. the medieval social interest in astrology and alchemy).

First of all, man is searching intensively for all kinds of materials and for cheap sources of energy, owing partly to catastrophic World War II losses, partly to normal population growth, and partly to an ever increasing demand for commodities.

Secondly, the dramatic use of atomic energy within six years after its identification has encouraged a belief that the usual timelag between discovery and application can be greatly decreased by a sufficient expenditure of simultaneous efforts. (A more recent, but less well-known example from solid-state science is the invention of the transistor.)

It is conceivable that the mastery of nature through science will make possible the mastery of the world. The uppermost question, therefore, in everyone's mind is this: if science is to rule the world, who is to rule science? Accordingly, we find governments generally sensitive to the basic research studies of technology. Sometimes, indeed, there is a deliberate attempt to make basic research captive, often indirectly through the support of education. For example, in recent years more than 60 percent of education in Great Britain has been supported by the national government; in Germany about 90 percent of all research at educational institutions has government funds for its source; in Russia technological development is being exploited in an all-out effort. Even in the United States it is estimated that the Federal Government supports about 70 percent of the research performed at educational institutions. Hence it is not surprising to find President J. D. Millet of the University of Miami, Chairman of the Commission on Financing Higher Education of the Association of American Universities, saying "Many of America's greatest universities are on the verge of becoming purely scientific, if not technological institutions." In any case the spectrum of the distribution of national funds for the support of science is anxiously watched as an index to technological progress.

Let us, therefore, consider in more detail the question: Is science essentially social? Some years ago Julian Huxley concluded his book on "Science and Social Needs" with the statement: "Science is not the disembodied sort of activity that some would make out, engaged in the abstract task of pursuing universal truth, but a social function, intimately linked with human history and human destiny." In the same spirit Hyman Levy in "The Universe of Science" has emphasized that science creates social needs, whereas Lancelot Hogben has boasted continually that science fulfills social needs. The Union of Soviet Socialist Republics notes in the Soviet encyclopedia that "The ultimate aim of all science is the satisfying of the needs of society." The Soviet Union itself is a good example of this thesis.

In the official Marxist Doctrine of 1930 we are informed that science is identical with technology; that science advances practical needs; that science, therefore, must be organized for practical needs; and that central direction is necessarily a part of economic planning. A dramatic illustration of this doctrine in practice was the recent development of biological science in the Soviet Union. In 1948 Lysenko expressed opposition to genetics because of its hereditary emphasis in contrast to the environmental factor, proper for Soviet thought. He was opposed also to Darwinian theories with their emphasis upon individual species combatting one another in contrast to the Lamarckian influence of environment. Within two years Michurin of Russia announced that through Lysenko's methods actual changes had been effected in plants, such as the transformations of wheat into rye, of elm into hazelwood, of pine into fir, et al. Two years later an announcement foretold animal changes soon to come (to date, the speaker has no knowledge of the fulfillment of this prophecy).

In practice the Soviet Doctrine resulted early in a nationalization of science quite contrary to the international character that has been generally accepted in western culture. For example, in 1935 Soviet scientists were not permitted to publish in scientific journals outside Russia; later the Soviet journals themselves were published only in the Russian language; still later, references were confined mostly to Russian literature. To say the least, history may become greatly distorted through such a procedure. (The new look of the U.S.S.R. is quite encouraging for an international outlook in the area of scientific publication--e. g., permission for external publication, and English abstracts of internal journals).

If we would see ourselves as others see us, we might well read the somewhat prejudiced book of S. F. Mason on "Main Currents of Scientific Thought" (1953). He argues that in the 19th century the main current of Soviet thought was essentially of a theoretical nature (cf. Lobachewsky's non-Euclidean geometry, Mendeleev's periodic table, Pavlov's conditioned reflexes), whereas in the United States it had more of a technological character (e. g., anesthetics, the telephone, the airplane, et al., culminating in the twentieth century production of the atomic bomb). Perhaps, we should look critically in our own historical mirror. We see Benjamin Franklin promoting in 1773 the founding of the American Philosophical Society "For Promoting Useful Knowledge." In 1836 Joseph Henry, before his appointment as Secretary of the Smithsonian Institution, said "Though many excel in the application of science to practical arts of life, few devote themselves to the continued labor and patient discovery and development of new truths." With respect to Thomas Edison, Henry Ford remarked "Today we think of scientific discoveries in connection with their possible or future application to the needs of man." In his "Science, the Endless Frontier" Vannevar Bush warned in 1945 "Our national prominence in the fields of applied research and development should not blind us to the truth that with respect to pure research--the discovery of fundamental new knowledge and basic scientific principles--America has occupied a second place." Thus, we see from the beginning of American history to modern times a utilitarian tradition.

Nowadays there appears to be a worldwide phenomenon of such technological emphasis. On the one hand, those countries without industries are urgently striving to encourage industrial research; while, on the other hand, those countries with well-developed industries are busily engaged in fostering military research. In Great Britain, for example, during the period 1936-37 to 1950-51 the Government support of basic research in the universities increased only sixfold, while Government expenditures increased eight times in agricultural research, nine times in medical research, ten times in industrial research, and sixty seven times in military research and development.

In all this social emphasis upon science, to be sure, there always lurks the potential danger of undesirable control. Physicists are ever mindful of the meeting of the British Association for the Advancement of Science in 1847 at which James Joule's experimental conclusion of the conservation of energy would have been dismissed ex cathedra by

the chairman had it not been for the alert and sensitive intervention of a young man by the name of William Thomson, later Lord Kelvin. A tragic series of events took place in Germany partly because of Hermann von Helmholtz's failure to recognize the theoretical work of Robert Mayer on the mechanical equivalent of heat in 1842, even though he admitted its value at the Innebruck meeting in 1869. We are all aware of the German decision not to develop atomic energy during World War II. An "expert" here once informed a class that supersonic flight of aircraft would never be a possibility--at the very time that the Germans had privately completed their basic aerodynamic research for the V-2. I myself still recall certain individuals who advised against sponsoring basic research on the long-range application of interferometry to jets because of a supposed urgency of a short-range duration. Then, too, I recollect the scoffing attitude of some persons who questioned certain theoretical work in favor of practical improvements amounting, say, to an increased efficiency of a tenth of one percent. It turned out later, however, that the theoretical ideas became embodied in the air-burst principle used in the bombing of Hiroshima and Nagasaki with its untold percentage increase in effectiveness.

Men of affairs unfortunately are not alone in being adept in making wrong choices. In his outstanding work on "Hydrodynamics" (6th edition) the scholar Horace Lamb mentions the basic Rankins-Hugonist law of shock waves only casually (in a footnote), viz, "No evidence has yet been adduced in support of this law." Yet since that year of 1933 shock waves have assumed a major role of practical importance and of theoretical significance. It is evident that the high stakes involved in wrong choices make the management problem of judging social significance a matter of utmost importance. Even though control of science by scientists is not without serious problems and handicaps, there would appear to be an even greater danger if the development of science should be controlled by nonscientists--for motives other than scientific progress.

What is more, there is always also a limiting manpower problem in any social endeavor. Some time ago a representative of a foreign oil company pointed out from an analysis he had made that research output has apparently doubled every seven years in recent times. He estimates that just one more effective doubling is possible owing to the limitation of sufficiently intelligent persons available for guiding basic research in a balanced economy. Regardless of the correctness of the prophecy, evidently the availability of scientific personnel at

any particular place and time does impose an upper limit so that efficient utilization of people may be of primary significance. In our own country we note the rapid depleting of scientific personnel in colleges and universities owing to the increasing competition among industries for technical talent at the very time when schools are beginning to bulge. It may well be that in this process we are all robbing the academic goose who lays the intellectual eggs. France long ago pointed to a more likely road to scientific achievement in the establishment of the Ecole Polytechnique with its utilization of research-minded individuals as teachers.

Is science, perhaps, inherently individualistic? There is no doubt that much scientific growth has psychological and sociological roots in more or less practical requirements. It must always be borne in mind, however, that intellectual curiosity per se also is often a primary incentive. The element of wonder and astonishment is always a pertinent motivating factor. Newton himself, when asked about his own discoveries, stated that he had made them "by always thinking aside about them." In more recent times, X-rays were discovered as a serendipity biological byproduct of a physics investigation. In the scientific laboratory, as well as in kindergarten, the intellectual activity must be fun. Perhaps, here is a clue to the scientific productivity of young people--their attitude toward real problems, rather than the condition of their environment. Strangely enough, Einstein as a young man made his brilliant discoveries about special relativity, the Brownian movements, and the photoelectric effect not in a university, not even in a laboratory, but in a Government patent office. Not only must we bear in mind socially that scientists are people, but individually that each scientist is a person--a person that sees visions and later dreams dreams. He is not so much a doer--or even a knower--he is truly a seer.

Science, indeed, is fundamentally not so much a commonsense residue from the past, but rather a challenge to the commonsense of the present. Perhaps, a familiar illustration may be useful. Here is a trailer with a candle in the center. When the candle is lighted, will the rays of light reach the front end or the back end of the trailer first? It is obvious that both will take place at the same time. I forgot to mention, however, that the trailer is moving (unknown and unknowable to the occupants), or is it the earth that is moving? To persons on the outside it is equally obvious that light will reach the back end of the trailer before light arrives at the forward end, which appears to be moving away from the initial position. In other words,

to these observers, the events are not simultaneous. The only knowledge used in making these two contrary deductions is the experimental fact that the velocity of light is the same for all observers regardless of their own state of motion. Thus the commonsense concept of simultaneity, which seems generally intelligible and self-evident to us, is challenged by science. It should be emphasized, however, that the real contribution of Einstein in this instance was to call attention not to the doubtful conclusions relative to different observers, but rather to the certainty resulting from that which is invariant with respect to all observers.

Another challenge to commonsense is seen in the very nature of energy. Here we find that by exercising the discipline with regard to logical consistency we arrive again at greater freedom of thought. Let us take another familiar example, say, a spaceship having two radio emitters inside, one at each end. The first station emits a radio beam consisting of electromagnetic radiation. It is known that such waves have momentum given by E/c, where E is the energy of the radiation and c its velocity. The action on this emitted radiation is associated with a reaction on the spaceship, which obtains an opposite momentum given by Mv, where M is the mass of the spaceship and v its resultant velocity. During the time that the radiation travels the distance l from the first station to the second one, where it is received, the ship will have moved a distance x, given by vt. There is no apparent reason why the two radio stations cannot then be interchanged (in principle), and the whole process repeated over and over again. In this event the spaceship would move on indefinitely in the same direction--a violation, of course, of the conservation of energy. In what respect, then, have we been theoretically inconsistent? We have not associated any mass with the radiation. Accordingly, in interchanging the stations we have failed to preserve the location of the center of mass of the whole system. In other words, Mx must equal ml, where m is the mass of the emitted radiation. From these few relations we find readily that the unknown mass m of the radiation is equal to E/c^2. In this simple way we have obtained an expression for the mass equivalent of radiation energy; and so we are compelled to think of atomic (mass) energy, in addition to mechanical energy, electrical energy, thermal energy, et al.

Perhaps, the greatest danger, however, that exists for the individual scientist who hopes to be free to see such visions, is the polluted atmosphere of materialism. To many people science has become socially just a magic phrase for nature like "open sesame," which will

reveal money for many things close to the heart's desire. As a graduate student, I heard a college preacher remind the students upon the occasion of a great monetary gift for buildings that universities consist not of things, but, in the main, of ideas. How sad it is to see inside many large edifices with magnificent equipment the obvious imprint "No men--at work." A more dangerous personal influence is the subtle, often subconscious lure of higher salaries, extra privileges, more power, which might even be called professional patronage in the vulgar sense. We are ever reminded that "Man does not live by bread alone;" that:

> "The world is too much with us, late and soon,
> Getting and spending, we lay waste our powers,
> Little we see in Nature that is ours."

Einstein remarked in his introduction to the 1931 reprint of Newton's Optics, "Fortunate Newton, happy childhood of science, he who has time and tranquillity can by reading this book, live again the wonderful advantages which the great Newton experienced in his young day." Time and tranquillity, rather than material benefits, these are the prerequisites for the individual scientist who wishes to understand the world about us.

Thus I find myself concluding that science is inherently individualistic in its origin. but essentially social in its development. Basically, it is manmade and hence anthropomorphic. Let us consider, therefore, what science is.

Science, I would say, is strictly the result of the use of the scientific method, and the scientific method is simply the instrument used by the scientist. The answer to the question, what is science, is given basically in terms of the scientist. A related question, of course, which we shall not be discussing today, is this one, "Who is man?"

In science we begin existentially with sense impressions, which change with our own impressionistic outlooks and which in their totality constitute observed facts. To many nonscientists science is nothing more than a collection of such observed facts--or at most combined with some inductive inferences, as in the early positivism of August Conte. It was recognized later, however, that a scientist just doesn't collect facts at random in the tradition of Francis Bacon. Who, for example, would note all the motional aspects of fluttering

leaves in order to ascertain the general laws of motion? On the contrary, one carefully selects facts together with their relations, which constitute the later positivism of Ernst Mach. It has become evident that the more popular or general a language, the more even simple interpretations of facts require some kind of semantics, or operational rules, as advocated by modern logical positivists. For example, what do we mean scientifically by the length of a body? No more than the answer we got in making a measurement, either thoughtfully or experimentally, in a certain prescribed manner regardless of any preconceived categories of knowledge! We note that in each case it is the scientist who collects, the scientist who selects, the scientist who operates.

Any person having objects of different sizes, shapes and colors will attempt to separate out those that are alike and, if possible, to relate those that are different into a single pattern. So, too, the scientist looks for related factors amid his collection of observed facts. In this respect, he may be guided by the cogency of logical consistency, or by the urgency of simplicity for economic or some other purposeful convenience. For example, it is well known that a descriptive characteristic of a material is its specific gravity, that is, the weight of a given sample relative to the weight of an equal volume of water. It is equally true, however, that the square of the specific gravity is also uniquely characteristic--not to mention the cube, etc. We prefer to utilize specific gravity because of the simplicity of its form. Here again it is the scientist who chooses the relations.

To the traveler who has gone along various roads and who has seen many places, it is always refreshing to go up on a mountain top from which he can see at a glance the whole surrounding region with its network of roads. So, too, the scientist is not content with the observed facts, or even with the related factors. He looks for an overall view, what the Greeks called a theory (from the same root word as theater); such a theory is necessarily factitious in that it is inspired in the scientist by compelling beauty or by ingrained truth (based on analogies with commonsense), or merely by the heuristic value of pragmatism. Not everyone could or would or should be an Einstein, a Bohr, et al. Max Born concludes his "Natural Philosophy of Cause and Chance" with the remark "Faith, imagination, intuition are decisive factors in the progress of science as in any other activity." The scientist is truly a maker, or to use the Greek word, a poet. In a strict sense the scientist strives to achieve a poetical view; his formal relations are freely creative, as Poincare has emphasized. Hence the scientist himself plays a major role in the development of

theory. He can never be completely eliminated. The studied attempt to eliminate the subject for greater objectivity finally becomes only increasingly more subjective.

Every scientist has a question in mind as he looks out upon the world about him. The observed facts are its answers. From them he obtains related factors. From both he makes a factitious theory, which enables him to see farther and wider so that new questions arise in his mind as he again looks out upon the world about him. The new answers are in the form of additional observed facts. The cycle will be continually repeated, although its completeness will ever depend upon the controllability of the material. For example, observed facts may be difficult to isolate as in self-involving social phenomena; or a factitious theory may be difficult to achieve as in the omnipresent observational earth sciences. In any case the cycle represents a single instrument in the hands of an instrument maker.

In the use of the scientific method, however, there are two necessary conditions. The first one is conformity to nature, which is based upon the assumption of the uniformity of nature. In other words, at all times predicted conclusions must check with observed data.

The second condition is acceptability by society, which is based upon the assumption of human comprehensibility of nature. Einstein once said that to him the most incomprehensible feature of nature is its comprehensibility. The scientist's understanding, his reasons for accepting certain general principles, depends on his own personality as well as the social class, the political group, the religious faith, et al, to which he adheres. In a strict sense such factors are included in the sociology of science. In the celebrated case of Galileo, we note, the Roman Catholic Church opposed the philosophically favored position of the sun. (One wonders what influence this social problem may have had later in the 18th century, which saw science in a dormant state both for the Catholic Italy of Galileo and for the Protestant Germany of Kepler, which was undoubtedly influenced by the antirational attitude of Luther.) In our own day we found Nazi leaders, with the physicist Johannes Stark as their spokesman, voicing similar opposition to the lack of favored observers from the relativistic point of view. They were opposed also to the concept of materialistic clocks for time determination, which seemed irreconcilable with their own idealistic position. On the other hand, in the U.S.S.R. also there has been official opposition to the relativity theory, but in this instance because of a supposedly idealistic view of material mass

as energy. (Can it be altogether accidental that the use of atomic energy was first developed in English-speaking countries?) The social acceptability of science is intrinsically involved in the philosophy of science, again impressing us with the fact that in all science there is indelibly imprinted something of the scientist himself.

As we look about us, we are aware of phenomena, appearances that play like Plato's shadows in his underground den. It is upon the foundation of the totality of these sense impressions, of course, that one constructs the world of science. Here, however, is always an element of surprise--the theories are never merely descriptive of what is known; in addition, they are predictive of what is unknown--probably due to the fact that a thing itself is always greater than any experiential impressions and, even more so, than any symbolic expressions of it. That there is a world of nature beyond sense impressions gains credence as a philosophy of nature extrascientific (metaphysical) in character. Thus, we find Max Planck insisting upon the existence of three worlds--the world of sense impressions, the world of science, and the real world, as he calls it. He says "Physical science demands that we admit the existence of a real world independent from us"--actually, an assumption.

As far as I can see, the data of sense impressions form a contact surface of phenomena, in which I am existentially involved, between two possible worlds, the world of nature and the world of science. What relationship, then, if any, exists between these two worlds? Is nature possibly nonexistent? Is science, perhaps, purely fictional? Is science merely the imperfect reflection, or imperfect image of nature made in the rational image of man? Are these two worlds possibly identical? Is science a reconstruction of the world of nature?

There are various views as to how the world of science may be related to the world of nature. P. Duhem urged "To the extent that physical theory makes progress, it becomes more and more similar to a natural classification which is its ideal end." A. A. Michelson once suggested that "The more artistic the statement of a problem in science, the richer the chance of presenting the truth." We are reminded here of Kent's creed that "Truth is beauty." P. Bridgman, however, cautions us that "The known laws of nature are simple if we consider only a limited range of facts." Hence we must always be aware of limitations of scientific data, which are necessarily incomplete and imperfectly described by man. We must be conscious also that the world of science, in turn, is necessarily incomplete as a description even

of the sense impressions, not to mention as a description of their matrix; at best it represents only an incomplete and imperfect theoretical outlook. Uniqueness, of course, is always wanting. It would seem unlikely, therefore, that a one-to-one correspondence would exist at anytime between the world of nature, involving the sense-data plane, and the world of science, involving that same plane. One would hardly be justified, I believe, in any extrapolation like that of P. Jordan in his "Science and the Course of History," viz., "The discovery of new laws of atomic physics has shown the old materialistic view to be untenable even in the field of physics." The necessary conditions of conformity to nature and of acceptability by man, moreover, may be related to the philosophy of nature as a guiding faith. To me the cumulative and integrative development of scientific theories, leading to more inclusive description and ever surprising prediction, points more and more to a probable world of nature, which may be susceptible of metaphysical interpretations, such as the theological premise "In the beginning God!" We should never dogmatically exclude Einstein's "Faith in the possibility that the regulations valid for the world of existence are rational."

Unfortunately there is a widening gap between any philosophy of science, approached from the standpoint of science, and any philosophy of nature, approached from the standpoint of philosophy per se. Yet there can be no sharp line of demarcation; for the scientist himself is the link. As man looks at the environment about him from the different points of view of physical, biological, psychological, and sociological sciences, it is always he himself who is viewing. Invariably, from any viewpoint he ponders three questions--What is true? What is real? What is value? The attempt to obtain answers to these questions in any discipline may properly be called the philosophy of that discipline. To seek common answers to these common questions is general philosophy. The attitude may be that of an agnostic, or of a skeptic, or of a man of faith. No compelling evidence will be agreed upon by all viewers. Because of inevitable incompleteness the same set of observed facts may be seen in different ways--as a cube may be visualized on a flat surface, or as a limited outlook of white clouds in a blue sky may be interpreted as white caps on a blue sea.

As far as I can see, there is no way of demonstrating just what is precisely true and just what is precisely false; for there are no general criteria for truth. The choice for each of us may be determined by unconditional imperatives like loyalty to a human cause, like love to a human partner, like obedience to a divine will, et al., or merely by

unconditional recognition of other people as individual persons. What must be admitted by all is that civilization is the product not of the pessimism of agnostics, and of skeptics, but of the optimism of men of faith. Enthusiastic men have varied as to what they have believed, but they have all believed either in some thing, or in some one. Some have believed that answers to the three questions can be obtained from one's environment (materialism); others, from men (humanism); still others, from God (theism). Unfortunately, while a man considers leisurely how to make up his mind, he may already be virtually making up his life. Three practical decisions are open to every man. He may refuse to consider the matter and thereby fix his ignorance; or he may purge his beliefs and thus leave a vacuum for chance filling in; or he may clarify all aspects and then make an intelligent (from the Latin words inter legere meaning to choose among) choice. We note that detachment is itself a choice.

What then shall we do about the original question. Is science inherently individualistic, or essentially social? Dr. Conant, I believe, gives us a clue when he says "Science should be relevant to man." In other words, as men, we cannot have science for the sake of science any more than we can have art for the sake of art. We must have science and art for the sake of man. Science is both an <u>end</u> for man and a <u>means</u> for society. The best results will be obtained, of course, if their interrelations are understood. Freedom for the individual, I would urge, should be listed first. Man is truly a social being; but first of all, a man is actually a man.

As I think of man and science, I find a parable in the apotheosis of Faust, as set forth in the poetical, philosophical autobiography of Goethe. The theme there seems to be that he who strives, strays, yet in that straying finds his salvation. At the beginning Faust flouts science. He tries vainly to make man master of his environment. Mephistopheles taunts Faust with his demand for everything, his satisfaction with nothing. He wagers that Faust will one day demand nothing, but will be satisfied with whatever chance throws his way. In the last scene we watch expectantly the 100-year old Faust looking upon the sand dunes along a shore marked with engineering feats of dykes and canals--a political enterprise in which people strive daily to make buttresses against the ever-surging sea. Faust muses on future generations living and laboring in this wholesome danger. He mutters "Verweile dech, du bist so schon," (stay, thou art so fair)--almost the very words of the original wager. Yet even here Faust is maintaining his enthusiasm for a difficult, but endless life:

"The noble spirit now is free
And saved from evil scheming!
Whoever aspires unweariedly
Is not beyond redeeming."

QUESTION: I am more curious as to where you propose to have the basic research done than in what basic research is.

DR. SEEGER: How can I know where to do it if I don't know what it is? Shall I answer that question? Let us leave out what basic research is for the moment. No, I can't leave it out. I have to tell you.

Let me say this: I think that there are different levels of understanding. I think usually when we use the term "basic research," we say we really want to understand a certain phenomenon. I want to suggest that there are different levels. The National Science Foundation deals with engineering science. It was again Dr. Priori who said there was no such thing as basic research in engineering. As a matter of fact, my friend Gamow said there wasn't any basic research in physics except what he was doing. It is always that way. What I am doing is basic research; what the other fellow is doing is not.

Take the atomic bomb. In order to use the atomic bomb, first of all, we must have some materials to use; we have to know something about the materials; we must have some understanding of the physical and chemical conditions. We must know how electrons behave within nature. In order to know that, we have to know how they run around between atoms and ions. What is an atom? Or even what is inside an atom. Then we get to the nucleus, and inside the nucleus. I would say all these are basic, beginning up here and ending down here, basic to the understanding of the level right above. So I would say basic research is a wide spectrum covering many things.

Specifically as to your question, where you would do it, obviously three places are available. All three of them in the name of this institution, the Industrial College of the Armed Forces. In other words, if you ask where, I will say you can do it at the university; you can do it in industry; and you can do it in Government; and here, you can do it all in one.

Now I would like to make a couple categorical remarks. I believe good basic research at all levels can be done and has been done at all these places. It disturbs you when you realize that to find validity, it must be done around the university. Yet Bell Telephone did work on radar and a great deal of SAC work on NRL aircraft. NACA outfits did good applied research during the war. So I think that all research of this kind can be done at all levels. I would also say that I believe all these must be done at any one time because of the unity of nature and the unity of science.

I think in the future we are going to be more understanding of what is an iron curtain, that we must have some kind of good communication. I would like to have a man on my staff, no matter what I am doing, who is familiar with each of these different fields, in university research, in teaching, in industry, in other words, whether I am interested in industrial application, which has the profit motive, or in Government, which is something else.

I remember some years ago speaking to some people at du Pont. There were people there with Ph.D.'s who were working on applied research. I said, "Don't they just want to do basic research of the purest kind without any reference to military applications or any kind of applications?" They said, "Yes, they do." I said, "What do you do?" They said, "We let them do it. But at the end of a year they notice that promotions and better pay are going to people doing applied research." That's a social phenomenon. They always say, "Let us do applied research." I think this is the thing we have to worry about.

What I am saying is I think the university has the primary job of teaching research; industry has the primary practical job; that the Government probably has to come in.

I know a lot of people are opposed to the Government laboratory. I think that is a lot of nonsense, frankly, because a lot of good has come out of Government laboratories. As a matter of fact, I think it is really quite a different social problem that we are concerned with here, which I will mention in just a moment.

There are so many different fields that Government has to worry about. For example, certain physical properties. I was amazed when we were going to build a big wind tunnel, they had to know the physical properties of the material. As a physicist, I thought I knew

all about it, but physicists are only interested down to hundredths of degrees, not in between. Somebody has to see it is done. If industry won't do it for profit, the university won't do it for curiosity, then let the Government do it. Another thing is that no industry wants to go into high explosives and have themselves blown up all over the place. No university wants to do it either.

Let me summarize what I am saying here by saying that I think you have to gear yourself into the primary job. Take Los Alamos, is that a university laboratory? Let us not kid ourselves. Just because it has a contract with a university, that doesn't mean it is a university laboratory. So I think we ought to do the thing at the place that is interested in gearing to it.

One of the important things is the organizational and the operational problem. Here is a man who parks anyplace. He fears neither God nor the police officer. He parks anyplace or anywhere. It would be nice for that man to live in a small town, by himself, not in a big city. You have a man who wants a great deal of freedom. You have a laboratory in industry or in Government with two or three thousand employees. You can't have all those people going around having freedom. You might have one or two. Then you can put them in a little area where they can't get away too far. I had a fellow one time and I said to him, "I would like to have you work for me but I can't hire 16 other people too, because that wouldn't give you the freedom." I think the problem people are worried about is the organizational problem. I don't know whether I have answered your question or not. Maybe you can phrase it another way.

QUESTION: I have been reading an awful lot and hearing an awful lot about this terrific shortage of scientists and engineers. How do we produce or how do you make scientists? Crank them out? We don't have any real pure scientists in the United States. We don't grow that way.

DR. SEEGER: John von Neumann gave a talk yesterday on this very question of manpower deficiency. I said, "How many do you need?" He said, "A thousand to 10,000." "Where are you going to get them?" "From chemists and physicists." Said I, getting very excited, "How about taking all the lawyers?" That might be a good way to solve some other problems we have.

I think the answer is this. I think our basic problems are these: We are not identifying and encouraging the potential scientists. This is the first thing we must do, identify and encourage.

My little child came home from school--the third grade--with some stars and planets. I said, "Oh, you are studying astronomy." "No, daddy, this is social studies." This is the introduction my little child is getting to science. I think this is horrible and wrong and will keep people from getting into science. I don't think we need so many in ordinary high-class scientists. We need more technicians. That will unbalance the economy. Somebody will have to do wise planning because we do need lawyers, we do need doctors, we do need mechanics. You can't have everybody being ministers. Our primary need, I think, is to get all those who are essentially able as scientists and at least let them have the opportunity to get into science; secondly, make them aware of manpower needs so far as economics is concerned.

QUESTION: You say that we have to identify the possible scientist. I think now we are able to identify intelligence, but how are we going to identify those people with the curiosity that you mentioned during your talk?

DR. SEEGER: May I say exactly where we are going to spend a lot of effort--in secondary school education. I came down last week to the Powell (?) school. They were reading about the Geneva conference and the teacher came to the conclusion there wasn't enough science in her curriculum--she was teaching the second and third grade--would I come out and talk on how to teach science?

I came up with the idea of teaching the center of gravity in the second grade. Eighty-three percent of the people who will go on into graduate work won't start their major unless they start out the first year. You have to go away down in the grade school for motivation. I think you can if you are alert and watch it. Let me give you a facetious answer which I think you will appreciate. You can try this out on your youngsters.

You say, "Here is a cow. A cow has four legs. Suppose we call the tail a leg, how many legs will the cow have altogether?" If the child says, "Five," that is mathematics. If he says, "It doesn't make any difference what you call that tail, it is still a tail," that's

science. If the child says to you, "Eight and nine are 27." please don't send him into engineering. And if the child looks at you with a nice smile and says, "That's a good question," administration. I tell you seriously I think you can do something.

QUESTION: I am interested in and somewhat concerned, as a matter of fact, about the seeming transition of industry into the scientific field, and it seems to me that for our older people, such as von Neumann, Vannevar Bush, people of that type, they are not to be bought for such a price, but the younger scientists who are coming out of school ready for science, instead of extending their own frontiers and seeking new truths, they can get paid for expressing and developing what they already know. What do you think is the solution to that?

DR. SEEGER: That is the problem. That is what worries me.

QUESTION: Would doing away with hunger do it?

DR. SEEGER: It would take a great deal to really buy me although I think I am buyable. Temptation--you never can tell until you get it. You begin to look at your children and your wife and you get to worrying. But I think this is where we really have to worry a little bit.

There was an article about this in "Time Magazine." We are responsible, we in the Government, because we say, "Here are X million dollars," and this starts the whole thing, and this is how you buy people to get the job done. I think it would be better in this case--this is my personal opinion--to leave the physical scientists who want to so this sort of thing at the university and then establish very good liaison with these people. But when you get into the competitive field, there is the profit motive and so you buy these people.

That reminds me of the story in the Old Testament where the people wanted to go to heaven, but at the same time they wanted to make money. To make money, you have to work--very modern. The trouble is that not only do we want to go out for this, but we want to put money in our pockets, too. As individuals, we want to do some other things, too. I don't think we should tempt them.

QUESTION: You mentioned that repose and relief from various other pressures is pretty important to good scientific thought. How fruitful do people feel that they have been at the Institute of Advanced Study at Princeton? Has it been a good environment?

DR. SEEGER: I think the answer there is very definitely yes. I know industry is going in for a lot of training, frankly, at universities, that is one way they buy the young people. "Earn while you learn" policy. It would be much better if they could get away and just relax. That is a very good example.

QUESTION: I am interested in this veil of secrecy that you mentioned shortly but didn't go into any more deeply. Since it is difficult to draw the line between what may be basic research, pure science and technology, at what point are you justified in cutting off communication between people?

DR. SEEGER: It doesn't make any difference what you tell the scientists. He will tell the people anyway. Don't make a veil of secrecy more drawn than on the surface. A great many who were not with the Manhattan Project knew what was going on. These things get around, of course. They are not altogether unintelligent. If they see a massing of people on a certain thing, they see what is possible to come up with. Certainly I would not make secrecy for a whole area. For example, I would not at this time make secrecy for high temperature and high pressure basic research. I think that this would be very dangerous. However, when it comes to using some of the ideas obtained, yes.

QUESTION: Speaking of environment, I refer to three establishments which I think have several things in common. All three of them have basic research, applied research, and development testing--even pilot production. From the standpoint of environment, what is your feeling so far as they are concerned?

DR. SEEGER: I am glad you mentioned that. That was what I meant when I said I think you must have a primary objective. I would expect a government laboratory like that to have a sort of pilot development. Of course, when you get into the last stage, obviously somebody geared to this sort of thing, like industry, is better able to do it. But if you take this essentially as development, not applied research, then I would say you must have some people there also who are concerned with the use of the thing after you get through with it. You don't develop something no one can use and you must have some people who are going along in their own way. These people are difficult to get to. It is hard to keep people interested.

The man who succeeded me at the Naval Ordnance Laboratory did basic research. He had been head of the Congressional group. He was very much interested in basic research, but mainly so in how it can be used. That is what I meant when I said to leave them at the university. I don't want them to be entirely academic. I want them to realize when they are in school they ought to know something about the outside world. There ought to be some things that are very basic; some things ought to be applied.

DR. REICHLEY: Dr. Seeger, on behalf of the students, the faculty, and the Commandant, I really want to thank you because you sure got us interested in basic research and its place and importance in national security. Thank you very much.

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