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A Scientific Society—The Beginnings

Our nascent scientific society has ingested science but has not yet begun to digest and assimilate it.

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John Wesley Powell was a man who stands large in the history of American science. He believed in the frontier, and he lived on it vigorously and adventurously, whether exploring the Colorado or insisting upon good science policy in Washington. Powell was a man of great vision. He saw clearly how science and engineering could develop the vast potential of the West to help make ours a great nation. He understood the nature of science and technology, and his Geological Survey demonstrated the usefulness of properly administered government science. It is with pride, therefore, that I speak in Powell's name, here in the West he knew so well.

As I prepared for this lecture and considered some of the developments in science since Powell's time, my thoughts drifted to personal reminiscence. I recalled that in this season 21 years ago, my colleagues and I were doing the experiment which resulted in the discovery of plutonium. Needless to say, my world has not been the same since. Nor has my experience been unusual. The same forces that have operated in my case have markedly altered the lives of many millions of people and, indeed, society itself. Granted that allowance must be made for the lack of perspective that accompanies our closeness to the events, it still seems pardonable to judge the past two decades to be one of the most portentous periods in human history. And this has been the result of science and technology.

I believe these things to be true not alone because of man's novel dilemma, revolving about nuclear weapons and the very survival of modern civilization, but also because of the general scientific-technological progress most dramatically exemplified by the peaceful atom and by space exploration.

What is perhaps more important in the long run, granted our ability to avert total nuclear war, is the fact that in these two decades science and technology have become a dominant force in our social order. Much has been written about the scientific society, usually in the future tense. I believe we are warranted in changing the tense to the present. Although it is in its infancy, the scientific society has arrived; it has crossed the threshold in its relationship to society as a whole.

Science and technology are now part of the fabric of government, industry, and business, and of our social institutions. The destinies of individuals and peoples are irrevocably associated, from day to day, with the growth and use of scientific knowledge.

As was to be expected, the birth of the new infant has not been an easy one. Nor will its development be untroubled. It seems clear that science and technology are the most powerful forces for material advancement unleashed by man. The changes these forces bring—and will continue to bring—run wide and deep through society. Men as a whole are not friendly to such changes and forces. But to scientists, these developments may seem clearer than to most men.

The author is chairman of the U.S. Atomic Energy Commission. This is the John Wesley Powell lecture, delivered 27 December at the Denver meeting of the AAAS.

Origins

The conception of our infant scientific society can best be assigned to the Renaissance. At that time, men challenged authority and the dogma that had ruled for centuries and questioned the nature of the universe and man's place in it. This spirit of questioning in the Western world occurred on many fronts—in religion and philosophy and political theory, in art and literature, and in science. One important result was the expression in the Declaration of Independence and the Bill of Rights of the Constitution of the idea of individual personal, political, and intellectual freedom as controlling in an organized society. The same forces that liberated men politically, and in other ways, also produced the scientific method. With the growth of freedom of inquiry and the development of techniques for discovery, there began an acceleration of our ideas about nature. And the knowledge gained became highly significant when translated by technologists into tools.

Through our privileged perspective, we can see that, given the conditions of the last five centuries, everything that has happened has been virtually inevitable. For the achievement by men of the right to search for truth was the critical breakthrough. When this right was established on a continuing basis, it was only a matter of time until bacteria were discovered, electricity was identified, and nuclear fission was revealed. In a word, modern scientific knowledge and its application are a consequence of the vigorous exercise of the freedoms that arose in Western Europe and America.

The Past Two Decades

I should like to introduce my stock-taking of the 20 years now ending by recalling some personal experiences to illustrate, in an anecdotal way, something of the changes within science and its new relationships to society.

In the fall of 1940 I was a young chemist at the University of California. We had been trained to believe that a deep gulf ran between pure and applied science. I was "pure," of course, searching for knowledge for its own sake. We were also poor—a property which followed purity like the night the day. But being pure, we could accept poverty with good grace and even with some pride. Our poverty, of course, pervaded our research operations. Research funds were almost unknown. We built as much of our equipment as we could, or coaxed our more talented friends into helping with it. Laboratory space was hard to come by. I can recall, as a graduate student, adopting the squatter's-rights technique to obtain some space in an abandoned and condemned old wooden structure. But these were the accepted conditions of research science in those days, and we were hardly aware that our difficulties were difficulties.

The Lawrence Radiation Laboratory was a new kind of thing on the scientific horizon. It gave us a foretaste of things to come in some fields. The equipment was huge—by 1939 there were two cyclotrons that were giants of scientific instrumentation. Scientists from a variety of fields found it profitable frequently to pool their talents in working with the cyclotrons and their products. In this way many of us encountered the emerging concept of group research. The laboratory budget, mostly from private sources, was considered enormous for the time, although this view might arouse some amusement today.

Of course, we were not unaware of what was happening in the world—of the war that had started, and of the power-mad dictator who was a threat to our ideals and who aspired to engulf humanity in his medieval social order. But, like many research scientists, I did not then relate my work very much to practical things, and certainly not to war.

Until 1940, my research had been concerned with the identification—with J. J. Livingood, primarily—of new radioisotopes. In the spring of that year, Edwin M. McMillan and Phillip H. Abelson opened the transuranium field with their brilliant discovery of element 93, neptunium. It is an interesting commentary on the thinking and the priorities of the time that McMillan, who had started work aimed toward the discovery of the next higher element—element 94—was called away to do defense research on radar at the Massachusetts Institute of Technology.

With the assent of McMillan, three of us—my associate the late Joseph W. Kennedy, Arthur C. Wahl, at that time a graduate student, and I—undertook to continue the research. It seems doubtful that many theses have been written that contained significance to rival that of Wahl's. A few days before Christmas, in 1940—just 21 years ago—the cyclotron bombardment was made which, in the succeeding few weeks, resulted in the chemical identification of plutonium. Plutonium may be said to have "come of age" as this meeting of the AAAS takes place.

Even at Christmas time in 1940 our work was not done in an atmosphere heavy with a sense of historical import, but rather in the carefree manner of young adventurers breaking new ground. It is true that fission and its implications were then known, and that some steps were being taken to learn how to exploit this discovery, in work with uranium-235. It was theoretically postulated, too, that an isotope of element 94 might be fissionable. Yet there was not, 21 years ago, any clear idea of how the then-identified element, if discovered, could be practically made in quantity and how it could be put to use as a military weapon.

Subsequently, with Emilio Segrè, we created and identified the fissionable isotope plutonium-239, in March 1941. And a way was soon visualized to make this element in quantity and to use it as a weapon. In a short time the knowledge gained in the search for truth became a formidable bulwark of national defense.

We crossed the divide between science and technology, and our work became useful in many ways, including its significant contributions to our arsenal of defense. We went from poverty to relative riches. Instead of working alone or with a colleague or two, we banded together in the team research pattern now so well established.

At times, during the war, we dreamed of a kind of scientific V-day after which we would return to the old ways, most especially the pursuit of knowledge for the sake of knowledge alone and divorced from application. Some of you probably were with me in the great hegira to fundamental research which actually did occur at the end of the war.

However, a large number of us found that the conditions of science had changed, in varying ways and to varying degrees. Perhaps the central point is that two decades ago science was called up, as it had been in the Civil War and in World War I, to fight a five-alarm blaze. But this time, in a sense, science did not return to the firehouse.

The use of the nuclear bomb crystallized, as never before and on a world stage, the enormous power of science and technology. But this power was not to be confined to war alone, but was to be used for man's benefit in the expansion of industrial productivity and the advancement of our economic system generally. Later in the two decades of which I speak, Sputnik further dramatized the lesson.

Moreover, the realization grew among us and among industrial and political leaders that the time fuse between discovery and application had become short and was growing shorter. The gulf between basic and applied science had narrowed, and in some instances had become imperceptible. This realization was expressed in many ways: for example, while the government after World War II continued the development of nuclear weapons, it dared not fail to support, at the same time, the fundamental research in particle physics. In addition, under the conditions of modern competition between great nations, the prestige and power of a society came to be measured in part by its accomplishments in the growth of all knowledge.

Science and Society

In the past two decades, then, science has come to stay, as a regular, essential, and pervasive activity in modern society. The signs that ours has become a scientific society are all around us. Suffice it to say here that government, business, and industry are dependent for survival and expansion not alone on technology but on an accelerating growth of knowledge deriving from research that once was sometimes described as "pure." Moreover, it appears

that nearly everyone is aware of this fact.

Let me give just one example of these developments, relating to the governmental agency of which I have the honor to be chairman. In 1940 there was no such thing as atomic energy. Today, atomic energy is one of our biggest enterprises. The capital investment of the Atomic Energy Commission is $7.5 billion before depreciation. Its annual budget is $2.5 billion. It is true that approximately 75 percent of this is devoted to defense activities. Yet, some $600 million per year are also dedicated to peaceful arts—to the development of productive industries for the present and the future, such as power reactors and research on controlled fusion; to the advance of medicine and its application; to the growth of knowledge in many areas of fundamental research; to the export of materials and techniques as a part of our international relations program. In addition, there is the private atomic energy industry, involving nongovernmental expenditures of $50 million annually on development, and with a capital investment of $400 to $500 million. And we can hardly visualize the ultimate potential of this great private industry. Yet, all of this emanated from one discovery in basic research.

The new relationship between society and science is also reflected in the spectacular growth in the numbers of people who are engaged in research and development or who play supporting roles in these efforts. It is to be seen in the federal budget for research and development—some $9 billion annually today, as compared with about $400 million in 1940. Even more important are the new attitudes—of society in general toward science, and of scientists toward society.

The former is symbolized by the policies of government and industry. Recognition by the government of the need to support basic research across a broad spectrum was slow and spotty after World War II. The tendency has been —and continues to be to a large extent —to support fashionable or dramatic areas and those that might have some early, foreseeable technological value. Considerable progress was made, however, in the early postwar days as a result of the enlightened policies of the Office of Naval Research and the later policies of the Atomic Energy Commission. The National Science Foundation has significantly expanded the concept of governmental support for broad advances in fundamental knowledge, and I believe this trend will continue and will increasingly embrace the policies of special agencies that support research. Today, about 12 percent of the federal funds for research and development are used to support basic research fields. In other words, we can detect a fairly general recognition of the fact that the growth of fundamental knowledge, even though it may not have specific foreseeable application, contributes to the general welfare. Perhaps we can even hope for an appreciation of the more subtle cultural values of basic research.

The enormous impact of the past two decades on the scientific community reflects significant integration of science into society. I do not detect any qualitative change in the spirit of scientific inquiry, fortunately. But it would appear that there is an important alteration in the attitude of scientists about the relationship of their work to the larger social environment. Many of us can recall a fairly general feeling of pride among scientists in the isolation of their work from the practical affairs of men. Indeed, it was not difficult to find resentment at any implication that a piece of research should have more than the remotest connection with application. Now, with the reduction of the time gap between basic and applied research, and with growing general appreciation of the value of knowledge, scientists seem more willing to relate themselves and their work to social objectives.

The material conditions have been modified, too. More and more, scientists find that they are supported adequately, if not opulently, and for sustained programs. Funds are available for "elegant" equipment that saves time and gives investigators greater power. Money can be obtained for assistants to do detailed work, giving researchers more time for creative effort. The improvements are not uniform, of course. Space to work is still in short supply, especially in our graduate schools, though new governmental policies promise some alleviation, and the personal rewards are still relatively less for those who train our scientists and generate much of our knowledge than for many others in our society who play much less significant roles.

The consolidation of science into society is striking in the field of governmental policy and international relations. The government has become increasingly dependent upon scientists for advice. This is true not only in the sphere of the administration of government science but in a much more comprehensive way. Any evaluation of the future of the economy must embrace scientific and technological knowledge. Decisions in military matters are intimately involved with science and technology. And any commitment of portions of our national resources for science and technology themselves must be decided with the help of men of wide knowledge in these fields.

The entry of scientists into areas where they serve the nation in important advisory capacities is an inevitable concomitant of the events of the last 20 years. I believe it is a healthy and essential development, and I have advocated it for many years. It does not seem to me that the influence of scientists in this respect is greater than it should be; indeed, in the national interest, I believe it must increase.

The question of the place of science in government touches upon some of the critical questions about the future evolution of a scientific society in a democratic context. Our aim must be to use science to strengthen democracy, not weaken it; to expand the potential fulfillment of the individual, not decrease it. We must avoid any erosion of the broad base of informed participation by the electorate. In the past two decades our democracy has ingested science, but it has not yet digested it—a measure of the infancy of our scientific society. This is not surprising, since our previous experience had not prepared us for anything like the explosion of those 20 years. We must expect the next 20 years to be even more dynamic. Therefore, it is urgent that we accelerate the process of assimilation.

Science and Humanism

A central problem in assimilation, it seems to me, is the extent to which men, including the otherwise well educated, fail to identify freedom of scientific inquiry with our political and other freedoms. In the somewhat less complicated world of the 18th century, a great thinker like Thomas Jefferson could be all at once a political theorist and practitioner, a philosopher, and a scientist. His mind could embrace and integrate a very large part of human knowledge. He had, therefore, a clear

appreciation of the broadly humanistic values which are the common heritage of all men who pursue the truth.

But as knowledge grew and fragmented, the specialties went their separate ways. Science has seemed to walk more apart than other fields, perhaps because the details of scientific truth touch infrequently a community of intellectual experience. Science became a stranger even to many intellectuals.

This estrangement has resulted in the paradox with which we are familiar: as science became more important to society, it apparently became less important in the curricula of liberal education. This fact was noticed as long ago as the last century by Thomas Huxley, who pleaded with contemporaries holding a narrow view of humanism to include a more generous helping of science in liberal education. A cultured or liberally educated person, Huxley maintained, is one capable of making a criticism of life—of evaluating the environment and making enlightened judgments.

Thirty years ago George Sarton wrote in the same vein in his volume *The History of Science and the New Humanism*. He stated the issue, which remains central for our nascent democratic-scientific society, as follows: "The main issue does not simply concern humanism but the whole of education from the cradle to the grave. And the real question is: will education include science, or will it exclude it? The intellectual elite is at present divided into two hostile groups—which we might call for short the literary and scientific—who do not speak the same language nor think in the same way. If nothing is done, the gap separating them must necessarily increase, together with the steady and irresistible progress of science. Shall we deliberately widen the gap as the old humanists would have it, or shall we take special pains to reduce it as much as we can?"

In our time, C. P. Snow has eloquently drawn attention to the same problem, in his discourses on the "two cultures."

To summarize the matter, I should like to ask a question paraphrasing Huxley: Who in our times can make an adequate criticism of life without knowledge of the ideals, the methods, and the dynamics of science?

The remedies have been widely discussed: a larger content of science in the lower schools and in the universities and colleges; a wide range of efforts to give the public some appreciation of science; a greater effort by scientists to explain their work in popular terms.

All of these measures are needed. It is necessary to bring about a larger understanding of scientific principles. But in striving toward this goal it may be even more important to promote a greater consciousness of the common heritage of all who pursue the truth. The philosopher, the social scientist, the artist, the writer, the natural scientist—all are intellectual brothers under the skin. Whether their technique involves the distillation of human experience or the ordering of measurable phenomena into statements of principles, their motivations, the quality of their experiences, and their satisfactions are rooted in a broadly defined humanism.

I am sure intellectuals generally know this to be true. Yet it would appear that it is often far back in the consciousness. I wonder if this fact is not responsible for much of the inability of Snow's two cultures to communicate? I wonder if there is not a common language, deriving from a community of basic ideals and purposes, whatever the details of different bodies of knowledge, that is the foundation for communication? I wonder if the barriers are not superficial, even as language is a superficial obstacle between men who share common bonds?

The achievement of a conscious, working realization of the common heritage of truth-seekers—among scientists as well as other intellectuals—can be significant in the successful evolution of our new kind of society. It should make it clearer that the free and uninhibited pursuit of truth in science is a natural part of the right of free inquiry that is inherent in democracy. It should do much to abolish fruitless discussions over whether we should continue the pursuit of science and whether scientists should not withhold scientific truths that may be used destructively. It should give wider acceptance of the inevitable growth of knowledge and of its continual change. It should force us to a greater awareness of the need to prepare for and to cope with the hazards that are a paradoxical by-product of the expansion of knowledge.

It has seemed natural to lay some emphasis on science in this discussion of the society that has developed in the last 20 years. I do not wish to give the impression, however, that I believe this new kind of society is the property of science. We cannot, of course, proceed intelligently without integrating into our thinking and our acting the full range of human wisdom. You will note that I have asked primarily for men generally, and for intellectuals in particular, to return science to the fold of humanism. It is unthinkable that a democratic-scientific society could evolve constructively without a wide endowment among its people of art, music, history, literature, and social dynamics.

Continuing Crisis

We can hardly discuss the future of the scientific society without relating it to the world struggle and the terrible dilemma confronting man as the result of the development of nuclear weapons.

I am reminded of the reaction of many scientists, including some of us who worked on nuclear weapons, to this dilemma, when it became a reality in 1945. Natural scientists sometimes have been called too optimistic and naive by social scientists. As a group, they are not lacking in idealism. Perhaps it was natural that many of us, recognizing from close at hand the significance of nuclear weapons, set out to advise the world that nuclear war was out of the question. To us, the data were unequivocal, the conclusions indisputable, and the course of action clear. We felt the world would quickly see this—and, seeing it, do something about it.

The half-life of disillusionment varied from individual to individual. Few have changed their minds about nuclear war. But many have become more sophisticated, if less idealistic. Much of what has been described as naiveté has rubbed off. But we should remember that idealism, happily, has not been limited to scientists. In the period following World War I, experienced statesmen, imperceptibly influenced by scientists, solemnly signed unrealistic treaties outlawing war. Perhaps sophisticated statesmen, aided by sophisticated scientists in an age of science, may be able to combine realism and idealism.

My own instruction in these matters includes the experience, earlier this year, of being appointed by President Kennedy to head the U.S. delegation to the 5th Annual Conference of the In-

ternational Atomic Energy Agency, in Vienna. This is an agency established to spread the peaceful uses of atomic energy throughout the world. Its problems, I found, are hardly less difficult than those of the United Nations.

I was impressed with the enormous difficulty of finding common solutions to problems when the effort had to be made with individuals who seem to speak a different language, not only linguistically but ideologically, and some of whom appear to possess a deterministic faith that is alien to our humanism.

While I found no basis for arrant optimism, neither did I find reason to stop trying. In the absence of any foreseeable breakthrough in diplomacy, it would appear that the best condition of the world we can hope for is a continuing crisis. In the competition of ideas which will accompany the crisis, the victory may be won by the successful evolution, here, of a society combining science and freedom.

Scientists and engineers can continue to make a major contribution in this contest, not only by achievements in the laboratory but also by participation in exchange programs and international meetings, and in other contacts with Iron Curtain nations through the medium of basic research, when and if the occasions arise. All these activities are essential to help keep the channels of communication and understanding open.

I believe each of us, scientist and nonscientist alike, must be aware of the importance of his own effort to the preservation of a libertarian society in the continuing crisis. Each of us needs a sense of responsibility and urgency, for the total of our efforts will be decisive, however remote from combat our work may seem. We must not do too little. We cannot delay. We must have both determination and good intentions; and what is most important, *we must act*. As I have advocated in the past, we must expand and raise the level of education all along the line. We must, especially, search out and cultivate the gifted and creative, for it is these who usually make the great breakthroughs in knowledge and understanding. We must mine every vein of our human resources and exploit our talents in the fullest measure.

The Preservation of Freedom

The democratic-scientific society has taken root in the past two decades, combining the values of freedom and individual worth with the promise of growing material well-being. Can we preserve it—not only for ourselves, but as a choice for other peoples?

I believe we can and will, partly because of the moral strength of freedom and partly because of the material power of our new society. We cannot be blind to the fact that freedom needs strength and determination as well as a good heart. Generosity has its place in relations between men, but it is, unfortunately, a quality not uniformly respected by all nations in relations between themselves. This is why, for example, we must be prepared to negotiate from a position of unquestioned strength as well as undoubted good faith. And negotiate we must; to turn our back on this most hopeful and sensible solution of the differences between East and West would be as foolish as it could perhaps be fatal. But we must recognize that until all nations can proceed from the same definition of right and truth, international agreements which involve our vital interests must incorporate provision for adequate controls against violations as well as provision recognizing the other's rights. We must be firm when our own security is at stake, as well as fair when another's is. I cannot help but recall, in this vein, that eloquent passage from President Kennedy's inaugural address: "civility is not a sign of weakness, and sincerity is always subject to proof. Let us never negotiate out of fear. But let us never fear to negotiate."

Beyond these principles, my confidence in freedom is based upon a personal faith, originating in my interpretation of human experience, to which one must appeal when scientific data are lacking or inconclusive. Many times in history the future has not looked bright. However, the things most feared have not always come to pass. Man's native faith and hope in his own destiny have motivated him to solve awesome problems. History does, we know, repeat itself—both in crises and in their resolution—and so, we must trust it will again.