

should distract us from setting goals for human use of such quality as to absorb constructively and beneficially any and all of the scientific findings to come.

On the other hand, we see the culture of science itself gaining from this endeavor, because the way of seeking these goals will demand an ever-increasing combination and even a fusion of scientific skills, from what have been called, up to now, "different" sciences. While the endless variety of approach to science must be zealously preserved, these differences between sciences will grow less and less. Many of us believe that this change itself will aid emergence of great unifying principles. (Think, for instance, of information theory, of the coding of electrical signals, of the coding of nerve impulses, of the coding of bases in nucleic acids and of their influence on protein configuration.) For those in science and engineering who seek to solve a worthy problem, and to reach an end which is important, broad, meaningful, are finding ways more and more to bring all kinds of minds and skills to work together.

SCIENCE AND THE SATISFACTION OF HUMAN ASPIRATIONS

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Ladies and gentlemen, here we are at the end of a long day after almost a week of much talk. Our next appointment is not till 7:30 this evening. I therefore have plenty of time to devote to my topic; however, my audience would decay exponentially. I hope not to detain you for long, for it is well known that only very few souls can be saved after half past three in the afternoon.

In this conference we have heard from some of the most eminent men of science in the land. Day after day the mysteries of life were laid bare, and antecedent to life the structure of matter and, indeed, of the universe were presented in dramatic and fascinating clarity. Although no attempt was made to make a real interdisciplinary connection between the various disciplines, nevertheless, the juxtaposition of topics did a very great deal to show us the essential unity of the scientific disciplines, however different their techniques. The very first day we went in progressive steps from the origin of the elements to the origins of life. In the second day we went from the almost philosophical consideration of the organization of the laws of nature to the organization of living matter. This afternoon, turning to less immediate questions, we have had a general overview of science from the aspects of communication and application both to industry and to public policy and welfare. We listened to great wisdom.

It is now my turn. The task assigned to me was to address myself to science in its more intimate relation to the individual: science and the satisfaction of human aspirations. The drives which cause men to become interested in science are almost as various as human personality. Science could not happen without a range of personalities and cultures. We see the interplay now of cultures in the successive contributions of Egypt, Babylon, Greece, Alexandria, Rome, Arabian-Italian Renaissance, and in the modern era Japan, America, and China, which should

perhaps be all by itself. There is the collector and classifier who may interest himself in stamps, books, pictures, or, on the other hand, in phases of botany, geology, astronomy, or even in parts of physics such as spectroscopy. We should not use the term "mere" with respect to these activities. High talents of intellect and insight can be devoted to these aspects of sciences. The hunt for a new species of plant or animal, a new spectral sequence, a new collection or system of galaxies can be both exciting and demanding. Ingenuity, persistence, and what may be called luck are necessary for success in these endeavors. The born hunter and alert observer will find success and satisfaction in this phase of science. We would be nowhere without this type of individual.

Basically, this element of science satisfies more immediately the desire to discover and to know the facts of nature. Nature with tremendous variety and charm captures the fancy and the spirit. To one person a fact is just a fact and of no further interest. Such a person may become a mathematician or a logician, but he will never be a true poet or scientist. The scientist, the experimental scientist at least, shares with the poet and artist a feeling for the value for the immediate and the empirical face of nature. The geologist loves his bright and shiny stone, his curious fossils, just as the physicist can never cease to be charmed by a spectrogram or the delightful paradoxes of the motion of a spinning top.

This aspect of the pursuit of science satisfies a basic desire or aspiration just to know, to find out, or perhaps make order out of the otherwise chaotic jumble of immediate experience. It is an aspiration shared with all mankind but more with youth and childhood than with adults. In this sense scientists are just children who never grew up, who never lost the nagging urge to ask how, why, and what. Like children, who in all innocence and high excitement bring a dangerous spider into the house and frighten the wits out of their elders, the scientist emerges with a smallpox vaccine or an atomic bomb.

There is another facet of human aspiration which contributes to the various faces of science. This is man in his aspect of the maker or doer. Again this aspect is strongest in childhood but persists longer into adulthood since its immediate use is obvious. The use of tools, the arts and crafts, are the hallmarks by which we rank prehistoric and primitive civilizations. Of course, arts and crafts are not yet science, but share with science the manipulation of nature. The one is to satisfy the desire for material needs of food, shelter, decoration, and of course armament. This is the usual, the normal—the sort of thing which is immediately understood by men of maturity and judgment such as we find in Congress. The other, the less practical but in the end more powerful, is to manipulate nature not for immediate or material ends but for the purpose of providing new knowledge or the tools which could provide new knowledge. This is the method of science.

It is rare that this aspiration for discovery is sufficiently understood by any community to the degree of actually providing funds for this purpose. Either the curiosity of childhood is soon lost (perhaps this change may have an actual survival value for the race) or somehow those who possess the gift lack the ability to communicate the deep meaning, the excitement, and the satisfactions of scientific discovery.

This question should be of the greatest concern to our scientific community. Unless the public shares in our aspirations and our satisfactions in the scientific

enterprise, the pure scientific impulse will always have to be diluted and even distorted with immediate ends, which in the last two decades have been primarily military.

I see nothing ignoble or degrading in the application of science to the defense of one's country—quite the contrary.

On the other hand, when the support of science is tied both administratively and by public interest directly to military and other purely practical uses, one begins to feel that somehow we as scientists have failed to arouse either interest or understanding in the public mind. We have failed to satisfy the aspirations which they share with the scientist by taking them with us as we go further along the road of scientific accomplishment. This community of interest which we have with the youth of the country in considerable measure does not extend to the adult population. Surely, science is not only for children young and old.

I will not infringe further on what I have hoped would be Dr. Oppenheimer's domain of science and communication, but go on to still another facet, perhaps the most significant of the scientific adventure, or scientific movement, or, as I prefer to call it, the scientific culture. In this, we share with the poet and artist the delight in immediate empirical experience with its aesthetic, emotional, and intellectual values, but we go further, not to express this experience in the language of the heart, but in the prose of the catalogue, finding similarities in differences and presenting the results as an intellectual structure which can inspire pleasure and interest. We share with the practical world the manipulation of nature but not principally directed to useful ends or ends which are said to be useful. Our ends go further, but we do share with the artisan and the engineer the pleasure of invention of novel combinations to achieve what had hitherto been difficult or impossible.

Our goal is a sort of bootstrap operation to utilize the tools of present knowledge to gain new knowledge, knowledge which we could hardly have foreseen or imagined. In these two illustrations I hoped to show that in our interaction with the world outside ourselves the scientific aspirations and satisfactions are basically aspirations which are shared by all. The scientists' satisfactions come in a special form which expresses itself in the desire to broaden and deepen our knowledge and understanding of all phenomena, but whereas the rest of mankind concentrates on man, his feelings and desires, the scientist tries to see the world as it really is or might be shorn of man's perhaps excessive preoccupation with himself. Clearly this is a quest which can never come to an end. Scientific curiosity will never be satisfied because it will never reach its goal to know all and understand all.

Such a goal and such an adventure will hardly satisfy the more prosaic and limited aspects of our human nature, but it nevertheless has a nobility of a kind which in other fields has called forth some of the greatest manifestations of the human spirit.

The third aspect of science which I wish to explore with you, and which may be as I suggested the most significant, is one which we share with the humanities and with religion. Except for some periods of uneasy truce, science and religion have always been in conflict. Since the time of Galileo this conflict has sharpened. Many able men, both from the side of science and of religion, have assured us that there is no conflict between the two. On closer examination, it is apparent that the synthesis

or bridge which they try to establish results only in a devaluation of both aspects of a powerful urge of the human spirit.

The urge to comprehend the visible and invisible universe and to find man's place within it is common to both science and religion. The conflict between science and religion is, therefore, more in the nature of a civil war between two parties with the same ultimate aims of comprehension and of submission to a higher order of knowledge and of insight.

In these matters religion has always taken the lead. Questions about man's place in the universe and his origins had to be given answers in each generation.

The ancient Hebrews could not wait for the discovery of the neutron and the development of the theory of stellar evolution, or for Darwin, Morgan, Crick, and Watson to explain the variety of life and the origins of man and of the universe.

The noble opening lines of Genesis cannot fail to move the most prosaic scientist even today. By means of dramatic imagery and lofty poetic insight, religions have provided world systems more or less complete which gave immediate satisfaction to the yearnings of man for order in the world and guidance in his life. They gave a release from certain fears, although they sometimes substituted others for those displaced. The great human quality of faith was always a basic prop to these religious structures. Religion and religious systems to be fully effective had to become established in law and custom, and in a certain sense their statements had to come to be regarded as self-evident.

Compared to the eagle flight of religious thought, science is more like the humdrum earthbound bulldozer. Where it has passed anyone can follow. Whereas religion is aristocratic and hierarchical, science is democratic and leveling. After the bulldozer has passed, a tangled jungle or many beautiful gardens and buildings enshrined in history and sentiment may be destroyed, but the ground is ready for newer and perhaps even more beautiful interesting cultivation, or perhaps not. In any event, a newer generation gets a new start.

It has often been said that science gives man knowledge but does not tell him what to do with it. These prescriptions and values he is supposed to get from religion or from the so-called humanities. To borrow a phrase from a great scientist, Enrico Fermi, "This is not very true." The great writings of the humanist and holy religious writ can do much to incite men to noble and charitable action as well as to acts of folly and cruelty.

Science can make no such claim. What science seeks to do in its limited way is to delineate the results of action through psychology on the individual himself, through the behavioral sciences on the others, and, above all, to present a choice of means, leaving the decision to an informed act of "free will" insofar as the term still has a meaning. Only those who do not care to make their actions their own will say that science does not contribute to values.

The conflict between science and religion, between science and the humanities, therefore remains. The latter must always claim more than it knows and, therefore, must always retreat and qualify as science advances. "Don't insult me with facts" is the hurt expression of punctured pretensions. The true humanist and religionist welcomes scientific advance because it also allows him to advance his cause with deeper understanding. The Holy Fathers of the Roman Catholic Church have made this point very clear.

In contrasting science with the humanities and religion, the more pedestrian elements of the relentless march of scientific discovery have been emphasized. Actually science does not march in battle order toward a predetermined goal. This would be a contradiction in terms.

Scientists traditionally are free, untrammled, and individualistic. Each sets his own goals following his interests. Such co-ordination as there is comes out of the nature of the subject matter and out of the tradition of the discipline; attempts to interfere, direct, or guide this freedom, as in some countries with overplanned societies, result in inefficiency and frustration of the creative urge. Scientists are well aware that they are prone to error. The observer in his laboratory knows full well that he can easily misinterpret his observation or miss the essential fact. The bold speculator can become so enamored of the beauty and sweep of his hypothesis that he may take it as an end in itself. It must be true, he feels, because it is so elegant. However, the court of highest appeal, which is nature itself, is relentless, and error cannot long survive.

Therein lies one of the greatest appeals of science, an appeal which makes it capable of satisfying one of the greatest of human aspirations—to be a member of a community which is free but not anarchical. Science possesses an infinite variety of limited goals but in the end marches toward a limitless horizon. It consolidates its gains but does not rest on its laurels. Members of this community possess an inner solidity which comes from a sense of achievement and an inner conviction that the advance of science is important and worthy of their greatest effort. This solidity comes in a context of fierce competition, strongly held conviction, and differing assessments as to the value of one achievement or another. Over and above all this too-human confusion is the assurance that with further study will come order and beauty and a deeper understanding.

One cannot close a discussion like this without bringing out one of the greatest rewards of the pursuit of scientific discovery. It comes accidentally and is often a matter of luck rather than the result of planning. It may come in an illuminating flash of insight or in the course of an experiment such as Rutherford's when he saw his alpha particles scattered through large angles, or Anderson's when he saw an electron track moving the wrong way and realized he had a positive electron, or Yukawa's when he saw that a supposed particle could account for nuclear forces. Although scientists don't write about these moments of exultation and ecstasy so different from the everyday routine of research, these fleeting visions can in one flash reward one for years of patient and exhausting work. At these times the scientist is filled with profound awe and humility that such wonders should be revealed through him. There is a quality about science, or rather about nature, which is always miraculous in its originality. To obtain a glimpse of this wonder can be the reward of a lifetime. This itself can be the sufficient satisfaction of the aspiration which makes scientists scientists.

At this point, at the end of my presentation and the end of this program, I can only wish the Academy and all mankind a century of achievement as great as the century which has passed in the life of our beloved Academy.