



TALK TO UNDERGRADUATES

by J. ROBERT OPPENHEIMER

Dr. Oppenheimer, director of the Institute for Advanced Study in Princeton, New Jersey, came to the Caltech campus this month as the first 1957 visitor in the Caltech YMCA's Leaders of America program. From February 28 to March 5 he spent most of his time in informal discussions with students. His one formal address, "Talk to Undergraduates," was given in Culbertson Hall on the evening of March 4. A transcript of the talk appears on the following pages.

I HAVE SPENT enough time here so that not all of you are complete strangers to me; but this is the first opportunity I have had to say some things which, though formal, are nonetheless very much heartfelt. I thank you for asking me out; I think it an honor. Those of you who have met with me, and seen me struggling with questions to which I did not know the answers, must be aware of the fact that I have had many misgivings as to whether I rated the honor. I want to thank you for the very great friendliness, the very great frankness and

the earnestness with which you have dealt with me. And I would like to thank you for adding a little to my understanding of the world we live in.

I have a few thoughts on the situation we face that I would like to talk about tonight. Of course, what I say is not only incomplete and partial, but there is a very special ground for some humility in what I do say. Between your generation and mine there are differences that neither of us is likely fully to understand. I am aware of this gulf and I don't underestimate it.

There is another reason for humility: What you have to deal with is partly the heritage of what the generations your senior have left you. I think we have no great reason for pride in the heritage. The problems seem to me very grave, and the measures and means for dealing with them and resolving them nothing to write home about.

Peculiarities of the time

Before talking about the specific problems of learning and ignorance—as they appear here, and as they appear in a larger sense for all of us—it may not be too bad to remind ourselves of some of the peculiarities of the time. It seems to me an extremely peculiar age. All ages are; but I am in some doubt as to whether there is any valid historical analog to this time.

I was reminded today of a story; and before outlining some of the traits of the mid-twentieth century, I may repeat it. It has a kind of moral, I think. A friend of mine signed up in the Army, after Pearl Harbor. He is a Greek philologist and philosopher, and the Army understood that he was a clever man and put him to work in Intelligence. Part of his job, in preparation for the invasion of Europe, was to interview men who had participated in the Canadian raid and in the evacuation from Dunkirk, and one day he talked to a fellow who had been the communications officer for his outfit. This fellow had come moderately late to Dunkirk and there were great masses of men on the beach waiting to be evacuated. So he dug down in the sand and turned on his radio and listened. There was a little bit of music—and that was all right—and then he got a BBC broadcast. The broadcast described how the ships were standing off to sea, waiting, and the men were waiting in long lines, and the Germans were approaching, and overhead there were dogfights—and the fellow said, "It was much too horrible; I had to turn it off."

So it is whenever we take an appraisal of our situation. One of the features of this time is that we live under a palpable threat of an apocalypse. I have talked with you enough so that you know that I don't regard this as inevitable; on the contrary, I think that for anyone who has an opportunity of working to avert it, that is a valid full-time job. It isn't like the apocalypse that was expected in the year 1000, but it is very much at the back of our minds in everything we do.

It is a strange time, too, in that never in the history of the world has there been as rapid a growth of knowl-

edge, as rapid a growth in understanding, or as great changes. I suppose that, in the 18th century, men talked about how knowledge doubled every 50 years. I think we could make a case for saying that it doubled every 10 years now.

This creates problems of which I will talk mostly tonight. But it also creates problems of the use of that knowledge, of the vast powers that it seems to make available, of the choices. It creates a world of incredibly rapid change. Almost nobody can look back to a schooling with a feeling that it is entirely relevant to the problems that he is now dealing with. Almost everyone has to have the sense that he goes to school all his life.

In some ways, this situation, which I think is a natural continuation of the fluidity and openness of American society—an openness now not with regard to the physical frontier, but with regard to the frontier of knowledge—has given this country a strange destiny. I cannot believe that other parts of the world will not also very rapidly be caught up in changes comparable to those in which we live. They are not prepared for it; they have remained in relatively steady, relatively quiet, relatively enduring forms. And how we deal with this, certainly will not be an example that other peoples will inevitably or rightly follow. But how we deal with it cannot be irrelevant to the future of the whole world.

A characteristic irony

This is also a time when the very rapidity of change seems to me to underline the irony that is so characteristic of history—the irony which makes the event, the outcome, so different from the human purpose.

Think of the communist movement; it began in compassion, and now it is probably the least compassionate of any major political force the world has seen for a long, long time. Think of China, with its pattern of respect and love for the family and the past, its addiction to reflection, and almost private beauty. Think what the Chinese have embraced in the way of forced, quick, violent, brilliant change—and how little they are prepared for it. Think of India, if you will, and a government in India which is a direct consequence of Cambridge, of Oxford and of London—these symbols of two centuries of oppression. And think of us, who founded ourselves in independence, and who are inextricably stuck in the most monstrous kind of interdependence—both here, where the vastness of all our affairs makes the individual's wink invisible, and even interdependent with very remote parts of the globe. Think of the irony of the great weapons, which, developed to give a military answer to the problem of security, have assumed such proportions that they almost cannot be used, and have produced for the general staffs that evoked them a nightmare of almost total insecurity.

All these things—and there are many more—could easily, it seems to me, make in the times a kind of bitterness and a kind of feeling that the individual had better see to his own delight and to heck with society, to heck

with virtue. That is not so different from the way it was in the decade when I grew up, after the first World War, where a kind of revolt was characteristic in the colleges, and in the arts. It was a revolt which said that what we have had from the past was not much of a guide for the future, a revolt where there was a hope of improvising something gay and new, where the bitter fruit of that terrible war seemed to call for a kind of new, fresh departure.

It isn't really quite like that now. I think that today, if I know you and your friends through the country, you hold very close to the ancient imperatives—the imperatives of Christianity, of our traditions, of our country. I think you are not after novelty and improvisation in art or politics or philosophy, or manners. I think that, even if the end of our time should come, you are quite content that we live out these days faithful to the gospels, faithful to the ethic, faithful to the sense of responsibility, which we have from times past.

These are some of the things that are in the background. Of course, the present problem of young people at college is the same everywhere. They are finding their way into an enormous cognitive jungle, the jungle of everything there is to know. They are finding their way into it with very little guide, either from synoptic kinds of knowledge, like philosophy, which say: This is important; this is unimportant; this fits in here; this fits in there—or from the state of the world, which doesn't, in any very clear or loud voice, say: Learn this; ignore that; learn this well; skip over that lightly.

Impossible choices

There is, in most places, the vast trouble of impossible choices. I have talked with and been among undergraduates—and school boys and graduate students as well—in some places around the country, and a typical agony is: "What do I do? Where am I headed?" The complement of that, of course, is to be told what to do, and in a measure, that is what goes on here. I think it varies from place to place, and there is no doubt that Caltech is far on one side of the spectrum—of the spectrum between openness and permissiveness on the one hand, and rather strict and specific guidance on the other; between knowledge as an end in itself, something to study because of the joy of it and the beauty of it—and knowledge as an instrument, as a way of getting on in the future. I think Caltech is very much on the instrumental side, and very much on the predetermined side.

But the sense of loss which I hear in you—I don't know whether it is exaggerated in our talk but I'm sure it's there—of the things which you are not studying; the sense of loss at all that you might be learning, and aren't; the slight fear that this might not be easy to make up at a later time; this is a much larger thing, a quite general part of human life. There is much more that one might know than any of us are ever going to know. There is much more to know than any of us are

ever going to catch up with; and this is not just the trivial fact that we don't work hard enough; it is not the trivial fact that things are difficult to learn. It is that any form of knowledge really precludes other forms; that any serious study of one thing cuts out some other part of your life. Narrowness is not an accident of one place, but it is a condition of knowledge.

I think myself that, with the growth of knowledge—the immense perplexity, the pervasive mutual relevance of different things to each other—all we can do is to accept the state of affairs, to affirm it and to accept it deeply. It is not that some courses are not better than others and some worse, some even good and some evil; it is that, in the balance between ignorance and loss on the one hand, and knowledge and richness of experience on the other, we have to keep the affirmative love of the knowledge and the richness very close and never deny that most of what men can know, we don't know; that much of what man can know, nobody knows.

Of course, in a certain sense, this is trivial and people have always known it. When it comes to the will, the element of choice has always been clear. The fact that you had one course which precluded another; you could take a job, or you could continue to study; you could marry, or you could say goodbye; everybody knows that. But I think it has not been quite as clear how, in the very conditions of knowledge, choice is built in and exclusion is part of depth.

I don't want to try to derive this from anything in science because it seems to me quite deep and quite commonsensical, and very much a part of all our experience. But I do want to give three examples from three different areas in science which illustrate it rather sharply. One is from the physiology of perception, one is from the psychology of learning, and one is from physics.

The philosophers like to talk about sense data as though they were something that came to all men who were properly constituted, a replica, a picture, a sign of something outside; and all philosophers have always been very confident that the sense datum was something very solid to build on. But, in being able to perceive, we take a far more active part, and not necessarily a conscious one.

A simple experiment

There is, for instance, an experiment of great simplicity having to do with hearing. The nerves running from the hair cells in a dog's ear toward the cortex can be tapped, and one can see what kind of electrical impulses travel along them. And if you take a dog so "hooked up," you will soon learn to recognize the electrical pattern of the signal that comes along when the dog hears a bell ring. If you put a piece of meat in front of the dog, that signal disappears. The way this happens is that, along with the afferent nerve fibers, there are finer nerve fibers which, so to speak, tell the nerves what to do, what to hear and what signals to send. This is not understood in detail. But the coding which we

always assume characterizes the human brain — the organization of material, the focusing of attention, animadversion, concentration, memory—this coding pervades the most primitive parts of the cognitive system, and the dog may or may not hear the bell. It isn't something that he fixes up inside himself; it is a question of what he is attuned to.

There are very similar experiments, having to do, for instance, with language—a whole series of them reported from the Harvard Cognition Project. It is astonishing what people will notice and what they will ignore. For instance, if you take some sounds that have some variations in them and say them, then an American who is attuned only to our language will hear differences—but only those differences which correspond to the way we spell and write, to our phonetic elements. Of course, we don't spell and write very accurately, but we recognize *a* as distinct from *e*, and *r* as distinct from *n* and so on. If you take a Navaho who doesn't know English, he will hear quite different things. He won't distinguish our vowels, but he will distinguish by the length of the vowel. You can teach the Navaho to notice the English differences and the American to notice the Navaho differences, but he doesn't normally do it. The possibility of communicating, of course, rests on the fact that we don't hear too much. You are hearing my talk, but only that part of it which really has meaning in English. All the rest of it—the rumble and roar that goes with it—you don't hear. It isn't that you hear it and ignore it.

Of the incredibly many examples, one of the most striking comes to anyone who tries to translate the words for colors from one language to another, even two languages that are Indo-Germanic. The English words for color distinguish spectrally what we call color, by the hue. The Greek words have to do almost entirely with depth and brightness, and you can't find a Greek word for blue. You can find one that sometimes means blue. All these questions of animadversion are extremely primitive.

An example from physics

And what is the example from physics? It is the one that I talk about much too much. Of course, if one is now learning atomic theory, one learns Schroedinger's equation in quantum mechanics, and it all seems very unphilosophical and practical. It is a wonderful way of describing atomic phenomena, and one tries to get the techniques and get it over with. But to anyone who lived with the development of this, it was quite a different story, because what one had to get through his head was something quite odd.

We are used to a world in which we can find out anything of interest about a large physical system without in any way questioning the means by which we can find it out. The classical examples are that we can tell where a planet is, and, by observing it successively, we can tell how fast it is moving. The question whether this ob-

servation could have any paradoxical features in it never arises. But in atomic mechanics, we had to learn that, although experiments in some ways like finding where a planet is, and in some ways like finding out its velocity, are indeed possible, and are indeed a part of describing what is going on. The kind of arrangement that is suitable for doing one of these experiments not only makes it impossible to do the other, but makes it logically contradictory to assume that the other quantity has a value, or has one of a number of values. In other words, we came to realize that, in the atomic scale, one can realize, by the way one goes about it in the laboratory, that there is some free choice. This is not free in the sense of an ethical problem, but just free for the physicist to decide what he is interested in or what he wants to study. Having made that choice, one has closed out the chance of doing the other thing, so that both are valid measurements, or so that he can even imagine that he has done both and that each has had a given result. If he imagines thus, and starts to draw the consequences, he will get a prediction for the future of that atom that has no relation to what he will find in the laboratory.

These are just three examples of the pervasiveness with which, in all scientific things, one meets again the fact that knowledge, by the very techniques, powers, and facts of its acquisition, by its organizing the chaos that is the world around us, precludes other knowledge.

A new picture of the cognitive world

This makes a picture of the cognitive world which, in many ways, is not the one we have inherited. It isn't as though we were in a room just looking at it, then, if we wanted to know some more, looking some more, exhausting all the properties of it, being able to talk about it all—as though we were in a temple and could go back over and over again, studying the peculiarities of the temple until there was nothing more to know, and then making a description of this room or this temple which was total and global.

It is much more as though we had deep, not always connected parts of knowledge—knowledge of physics, knowledge of life, knowledge of man, knowledge of history. Between these things that are known to any one of us, there is always potential relevance, so that one can never say, even of the most implausibly abstract kind of mathematics: This will not be relevant to psychology or physics. But the image that comes to my mind is not that of the chamber that can be exhausted, but of an essentially infinite world, knowable in many different ways; and all these paths of knowledge are interconnected, and some are interconnected, like a great network—a great network between people, between ideas, between systems of knowledge—a reticulated kind of structure which is human culture and human society.

This means that I am very suspicious of statements that refer to totality or completeness; that I am very suspicious of our ability to have more than partial knowledge, in the very real sense that it can be supplemented

and that it doesn't close. It means that I am very suspicious also of order which is hierarchical in the sense that it says that some things are more important than others—that some things are so important that you can derive everything else from them. These were great hopes of man, and philosophical systems are their monuments. I don't think that the prospects of their being realized look very good.

The collar

Now, one could take an attitude of real horror toward this and say that one can't live with it—that this is to offer man not knowledge, but chaos. I don't think that is right. We have all had the experience of seeing the relevance of something that we hadn't known before, of learning at all times in our lives something deep and new and wonderful that had been hidden before. We have all had the experience of what companionship and intercourse and an open mind can do; and I don't think the absence of global traits to our knowledge is a cause for despair. But I'd like to read you a poem that seems to me to fit a little, not only with this general situation, but perhaps even with the local situation. It is not a new poem; it is three centuries old and the language is archaic, and I can't be sure you'll like it—but I can say I like it. It is called "The Collar," and it is by a devout Anglican named George Herbert. Some of you may know it; it goes like this:

I struck the board, and cry'd No more;
 I will abroad.
 What? Shall I ever sigh and pine?
 My lines and life are free; free as the road.
 Loose as the wind, as large as store.
 Shall I be still in suit?
 Have I no harvest but a thorn
 To let me blood, and not restore
 What I have lost with cordial fruit?
 Sure there was wine,
 Before my sighs did dry it: there was corn,
 Before my tears did drown it.
 Is the year only lost to me?
 Have I no bays to crown it?
 No flowers, no garlands gay? all blasted?
 All wasted?
 Not so, my heart: but there is fruit,
 And thou hast hands.
 Recover all thy sigh-blown age
 On double pleasures: leave thy cold dispute
 Of what is fit, and not forsake thy cage,
 Thy rope of sands,
 Which petty thoughts have made, and made to thee
 Good cable, to enforce and draw,
 And be thy law.
 While thou didst wink and wouldst not see.
 Away: take heed:
 I will abroad.
 Call in thy deaths head there: tie up thy fears.
 He that forebears
 To suit and serve his need,
 Deserves his load.
 But as I raved and grew more fierce and wild,
 At every word,
 Methought I heard one calling, Child;
 and I reply'd, My Lord.

Having spoken so, and tried to measure what the flowering, changing, rich, but only partially ordered world of the mind means for us, it may not be inappropriate to stress what seem to me a few of the things that will be useful in living with it. They are certainly not new things; they have always been useful.

The first is to have a kind of deep reverence, not, certainly, for the learned man or the stuffed shirt, but for learning, for knowledge and skill; and to hold tight to it, and not to be talked out of it by any superficial parody of what it is, the kind of thing we learn in school where we learn to do and create and understand, and where we learn really to act with the knowledge we get.

This is something that isn't easy to come by. It hasn't been easy for man; it isn't being easy now, and it is incredibly precious; and the world is full of it. Accounts of this—stories (whether in general education or in *Life Magazine*), short cuts, and synopses—miss most of the point. It is just the technique and the wonder of one's own ability to do it that is part of the value of it. And in ourselves and in other people this is, I think, to be held on to very tight. If you have learned how to be something, how to be a competent professional, you will know a great deal about what is good in this world. You will have a bond in common with every other man who is a scholar or a scientist.

The greatest of all protections against narrowness, and the greatest relief and opening, is comradeship, and that ability to learn from others of what their world is like. Learn from books for sure; learn from people, but learn with a kind of sense that every man enriches you and enlarges you if you only have the strength, the wit, the openness, the fortitude to learn what he is all about and what he knows.

The otherness of people

And very much we need tolerance. We are all incredibly different. I think sometimes that one of the unexpected fruits of biological research may be that we can, on occasion, be made to feel more like somebody else than we normally do, and so get some impression of the immense diversity in human experience. But, of course, as it is, we don't have that. Through art, through affection, we have some sense of a global kind of what other people are like, of what life means to them, of what makes them tick, and of what their learning and their understanding is. But an immense sense of the otherness of people, and the otherness of possible worlds and ideas is, I guess, the basis of tolerance. I don't mean, in any simple way, tolerance of evil in one's self, but rather a recognition that even two people, hearing the same words, living together, seeing the same things, have some measure of gulf between them; and a recognition that when we are dealing with remote peoples, remote traditions, we need to bring an overpowering humility to our estimate of what they are, and our measure of them.

I have the impression that if we, in this time and this age, manage properly to live with the wealth of knowledge, the wealth of change, the responsibility, and the traits of impotence, which these times dish up, we will really be quite something, and that maybe there will be places and people and times that come after who will have reason to be grateful to us.