

## Remarks made at “Porte Aperte” at the University of Trieste: On scientific integrity

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The last two hundred years are a mere blip in human history---an even tinier blip in the history of life on earth, and of the lifespan of the earth itself. Yet, in this short time, our lives have changed irretrievably. Our understanding of the universe now is closer to truth than at any earlier time. Many amenities that were totally unthinkable previously have become possible and more of them, which were once the privilege of a few, are becoming available to a larger population. For example, millions can enjoy great music without having to go to exclusive concert halls in a distant city. Consider the impact on our lives of jet planes, the television, cell phones, microwave ovens, green revolution, polyester clothing, computers, credit cards and i-pods. Improved public health and medical care have made it possible to live longer and enjoy better conditions of fitness. All this and more has been possible because of science (in which I include technology for present purposes). This is democracy in action.

On the debit side of science are nuclear weapons, increasingly destructive weaponry, excessive industrialization and greenhouse effects, exaggerated claims of the good that science can do, scandals of false claims, globalization of terror, abuse of science in pushing certain ideologies, and occasional confrontation with ethical values that the society has held dear for a long time.

It is no surprise that some people are conflicted about science; it is no wonder that there is mistrust about the ability of science to be the agent of ultimately positive changes.

Rapid progress in science will stay with us because we are turning to it for guidance as never before. We turn to science (generally successfully) to predict the course of a hurricane, to contain certain epidemics, and to make airplane travel safer. We turn to science to grow more food and keep more of the world population free from terrible diseases. There is a deeper reason why science will be with us for ever. Our universe is full of unexplained wonders, and it is both exciting and satisfying to be able to understand some of these great mysteries. Fascinating questions such as, How was the universe created and what is in store for its future?, What is the essence of human consciousness?, have been with us for a long time, and new and equally tantalizing ones have arisen as we have made progress. For example, we can ask questions such as: Why do massive stars explode when they run out of the nuclear fuel that sustained them? Do the same fundamental laws govern subatomic particles and massive galaxies? What parts of the human brain relate to which bodily functions? We could not have asked these questions a hundred years ago with the same precision as we can now. Science has been an expanding frontier, and I have no particular worries that the landscape will become barren anytime soon.

I do not wish to say more about the future of science. It is futile to expect that I can somehow project the important scientific questions of this century. Those who have tried such exercises have often been wrong. I could speak a lot about my own work but you might not appreciate that very much. I have therefore chosen to speak about one or two general issues that concern science in the abstract and all scientists individually, now and forever.

Since the directions in science are often hard to predict, the more important point than the questions themselves is the attitude with which questions are addressed. The basic difference between the middle ages and now is that we are honestly appealing to external evidence to validate answers instead of being content with internal convictions. This approach has been quite successful so far and is the lasting legacy of the scientific age.

I hope that some of you will go into science and keep in mind its romantic aspects. That you could add a brick or two to the edifice of science, or plug a hole or mend a crack, is what should drive you towards it, not other rewards. If you are lucky, you might be able to build a modest edifice of your own, or rearrange the existing structure somewhat, and become immortal. While very few

can be a Newton, a Darwin or an Einstein, we can all do our part rewardingly. All of you need not become scientists, and I hope that some will blaze new avenues as did Dante, Michelangelo, Gandhi or Mother Teresa. That would be no less exciting. The least I can hope is that you will all grow up to be productive citizens, giving something back to the society that has nourished you, keeping in mind the needs of those who are less fortunate than you, and occasionally doing something concrete about it. That is the most important thing.

To those of you who *will* go into science, what else shall I say? The future of mankind is to some extent in your hands. Progress in advanced technologies may ensure sustainable development and that advances in medicine may alleviate disease and poverty. The consequences of science can be negative in the wrong hands, as I have already said, so there are special responsibilities that you have to shoulder. One such responsibility is scientific integrity. I shall elaborate a bit on this. It is better to quote---albeit somewhat selectively---from the address that Richard Feynman, a great physicist of the last century, gave at the Caltech commencement in 1974. His remarks pertain largely to the practice of science itself but also to what scientific integrity means in terms of the interaction with the society at large. He said:

"...It is a kind of scientific integrity, a principle of scientific thought that corresponds to a kind of utter honesty---a kind of leaning over backwards. For example, if you are doing an experiment, you should report everything that you think might make it invalid---not only what you think is right about it: other causes that could possibly explain your results; and things you thought of that you've eliminated by some other experiment, and how they worked...

"Details that could throw doubt on your interpretation must be given, if you know them. You must do the best you can---if you know anything at all wrong, or possibly wrong---to explain it. If you make a theory, for example, and advertise it, or put it out, then you must also put down all the facts that disagree with it, as well as those that agree with it. There is also a more subtle problem. When you have put a lot of ideas together to make an elaborate theory, you want to make sure, when explaining what it fits, that those things it fits are not just the things that gave you the idea for the theory; but that the finished theory makes something else come out right, in addition.

"...The first principle is not to fool yourself---and you are the easiest person to fool. So you have to be very careful about that. After you have not fooled yourself, it's easy not to fool other scientists. You just have to be honest in a conventional way after that.

"...I would like to add something that's not essential to the science, but something I kind of believe, which is that you should not fool the layman when you are talking as a scientist... And that is our responsibility as scientists, certainly to other scientists, and I think to laymen."

This utter honesty is the hallmark of a scientist. It is true that there are dishonest scientists, just as there are demagogue scientists of shameless proportion, but the culture of science ultimately honors the integrity that Feynman spoke about. Indeed, everyone will agree---even if we fall short of this ideal---that it is what keeps the enterprise going. In the end, this is what makes science special.

It is not clear if this trait can be transported to the rest of the society; if we can, we have done more than we have reasons to hope. However, we ourselves have to take this extra responsibility seriously. It becomes second nature once we train ourselves in the beginning of our careers. It neither constrains our creativity nor burdens our style. Instead, it will enhance our sense of self-worth immensely.

I wish to stress one element further, namely the excitement of doing science. When you find out something for the first time, even if it is not earth-shaking, you feel a sense of elation and oneness with the universe. You get paid by the society for creating this personal pleasure for yourself, and, if you are lucky, engraved for ever in the history of human accomplishment. What more can you ask for!