

FIFTY-SECOND CONVOCAATION ADDRESS

by

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It is a great honor and delight to speak at this convocation, to congratulate the graduating students of I.S.I., their parents and friends and to address you briefly. You might have been surprised that I, a theoretical physicist, was asked to address the Indian Statistical Institute. I too was somewhat surprised to be asked. But Statistics and Physics have much in common. Later today I will give a public lecture on the many connections and strong ties between physics and mathematics, and statistical theory is part of mathematics. More specifically, modern science would not be possible without the tools of statistical theory developed over the last 300 years; tools that have enabled scientists to avoid unconscious bias and improve the analysis of complex data. Also, theoretical physicists and statisticians, in my experience, share a quality that many mathematicians (with many notable exceptions) often lack—common sense. I think that this common sense arises from the exposure of physicists to real concrete phenomena and the exposure of statisticians to real data. Educated and sophisticated common sense is a very valuable tool that enables both physicists and statisticians to apply their skills to fields far from their original areas of expertise. So maybe it is not unreasonable for a physicist to talk to you on this occasion.

Many of you are completing your education today and are wondering what the next few years will bring. The one thing I am sure of is that no one, certainly not I, can give you the answer. The world is undergoing rapid change and, as the events of the last year show, no one can predict what will happen next year, much less beyond that. The same is true of science, and of ones career in science. I received my Ph. D. from the University of California at Berkeley 51 years ago, to begin a career in theoretical physics—more specifically the study of the elementary particles and the fundamental

forces of nature. The focus of attention then was the study of two of the four forces of nature, the two that operate within the nucleus, the weak force responsible for radioactivity and the strong force that holds the nuclei together. Little was understood; the strong force was especially mysterious. The prevalent feeling was that it would take a very long time to understand the strong force and that it would require revolutionary concepts. Freeman Dyson had asserted that "the correct theory will not be found in the next hundred years." For a young graduate student, such as myself, this was clearly the biggest challenge.

Little could I dream that, only seven years after I graduated, we would discover the secret of the strong force that binds quarks within the nucleus. This secret is the phenomenon we called asymptotic freedom, the fact that certain generalizations of electromagnetism, had the property that the force between charged particles would decrease at short distances—thus explaining the free behavior of quarks within nucleons at short distances---and conversely grow arbitrarily strong at large distances—thus explaining why quarks cannot be pulled out of the proton. This led us to the beautiful theory that describes this force. It was this discovery and this theory, Quantum Chromodynamics or QCD that won us the Nobel Prize in Physics.

Life is made not of years but of moments. As we look back on our life what we remember is a collection of moments. None of us remember our beginning, and none will remember our end. Most other remembered moments that mark our years, are both endings and beginnings. This moment too, is both a beginning and an ending.

For many of you it is the end of college tuition and the beginning of repayment of student loans. For many of you it is the end of the process in which you absorb past knowledge and the beginning of the process where you begin to apply that knowledge or start to pass it on to the next generation. For many of you it is the end of formal education and the beginning of so-called "real life". For many of you it is the end of the period in life where you receive from your parents and society and the beginning of the period where you give back to society.

There is much that you can give back, for you are a privileged lot. You are privileged to be citizens of a rapidly growing country that is moving to take its rightful place in the world. You are fortunate to have lived free of the disease and hunger and war that plague much of humanity. You are privileged to have attended a great institute and to have acquired much knowledge. You live better than kings and queens did only a few hundred years ago; you know more than the greatest scholars did, only a few generations ago.

But with all of these privileges comes the responsibility to use your knowledge to improve the lot of the less fortunate in my country, in your country and around the world, and to tackle the many problems and confront the many dangers that my generation has left for you to deal with. And there are many problems and dangers that we all face: the massive inequalities that exist in and among nations, the persistence of useless war and violence, the danger of fanaticism and terror, the threats to the environment and to the health of our planet.

The cause of many of these problems is sheer ignorance—the ignorance of the science that could solve many of the world’s problems, the ignorance of basic facts---such as the fact that all of us had a single mother only a few thousand generations ago---that make racism and bigotry still possible, and the ignorance of other cultures that promotes fanatical nationalism. As the possessors of the knowledge of the 21st century you have the responsibility to be forces for enlightenment and to strive to dispel this ignorance.

But ignorance is not all bad. Thomas Jefferson said: “Ignorance is preferable to error, and he is less remote from the truth who believes nothing than he who believes what is wrong.” The greatest obstacle to progress is not ignorance, but the illusion of knowledge. The reason that the fundamentalists are so dangerous is not so much that they are ignorant but that they are certain that they possess the absolute truth. It is this certainty that can lead to repression, bigotry, racism, and fanaticism.

The main lesson of science is not the partial truth that we labor to reveal, but our attitude of skepticism towards these truths. We must always remain skeptical, always question our beliefs and confront them with nature.

And ignorance itself is not so bad. I often say that the most important product of knowledge is ignorance. Indeed, the driving force of science is the questions we ask, which are the embodiment of our ignorance.

As knowledge increases one might imagine that the pace of scientific discovery would slow as more and more questions are answered. But this has not turned out to be the case. As knowledge increases so does ignorance; the more we know, the more aware we are of what we know not. The questions we ask today are more profound and more interesting than those we asked years ago when I was a graduate student. Many of those we have answered. But back then we did not possess enough knowledge to be as intelligently ignorant as we are now, and therefore to ask the wonderful questions we ask today.

Among the questions we ask now are: How did the universe begin? How many dimensions of space are there? What unifies all the forces of

nature, what is the physical origin of consciousness, is the galaxy teeming with life, and more and more? Wonderful questions, most of which I believe will be answered in your lifetime – lucky you!

Some wonder whether some day we will arrive at a theory of everything and run out of new problems to solve, much as the effort to explore the earth ran out of new continents to explore. While this is conceivably possible, I am happy to report that there is no evidence that we are running out of our most important resource – ignorance.

Reporters often ask me: what advice would you give students embarking on a scientific career? I feel very uncomfortable answering such a question. Most of the advice I could give is self evident, or would consist of saying: Be like me if you want to succeed. But there is two pieces of advice that I do give all my students and which is applicable, I think, in all aspects of life. It is first: **Follow your heart.**

You will face many difficult choices in the years ahead – what career to follow, what field of science should you work in. When student ask me what field of science should they go into I always answer – find out what you truly love to do and, if possible, do that. I do not think that you can succeed unless you are engaged in what you truly love to do. If you are working in what you love to do than you will be able to marshal the concentration, creativity and hard work necessary for success. And, most important, you will enjoy the journey.

Second: and **Aim high and dare to fail.**

If you never attempt goals that might appear to be impossible, you are guaranteed not to achieve these goals. If you try, you might very well fail. But so what! You might succeed and in any case you will know that you gave it your best shot and will have fun along the way, especially if you are engaged with what you love.

Take a chance to make a difference in all aspects of life; do not sell your dreams short. Do not be afraid to follow your most ambitious plans and to pursue your most outlandish ideas. Dare to connect with other human beings and to love deeply.

And if you do there will be many moments like this, moments of triumphant endings, moments of hopeful beginnings.

Thank you.