FIFTY-FIRST CONVOCATION ADDRESS

BY

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First, Congratulations. Congratulations to the graduating students, and Congratulations to your parents and families. To you the graduating students, this day symbolizes the significant results and achievements of your sustained work over a long period. The real rewards of your efforts lie invisible in your brains, which makes it appropriate to acknowledge your accomplishments visibly at this ceremony.

This day also symbolizes an actual transition point in your lives – in the future life *will* be different. So this is a good day to celebrate, and to take stock of where you are.

I believe you are in a good place. Besides being able to do something well, it is often equally critical to be able to choose the right thing to do in the first place. I therefore congratulate you also for having chosen to pursue a scientific discipline and so join the global science enterprise.

There are many wonderful things about science. A first thing is *universality.* Just imagine, someone like me can come from the other side of the world, and be in your city for the first time, and still have some understanding of what your institution does and what you have done here. In fact the contents of the science and mathematics courses here are probably similar to those at my institution, or anywhere else in the world, and are independent of location and culture. While there is a place for multiple cultures, there is also a place for celebrating world-wide universality. There, science is playing a unique role in bringing people together from around the world for a common purpose.

A second remarkable thing about science is its uniquely *cumulative nature.* Each field is a remarkable edifice built by many people, sometimes over many generations. Physics, statistics, computer

science, and many of their numerous subfields are already highly developed. There is no chance that one person could have dreamt up even a small fraction even of one of the many subfields. For example, it is generally recognized that quantum mechanics, as currently understood, is the result of a series of insights, arrived at successively by a number of remarkable scientists each building on the work of their predecessors. Computational complexity, the field in which I started, has a similar history. The remarkable thing is that such fields build up into a complex edifice, which no one person could have created, but nevertheless have enough unity that a person like you can come to study and understand the essential parts of theses edifices at an institution like this.

Of course there are extreme high points in the history of science. Albert Einstein in his General Relativity did change how we think about space and time. Alan Turing, with his universal machine did change our view of computation. However, even these singular achievements are building blocks that fit into a much larger picture, where the individual contributions of many fit together, like a jig-saw puzzle, to give overall theories having stunning unity, which we can often fully appreciate only many years later.

So the question for an individual who is entering a career in science or using science, whether in academia, industry or elsewhere, is "Where do I fit in?"

This question can be daunting. After all, none of us will ever understand any significant fraction of current understanding in mathematics and science, and none of us will contribute more than an even smaller vanishing fraction of the fraction we understand. Also, one is reminded of these facts as never before. If one looks up a newly minted paper on arxiv, the widely used online archiving service, one notices that beside the paper you are looking up, another 10,000 or so have also been submitted in the previous

month. Most of these papers are technically challenging to read and understand, and have merit. So where do you start?

But before we get into that I want to remind you that through your degrees, you are all now anchored into the amazing global scientific enterprise. And we are at a time when developments in science and its applications are as far reaching as at any time previously. Until a few centuries ago there was no such global scientific enterprise, and until a few decades ago it was open to only a minute fraction of the world's population. The potential of science to affect all aspects of our lives is as great as ever. In that sense you are all empowered as very few in previous generations have been. This holds whether you choose in your career to teach science, use science or add to science. These are very good times for science.

The enhanced position of science as a driver of changes in society is in significant part due to the pervasive use of computers. Above all computers have revolutionized the applications of mathematics. When I received my undergraduate degree in mathematics there were very few jobs where you could use mathematics directly. Now, computers can apply a mathematical idea to masses of data in a flash, and this magnifies the direct applicability of mathematics to all areas of life. More than fifty years ago the Nobel Laureate in physics, Eugene Wigner, wrote a famous essay expressing puzzlement at the success of mathematics in formulating physical laws. He concluded his essay with the words "The miracle of the appropriateness of the language of mathematics for the formulation of the laws of physics is a wonderful gift which we neither understand nor deserve. We should be grateful for it and hope that it will remain valid in future research and that it will extend, for better or for worse, to our pleasure, even though perhaps also to our bafflement, to wide branches of learning." This extension is now happening, again thanks in part to the wide

availability of computers, and is reflected in how science is taught world-wide.

To conclude, I would like to return to the question of how an individual can fit into this global scientific enterprise. My personal experience has been in academia, but some of these remarks may apply equally if you go into other spheres.

First, because of the modular nature of science, with its various bricks fitting together mysteriously like a jigsaw, it is possible, valid and probably inevitable that you start in a particular specialized looking place, and invest your time in understanding well one of these constituent bricks. Of course, as with anything, your taste in choosing the right brick does matter. Some bricks are more equal, in this case more fundamental, or more timely for progress, than others.

Second, it is good to have heroes, people whose achievements you respect. But aiming simply to imitate someone else is a bad idea. As the saying goes, "Be yourself; everyone else is already taken."

Third, do not be put off by the fear that you will not achieve as much as some have. Statistically that fear may be well founded. But that fear would apply to everybody equally. Alan Turing had an inauspicious high school career. Yet at the age of 24, with no previous indication of greatness, he did formulate a mathematical theory of abstract machines, which had no precedent, and which ushered in the computer age. Albert Einstein, with a similarly inauspicious start, had his annus mirabilis at a similar age. Like anyone else, they had reason to fear that they were not up to their ambitions, but at least they were not crippled by that fear.

Lastly, we are all different, with different combinations of interests and aptitudes. I think there is room for a good career for anyone

with enough commitment. Your most precious commodity is time, and in choosing your next endeavor you are gambling with this precious commodity. Self-knowledge plays a big part in winning this gamble. The trick is finding an occupation that matches your interests, and also matches your aptitudes, so that you will be able to put in sufficient effort, with pleasure, and that your efforts will be successful.

Good fortune is enjoying what you are good at.

Congratulations to you all, and good fortune!