Tribute to

Freeman J. Dyson

Ladies and Gentlemen, colleagues and friends,

Dear Freeman:

When I was asked to prepare an appraisal of Freeman Dyson's scientific work for today's Prize ceremony my first reaction was to propose some colleagues who are more distinguished and more highly qualified for this job than I am. Unfortunately my proposals could not be accepted. My second reaction was one of considerable anxiety. *Who am I to dare appraise Dyson's work?* He is *the* leading mathematical physicist of the second half of the 20th Century. Back in the late sixties, when I was a student, my teachers Klaus Hepp and Res Jost admired him. Ever since, he has been a model for all of us in the mathematical physics community.

But then I told myself that Dyson's outstanding accomplishments are so exceedingly well known, and that it is so obvious that he should receive – actually, should *have* received – this particular Prize that my appraisal is essentially superfluous, and that I will be forgiven small lapses that may sneak into my presentation.

When I just started to enjoy studying somewhat voluminous sources of information on Freeman's life and work and had prepared the first thirty minutes of my speech, I was told that I actually had only *five* minutes to talk – at which point I developed acute feelings of panic.

I turned to "Google" for help, where I found out[1] that Freeman Dyson – and I quote – "is best known for his speculative work on the possibility of extraterrestrial civilizations," or "for his speculations on the philosophical implications of science and its political uses," or that "he is not an unqualified believer in the predictions being made by the believers in global warming," or that he "has suggested a kind of metaphysics of mind" on three levels. Well, all this actually points to different compartments of Freeman's mind and thinking. But, today, we are most interested in the compartment of his creative thinking that relates to mathematical physics!

Let me recall a few basic biographical dates and facts.

Freeman John Dyson was born in Crowthorne, Berkshire, in the United Kingdom, on December 15, 1923. His father was the musician and composer Sir George Dyson, his mother, Mildred Lucy Atkey, was a lawyer and social worker. According to Dyson's own testimony, he became interested in mathematics and astronomy at the age of six. At the age of twelve, he won first place in a scholarship examination to Winchester College, an early indication of his extraordinary talent. In an after-dinner speech, Freeman once described his early education at Winchester. He said that the scope of the official curriculum at the College was limited to imparting basic skills in languages and mathematics;

[1] beside advertisements for the ‚Dyson vacuum cleaner' and the ‚Dyson airblade'

everything else was in the responsibility of the students. He took that responsibility seriously and went ahead to learn whatever he found interesting and important, including, for example, Russian, in order to be able to understand Vinogradov's *'Introduction to the Theory of Numbers'.*

In 1941, Dyson won a scholarship to Trinity College in Cambridge. He studied physics with Dirac and Eddington and mathematics with Hardy, Littlewood and Besicovitch, the latter apparently having the strongest influence on his early development and scientific style. He published several excellent papers on problems in number theory, analysis and algebraic topology.

After finishing his undergraduate studies in mathematics, in 1945, and reading Heitler's *'Quantum Theory of Radiation'* and the Smyth Report on the Manhattan Project, Dyson came to the conclusion that – and I quote him – "physics would be a major stream of scientific progress, during the next 25 years," and he decided to trade pure mathematics for theoretical physics.

After having won a Commonwealth Fund Fellowship in 1947, Dyson applied to become a Ph.D. student of Hans Bethe at Cornell. It may be appropriate to ask why he decided to leave Cambridge, the place where the incomparable Dirac and where Eddington and Kemmer taught, and to move to America.

In an article entitled *"The Future of Science"*, Dyson writes, and I quote: "Scientists come in two varieties, which Isaiah Berlin[2], [...], called 'foxes' and 'hedgehogs'. Foxes know many tricks, hedgehogs only one. Foxes are broad, while hedgehogs are deep. Foxes are interested in everything and move easily from one problem to another. Hedgehogs are interested in just a few problems that they consider fundamental and stick with the same problems for years or decades. [...] Some periods in the history of science are good times for hedgehogs, while other periods are good times for foxes. The beginning of the twentieth century was good for hedgehogs. [...] in the middle of the century, the foundations were firm and the universe was wide open for foxes to explore."

Obviously, Freeman Dyson is the archetypal 'fox', and the period in physics when he started to do research and scored his first great successes was *exactly right for foxes*. Freeman is so much a fox that he never got around completing his Ph.D.

At the time Dyson started his research career in theoretical physics, the foundations of quantum theory had been laid, but relativistic quantum field theory was in a messy state. The hedgehogs, notably Dirac and Heisenberg, who had created quantum theory, thought that yet another revolution was necessary to have quantum field theory superseded by a better theory. But Dyson, the fox, understood that what was necessary was to better understand the intricacies of the already existing theory and to proceed to doing concrete calculations explaining experimental data. He had learnt some quantum field theory from his friend Nicholas Kemmer and from Wentzel's book, entitled "Quantentheorie der Wellenfelder". Dyson writes: "It was my luck that I arrived with this gift from Europe just at the moment when the new precise experiments of Lamb and others ... required quantum field theory for their correct interpretation. When I used quantum field theory to calculate an experimental number, the Lamb shift [...], Bethe was impressed." Not only did Dyson play a seminal role in making

[2] Incidentally, in his book, Berlin tells us many interesting things about Tolstoy's views of history that are surprisingly topical and worth thinking about.

quantum field theory useful for the theoretical interpretation of experimental facts, but he also distilled the right general concepts, in particular the *renormalization method*, that made it more than a miraculous machine spitting out numbers. Dyson's understanding of the relationship between Feynman's and Schwinger's approaches to QED and the general concepts he introduced made quantum field theory a systematic, even if mathematically incomplete, theory that keeps theorists busy till this day. Dyson was first in understanding the importance of scale separation in analyzing quantum field theoretic problems, an idea that later gave rise to the renormalization group. It is an early manifestation of Dyson's great intellectual generosity to have shared his understanding of quantum field theory with Bethe and Feynman and to have played a crucial role in explaining Feynman's approach to people like Oppenheimer and convincing them that it was useful, before it was published. Actually, Dyson went on to give further demonstrations of his generosity with his important input into the beginnings of general or axiomatic field theory.

Since Dyson is a 'fox', it is unimaginable that he would work in the same field for more than a year or so at a time. Indeed, right after his initial successes with QED (and with meson theory[3]), he moved on to work on problems in statistical mechanics and solid-state physics. Many of his contributions are, others ought to be well known. Let me mention his work on disordered chains that set the stage for Anderson's discovery of localization, his "Citation Classic" on interacting spin waves, his incredibly original analysis of the ground-state energy of the hard sphere Bose gas, and his seminal work on one-dimensional long-range Ising ferromagnets, which played an important role in the development of the mathematics of renormalization group methods – besides playing some role in the scientific trajectories of Tom Spencer and myself.

In a Foreword to Freeman Dyson's *'Selected Papers'*, Elliott Lieb writes, and I quote: "In the sixties, and even into the early seventies statistical mechanics was considered by the majority of physicists to be an uninteresting backwater. The situation today is quite different, [...]. One of the people who changed all that was Freeman [...]. The beauty of [his] papers cannot be easily described without going into details but one can say that a paper by Dyson will contain the final word, arrived at in the most direct and elegant way. [...] Sometimes "final" means "two or three decades", which is the time scale needed to make a substantial improvement on a Dyson paper." Elliott then mentions the celebrated work by Dyson and Lenard on *"Stability of Matter".* He refers to Dyson's $N^{7/5}$ Law for bosons, which was proven only 21 years after Dyson had conjectured it.

Dyson has made numerous further contributions to mathematical and general theoretical physics, and to engineering. I want to mention his seminal work on *"Random Matrix Theory"*, which – to show that Elliott has been too optimistic – has seen a strong renaissance, not twenty, but only *forty* years after it had been carried out by Dyson, and after he complained that it had little impact. (Of course, it *had* had impact, e.g., in number-theory, in the work of Montgomery on the zeros of the Riemann zeta function.) His works on *"The Search for Extraterrestrial Technology"* and on *"Artificial Stellar Sources of Infrared Radiation"* deserve to be mentioned, which – if we believe "Google" – are representative for what Freeman is most famous for. I should like to also draw

[3] Applications of the Tamm-Dankoff method

attention to Dyson's work on more applied problems in science, e.g., concerning noise in active optical systems, interstellar communication, or biological problems, etc.

Dyson is a 'fox'. He has not discovered a new physical theory. That is a job for hedgehogs. Let me quote Freeman himself to describe what *his job* in physics has been: "I define a pure mathematician to be somebody who creates mathematical ideas, and I define an applied mathematician to be somebody who uses existing mathematical ideas to solve problems. According to this definition, I was always an applied mathematician, whether I was solving problems in number-theory or in physics." I would like to add that Freeman is *the prime* model of a successful mathematical physicist; namely of somebody who knows the existing theories of physics and, with an unfailing instinct for the most important open questions and the most pressing concrete problems, goes ahead and elucidates them mathematically. He is a model in other respects, too: He never published every idea that crossed his mind; he has been generous to his colleagues; he has fought against trends converting the world of science into a jungle and has adhered to noble principles of intellectual honesty and integrity.

It is well known that Dyson has engaged in many other activities. One might mention his involvement with "General Atomic" (design of the TRIGA reactor, Project Orion), or his writing of books directed at a general readership. Who has never heard of "Disturbing the Universe", or of "Weapons and Hope", or of "Origins of Life", or of "Infinite in All Directions"? I am not closely familiar with these books, except for "Disturbing the Universe". But I believe they convey a strong impression of Freeman's infinite and infinitely charming intellectual curiosity.

I could easily spend the next 15 minutes reading a list of Prizes and honors Freeman has been awarded. Let me just mention a few:

- Dannie-Heineman Prize 1965
- Max-Planck Medal 1969
- Wolf Prize 1981
- National Books Critics Circle Award for Non-Fiction 1984
- Oersted Medal 1991
- Enrico Fermi Award
- Antonio Feltrinelli International Prize 1996
- Templeton Prize 2000

Etc. He has more than twenty honorary degrees, including one from ETH Zurich, and is a member of numerous learned societies and academies.

One of Freeman's predilections appears to be to think about the future of the planet and of mankind and to imagine all the new possibilities that may appear on the horizon. He is upholding a strong belief in the survival of our species and an infectious optimism in its potential, which I do not entirely share. My guess is that we will only save the future of the planet and of our species by not loosing our past! For me, Freeman Dyson represents a better past in theoretical science, a scientific tradition that we are in some danger of loosing. We should preserve and cherish it if we want theoretical science and, in particular, mathematical physics to survive!

One might say that, today, the IAMP is honoring itself by bestowing this Prize upon Freeman Dyson. It is my privilege and pleasure to congratulate him wholeheartedly in the name of the entire mathematical physics community and

to wish him good health and continued pleasure and many further surprises in science.

THANK YOU!