My Einstein

George F. Smoot

Albert Einstein is such a towering public figure that one learns about him even when one is a child. Einstein has achieved the status of public icon. Once when needing suspenders for a tuxedo, I went shopping and found limited choices: formal geometric, Marylyn Monroe, and Einstein patterns. Here's one of the many anecdotes I heard many years ago and particularly appreciate now: It became a tradition in Einstein's later years for him to grant interviews to the press on his birthday. One year a reporter asked him whether he could imagine having lived a different life. Would he have been happy in another profession? After a moment of reflection, Einstein replied, "I think I would have enjoyed being a plumber."

After this remark was reported, the Plumbers and Steamfitters Union A.F.L. in Washington D.C. voted to grant Einstein an honorary membership, and a New York plumbers' local presented him with a gold-plated set of plumbers' tools. Einstein was said to be highly pleased. Some years later, Einstein's neighbor, a younger physicist, came over one day and asked to borrow a pipe wrench because his kitchen sink was leaking. Einstein replied, "Sure, if you'll let me help. You don't know how long I have been waiting to use it!" As a do-it-yourselfer myself, I like to picture Einstein with his gold-plated wrench and his legs sticking out from under the sink, dirty water dripping on him as he tries to get the connection properly fitted without skinning his knuckles.

Einstein was not known as a hands-on physicist—that is, an experimentalist—but as a thinker, a theoretician. When I was a younger, beginning physicist, my primary scientific hero and role model was Enrico Fermi, who was superb both as a theorist and an experimentalist. From several people I have heard the story of his stunning insouciance on the day in 1942 when the world's first nuclear reactor, which he and his team had built at the University of Chicago, was ready to be tested: Just before it was to go operational for the first time, he called a break for lunch; after lunch, the team returned and successfully initiated the first sustained nuclear reaction. Fermi went on to Los Alamos as one of the leaders in the Manhattan Project. But he wasn't just a tinkerer. In the 1920s, he and Paul A. M. Dirac worked out the quantum behavior of half-integral spin particles. In this period Einstein developed the ideas of Satyendranath Bose to understand the statistics of integral spin particles. Fermi was nicknamed the Pope by his colleagues, because of his reputation for scientific infallibility.

In the early phase of my career, my research was influenced almost equally by the work of Fermi and of Einstein. There were times when I felt that Einstein was getting more public attention and credit than was warranted, relative to the scientific contribution of others. The press, and thus the public, will often focus on an individual, especially one who captures the imagination and seems accessible. Einstein had an attractively human side, as his plumbing aspirations indicate; perhaps on the day he confessed them to the press he was wistfully hoping for a chance to lead a normal life of independence, such as a plumber might. Fermi, outstanding in both experiment and theory but not as iconic a public figure, seemed like a better role model to me at the time, a sentiment shared by a number of my colleagues. We made much of our scientific lineage, tracing it back through our PhD advisors to Fermi, and on back to Galileo. It was through this handing down of training, technique, and scientific attitudes that we felt we had become genuine research scientists. Einstein's approach and Einstein's history seemed at odds with this idea of a scientific lineage. His image was that of the outsider, the solitary genius whose startling new ideas burst from an unexpected quarter.

Later, as science and my career advanced and changed, I found my daily life, both research and teaching, more and more directly affected by Einstein's work. Much of Fermi's theoretical efforts were absorbed into the fabric of a larger model of physics. Einstein's relativities, special and general, continue whole cloth. For many decades, most physicists have treated them as effectively sacrosanct. There were those who were disturbed by the implications and tried to modify or subvert relativity theory; they were regarded as misguided and off track. The several early experimental verifications aside, the theories' beauty and intrinsic symmetry alone seemed a powerful indication of their correctness. Ultimately, in physics, observation and experiment are the final arbiter, and in the last decade there has been a shifting of attitude toward general relativity and a growing acceptance of the idea that it will eventually be supplanted by a more advanced theory, much as Einstein's relativity theories supplanted Newtonian physics.

When you are young, you want to learn the work and theory that has preceded you, and then you want to go beyond. As you get older and have done research and taught for a while, you develop an interest in understanding the thought processes of your predecessors in physics and the trial and error aspects of their work. You see that rarely does an idea or result leap full-blown from the mind, like Venus rising from the sea. Much more often there are starts and stops, blind alleys, and a lot of plain, dull work before things emerge or the epiphany occurs. There is prolonged labor before the actual birth. I have often wondered what special abilities and circumstances led Einstein to his breakthroughs in the miracle year of 1905. When I taught special relativity to my physics students at Berkeley, I tended, like many of my colleagues, to follow the well-worn path: first, the Michelson-Morley experiment ("The most important thing that ever happened in Cleveland"), with its null result on the motion of the Earth through the so-called luminerifous ether (thought to be the medium carrying light waves) and their demonstration that the speed of light is constant. Then the hypothesis put forth by George Fitzgerald, to account for this result, that lengths contract in the direction of motion, an idea picked up by Hendrik Lorentz, who produced the formulas that connect space and time in one frame of reference to another moving at a velocity. Then Einstein's revelation of a whole new perspective through the transformations we call special relativity. This made a nice logical and pedagogical chain and helped students to understand and accept special relativity as grounded in experiment. The flaw in this beautiful account was that Einstein had often denied knowing about the work of A. A. Michelson and Edward Morley; his ideas came from thinking about what it would be like to ride along on a beam of light. It would seem that we were misleading the students to the right conclusions.

This discrepancy disturbed me, and years ago I searched out an obscure report of an interview with Einstein in Japan, in which he remarked that he had indeed heard of the Michelson-Morley result *before* 1905. Why was this remark buried beneath his other widely-covered comments that he had come to special relativity by what appeared to be pure thought. Einstein certainly did know of Lorentz's work and by implication that of Michelson and Morely.

Einstein's relativities do both appear to have come in large part from thought and aesthetic considerations, though much of his other work is an interpretation of observation—e.g., the photoelectric effect, atomic and molecular sizes, Brownian motion. This reliance on thought alone seemed to me, increasingly, to be setting a bad role model for budding physicists, especially for aspiring theorists who all seemed to want to be the next Einstein. Of course I might have been biased because almost all of my own work was experimental and observational and it was my firm belief that the integrity and power of science came from probing nature and not from divine insight. This was the experimentalist's canon, capital letters and all:

1) Discover an Important Effect or New Thing never before thought of
2) Disprove an Important Theory to show that new science is needed
3) Confirm a Great New Theory
4) Disprove a competitor's experimental results—or—
5) At least Confirm a competitor's experimental results

While it is easy to see the personal-reward priority in the list, all of these items are valuable and essential to the progress of science—indeed, are the only way to keep the system self-correcting. Appealing to the beauty and purity of a thought to judge the correctness of science is not at all as robust a path to a correct theory. Einstein himself provides a couple of examples of this lack of robustness:

1) The cosmological constant, which he famously referred to as "my greatest blunder." He added it to his general-relativity equations in order to produce a static universe. At the time, the universe was presumed to be static, but a decade later Edwin Hubble showed that it was expanding. The cosmological constant was seen to be unnecessary (although it has lately been invoked to accommodate what appears to be an accelerated expansion—*plus ça change, plus c'est la meme chose*).

2) In a letter to Max Born (4 December 1926), Einstein made his famous statement that "Quantum mechanics is very impressive. But an inner voice tells me that it is not yet the real thing. The theory produces a good deal but hardly brings us closer to the secret of the Old One. I am at all events convinced that He does not play dice." Quantum mechanics continues to be validated by experiment.

3) The role of *der Alte* is summed up in another pair of quotes: "When the solution is simple, God is answering." And a comment after Arthur Eddington's eclipse

expedition confirmed the (corrected) prediction of general relativity, to the effect that Einstein would feel sorry for God if the confirmation had not been made, because "the theory is correct."

But aesthetic arguments, while useful as development tools especially when there are no observations to guide the effort, made me uneasy—seemed a throwback to Greek reasoning about the celestial spheres. More recently, I came to realize that Einstein built special relativity not from pure thought alone but firmly based upon a great deal of physical observation and codifying theory. In particular, electromagnetism and the theory of light via James Clerk Maxwell's equations. Surely Einstein was aware of Lorentz's work, but was coming from the Maxwell side, not the Michelson-Morley results. Einstein was reducing these ideas down to two essential postulates added onto the existing physics: (1) The speed of light is definite and independent of the speed of the source or of the observer, and (2) the laws of physics are the same in every inertial frame. From these two postulates and thought-experiments, one can derive all the consequences of special relativity, including the Lorentz transformations, time dilation, length contraction, loss of simultaneity, $E=mc^2$, and the lot! Structured in this way, special relativity is a theory of great beauty and one with surprisingly great implications.

It was the reinterpretation of special relativity in 1907 by the mathematician Hermann Minkowski that made its calculations straightforward and helped us realize that we live in four dimensions, three of space and one of time, known colloquially as the spacetime continuum. This is the starting point for an understanding of general relativity.

In the spring of 2003, while I was teaching a course on Relativity, I was contacted by Peter Minkowski, Hermann's nephew, who informed me that I would be the recipient of the 2003 Einstein Medal, to be awarded in Berne in June by the Einstein Society. I was greatly honored; such a named medal is instantly recognized and the previous winners—Stephen Hawking, Ed Witten, and John Wheeler among them—were illustrious. It was all the better that the medal would be awarded in Berne, where Einstein was living when he published his famous 1905 suite of papers. I was then teaching a senior course in relativity and enjoying it more than usual, since I was paying extra attention to the background of Einstein. The chance to see Berne and to think about how Einstein lived his daily life during the time he was so productive and innovative was exciting to me.

A high point was a private visit to the Einstein Haus at 49 Kremgasse in the center of the city, on a main street, one floor above a restaurant that spills out onto the sidewalk—the apartment where Einstein lived from 1903 through 1905, when he was developing and publishing those five remarkable papers. I was also given a folio of precise reprints of them. Though the ceremony, the talks at the University of Berne, and the dinner were all wonderful, being in Einstein's home and seeing pictures of his family and associates and material about what was going on in physics at the time had the greatest emotional effect on me—an effect heightened by being allowed to roam through the apartment alone, which is maintained and being restored by the Einstein Society. The apartment seemed a very nice one for a struggling young man with a wife (Mileva Maric) and a new baby (Hans Albert was born in May 1904), though the family did have to share a bathroom with a family in an adjoining apartment. The overall apartment was cosy with a nice fireplace, hardwood floors and many architectural details. The living room has two large windows with a good view of the old street below, flower boxes, and which let in a lot of light. The living room also has high ceilings, formal wall paper and plenty of room and comfort for his friends and colleagues who gathered there. Einstein, who had hoped for a position at the university, first supported himself and Mileva by a temporary position as a mathematics teacher at the Technical High School in Winterthur. Another temporary position teaching in a private school in Schaffhausen followed. In 1902 Einstein obtained a job as a patent clerk in Bern that provided stability and allowed them to have the apartment. Einstein was appointed as a technical expert third class. Einstein worked in the Berne patent office from 1902 to 1909, holding a temporary post when he was first appointed, but by 1904 the position was made permanent and in 1906 he was promoted to technical expert second class. While in the Berne patent office he completed an astonishing range of theoretical physics publications, written in his spare time without the benefit of close contact with scientific literature or many colleagues. He must have had a burning desire to do physics, what with the distractions of the job and family and the need to finish his PhD thesis. Yet he managed to meet regularly to talk physics with his friends and he found the time to write his papers.

I spent some time going around the city, which is little changed since Einstein's day, taking in the shops and cafes, walking to the University, enjoying Berne, and imagining what Einstein's life might have been like. How and how much did his surroundings affect him? Where and how did he get and develop his ideas? Was it the quiet time in the patent office or the conversations with his friends, going to talks at the University, doodling on napkins at a café? Did the pace of life and the intellectual exposure with time to think make it possible? On the weekend, I took a train from Berne to the Alps and hiked above the Lauterbrunnen valley, across from the Jungfrau, as I guessed Einstein might have done. I wondered if the beauty of nature and the physical monotony of walking had freed his mind to new ways of looking at old things. I found that I was distracted much of the time. But if you prepare yourself well, with what is known to be valid, perhaps Einstein was right—careful thought is the way to new understanding.

Beginning in 1905, Einstein achieved what no one since has equaled: a decade-long run at the cutting edge of physics. We celebrate this, a century later. I proudly wear my Einstein suspenders.

GEORGE SMOOT received his Ph.D. in physics from M.I.T. in 1970 and was a postdoctoral researcher there before moving in 1971 to the University of California at Berkeley in 1971. His group at Lawrence Berkeley National Laboratory conducts experiments observing our galaxy and the cosmic background radiation, a remnant of the fiery beginning of the universe. Projects include ground-based radio-telescope observations, balloon-borne instrumentation, and satellite experiments. The most famous of these is COBE (the NASA Cosmic Background Explorer satellite), which has shown that the cosmic background radiation intensity has a wavelength dependence precisely that of a perfectly absorbing body, indicating that it is the relic radiation from the Big Bang. Smoot's honors include, besides the Medal of the Einstein Society, NASA's Medal for Exceptional Science Achievement, the Kilby Award for his contributions to science and technology, and the Department of Energy's Ernest Orlando Lawrence Award. Dr. Smoot has also published a popular book on cosmology entitled *Wrinkles in Time*.