



The Quotable Feynman

edited by MICHELLE FEYNMAN

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Feynman

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To Ava and Marco

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A Brief Note on Sources

Richard Feynman has been called the great explainer. This book of quotes characterizes my father's approach to scientific problem solving, his philosophy, and his communication style. Taken by topic, these quotes provide a richer, deeper understanding of how he thought, emphasize what he thought was important, and give shining examples of how he expressed himself.

Sources were his many published works, his personal papers that occupy 14 file drawers, and dozens of hours of recorded lectures. A number of important quotes also came from interviews that he did with Charles Weiner for an oral history project for the American Institute of Physics from 1966–1973. I, along with research assistants Anisha Cook and Janna Wennberg, who were instrumental in the book's shape over the final summer, gathered thousands of quotes and then sorted them into the 26 topics that make up this book.

While no collection of quotations drawn from written works, notes, correspondence, and lectures can fully capture my father's wide-ranging thoughts on various topics, it is my hope this compilation will provide the reader with a sense of his clarity, his humor, his unique way of looking at the world.

Michelle Feynman

Foreword

If you go into any physics department at any university in the world and ask the undergraduates which scientist they most aspire to be like, I think a majority would say “Richard Feynman.” Einstein might come a close second. I would say Feynman.

Richard Feynman was one of the greatest physicists of the 20th century. His 1965 Nobel Prize, shared with Julian Schwinger and Sin-Itiro Tomonaga, was awarded for their work in developing the theory of quantum electrodynamics, which to this day stands as our most precise description of the interaction between light and matter. We wouldn't understand atoms without it. Feynman's name is most closely associated with the theory because of his introduction of Feynman diagrams. Every physicist working at CERN, or any modern particle physics laboratory, has been taught how to use Feynman diagrams. They are the foundation of our understanding of the subatomic world, allowing us to calculate what will happen when particles collide and even to predict the existence of new ones, like the Higgs Boson. I cannot imagine particle physics without them, and they probably wouldn't exist today without Feynman; I don't think anyone else would have come up with them. They are intuitively obvious after they have been explained to you, and yet you get the feeling that you'd never have invented them yourself. This was Richard Feynman's particular genius; exploring nature using a sort of internalized intuitive magic. His approach was summarized famously by his friend and colleague Hans Bethe: “There are two types of genius.

Ordinary geniuses do great things, but they leave you room to believe that you could do the same if only you worked hard enough. Then there are magicians, and you can have no idea how they do it. Feynman was a magician.”

Quantum electrodynamics alone is enough to place Feynman firmly among the greats, but there are plenty of Nobel Prize-winning physicists whose names few undergraduates would even recall, let alone hero worship. The reason for the unique esteem in which Richard Feynman is held, I think, can be found in this book. It is his incisive, humble logic; razor-sharp precision deployed with humanity; wonder catalyzing discovery; a deep love of nature and a powerful desire to understand how it works. When I read his words, which should be read in a New York workingman’s accent, I hear the reassuring clarity of an old engineer who’s popped ’round to fix your plumbing. There is no artifice, no obfuscation, no attempt to bamboozle or self-aggrandize; just a feeling that this person will get the job done with a minimum of fuss. Richard Feynman thought about physics like that. I often quote him in my own books because I can never put my feelings about physics quite as clearly as he could. There is a beautiful interview broadcast by the BBC in 1981 called “The Pleasure of Finding Things Out,” in which Feynman is asked about the possibility of discovering a “Theory of Everything” — a complete mathematical framework which describes all of Nature at the most fundamental level.

“People say to me, ‘Are you looking for the ultimate laws of physics?’ No, I’m not. I’m just looking to find out more about the world, and if it turns out there is a simple ultimate law which explains everything, so be it; that would be very nice to discover. If it turns out it’s like an onion with millions of layers and we’re

just sick and tired of looking at the layers, then that's the way it is! And therefore when we go to investigate we shouldn't pre-decide what it is we are trying to do except to find out more about it. . . . My interest in science is to simply find out more about the world."

That is, for me, a perfect description of science. Take delight in the small, rather than adopting futile intellectual postures in the face of the intricate infinite delicacy of nature and you might make a little progress. Reading his words, you will hear that message over and over again. I am a simple man, and I like to think carefully about simple things. That's a real physicist talking.

This direct simplicity certainly didn't preclude lyricism when it came to describing the process of doing science. Some of my favorite quotes are those that reveal Feynman's inner picture of the scientific endeavor: "We live in a heroic, a unique and wonderful age of excitement. It's going to be looked at with great jealousy in the ages to come. How would it have been to live in the time when they were discovering the fundamental laws?" This is suffused with, to use a cliché often hurled at scientists, child-like wonder, and Feynman was absolutely comfortable with such a double-edged compliment. "I hate adults."

Feynman was also a polemicist, deploying his deliberate linguistic clarity to powerful effect whenever he got the chance. I can think of few physicists who would write, in an introductory lecture on electromagnetism: "From a long view of the history of mankind, seen from, say, ten thousand years from now, there can be little doubt that the most significant event of the 19th century will be judged as Maxwell's discovery of the laws of electrodynamics. The American Civil War will pale into provincial insignificance in comparison with this important scientific event of the same decade." I love this. I read it as an entirely appropriate

swipe at the futility of provincial wars, prefiguring Carl Sagan's *Pale Blue Dot*, the great lament for parochial human stupidity written three decades later: "The Earth is a very small stage in a vast cosmic arena. Think of the rivers of blood spilled by all those generals and emperors so that in glory and triumph they could become the momentary masters of a fraction of a dot."

In these pages, then, you will catch a glimpse of genius, read the thoughts of one of history's great polymaths and one of the greatest scientists who ever lived. I hope you will learn a lot, as I have, and perhaps emerge with a little additional curiosity, wonder, humility, and respect for the natural world. Having said that, "I don't wanna take this stuff seriously. I think we should just have fun imagining it and not worry about it."

Brian Cox
Professor of Particle Physics
The University of Manchester

Reflections on Richard Feynman

There seems to be an insatiable public appetite to feel a closeness with the giant mind and personality of Richard Feynman. This curiosity transcends generations, crosses disciplines and cultures. Over a quarter of a century after his passing, he remains alive in the public consciousness, his books are still in print, his legendary lectures are online, scientists are continuing to grapple and tangle with many of the theories he put forth decades ago.

So where does the longevity of his aura come from? I can only offer a sliver of a snapshot.

Over three decades ago, I used to see Richard backstage at concerts. He came not because he liked cello playing particularly, but because his beloved young daughter, Michelle, played, and of course, what doting father wouldn't want to please his daughter? Sometimes we would pass time bantering about what truth is in science and art, and he would always say, "In science you have to prove it." And then he would regale us with stories of his adventures playing the bongo drums. Once we went to the house and he showed us his beautiful drawings of the human figure. He talked about how his desire to go to Tuva came about from playing a geography game. He was always energetic, attentive, and present.

One of my heroes, as I was growing up, was the great cellist Pablo Casals. I was particularly impressed when he remarked

that he was a human being first, a musician second, and a cellist third. I was similarly taken when I read one of Richard's quotes: "You cannot develop a personality with physics alone; the rest of your life must be worked in."

Therein lies a clue to the longevity of Richard Feynman. Yes, he was one of the all-time great physicists, but he also paid attention to life and love, to his children, to his family, to the sensuality of the human figure, to the primal complexities of drumming, to his entire environment. While he paid close attention to problems we face and generate, he also knew that humans are a subset of nature, and nature held for him the greatest fascination — for the imagination of nature is far, far greater than the imagination of man, and nature guards her secrets jealously.

Thus, for him, it was worth the years of work to extract some of those secrets in order to pass them on in the most direct and understandable form to the rest of us. Because he worked his whole life into his personality, we could identify with his humanness and therefore stay with him as he took us on the most spectacular journey of all, the never-ending quest to understand everything.

Surely you must still be joking, Mr. Feynman!

Yo-Yo Ma
Cellist

Preface

My Quotable Father

I recently came across a few of my notebooks from high school and college and found scribbles from my time in the classroom. By turns funny, uplifting, heartbreaking, and occasionally annoying, those excerpts from my life of years ago remind me of a particular moment or a class much more quickly than do my actual class notes — there is something very powerful about a concise statement. And so I have always loved quotes.

One of my favorite quotes from my father came in a birthday card he gave me when I turned 18: “Go forth!” he wrote. When I read those words, I remember my reaction — pride and excitement, mixed with some apprehension. I also recall that he usually didn’t bother himself with the trivialities of birthday cards; he left that to my mother, which made this particular quote that much more poignant.

My father left me his words. From them I remember both his outlook on life and his voice, positive and clear. He was someone who didn’t worry about small problems. His advice here — leave it; let it go — is inspiring:

And we all do stupid things, and we know some people do more than others, but there is no use in trying to check who does the most.

I'm often asked what kind of father he was, and although I occasionally teased him for not remembering what I thought were pertinent details of my life (age, school, etc.), he was always happy and ready to spend time with me. He might have had a reputation for not suffering fools gladly, but I remember him as a funny, energetic, kind, playful, patient man. I recall his wise advice about finding a career, very similar to a letter he wrote to a high school student in 1984:

It is wonderful if you can find something you love to do in your youth which is big enough to sustain your interest through all your adult life. Because, whatever it is, if you do it well enough (and you will, if you truly love it), people will pay you to do what you want to do anyway.

Whenever I read his words, I hear his voice. It still makes me laugh to think that he used the phrase “cooked up” in his Nobel Prize lecture:

I never used all that machinery which I had cooked up to solve a single relativistic problem.

I am charmed by my father's use of expressions that are no longer in rotation, and I am mesmerized by his distinct rhythm of speaking. I remember a few archaic expressions from when I was growing up — the refrigerator was the “icebox,” for goodness' sake! Or “They go all around Robin Hood's barn to come around here” to describe a round-about path.

I know he was fascinated by Las Vegas. He incorporated stories from visits there in his lectures. I really love the following excerpt because he was such an expert at breaking grammatical rules. The rhythm really sets the scene:

Example. I'm in Las Vegas, suppose. And I meet a mindreader, or, let's say, a man who claims not to be a mindreader, but more technically speaking to have the ability of telekinesis, which means that he can influence the way things behave by pure thought. This fellow comes to me, and he says, "I will demonstrate this to you. We will stand at the roulette wheel and I will tell you ahead of time whether it is going to be black or red on every shot."

I believe, say, before I begin, it doesn't make any difference what number you choose for this. I happen to be prejudiced against mindreaders from experience in nature, in physics. I don't see, if I believe that man is made out of atoms and if I know all of the — most of the — ways atoms interact with each other, any direct way in which the machinations in the mind can affect the ball. So from other experience and general knowledge, I have a strong prejudice against mind readers. Million to one.

Now we begin. The mind reader says it's going to be black. It's black. The mind reader says it's going to be red. It's red. Do I believe in mindreaders? No. It could happen. The mindreader says it's going to be red. It's red. Sweat. I'm about to learn something . . .

It was also revealing to see how he spent his leisure time. Was I surprised to see quotes that revealed his penchant for always working on physics? Not really. It was a switch he couldn't turn off. I remember he always seemed to be thinking about physics. When he didn't have a pad of paper, it was common to find equations on scraps of paper — even margins of the newspaper. Even when he was very young, he recalled, he was annoyed at being pulled away from working.

I didn't get to do as much as I wanted to, because my mother kept putting me out all the time, to play.

That one really made me laugh. These next two exemplify his open, honest attitude and how he loved nothing better than thinking about physics:

It is a nice problem, however, and I often spend time on airplanes trying to figure it out. I haven't cracked it yet.

It must have been a day or so later when I was lying in bed thinking about these things that I imagined what would happen if I wanted to calculate the wave function at a finite interval later.

I've always been impressed by his humility:

I suffer from the disease that all professors suffer from — that is, there never seems to be enough time, and I invented more problems than undoubtedly we'll be able to do, and therefore I've tried to speed things up by writing some things on the board beforehand, with the illusion that every professor has: that if he talks about more things, he'll teach more things. Of course, there's only a finite rate at which material can be absorbed by the human mind, yet we disregard that phenomenon, and in spite of it we go too fast.

I remember so much advice from my father: Think about a math problem to see whether your answer makes sense. Work to be direct and honest in communication. Aim to be friendly and kind. Realize that life is an exciting adventure. Find something to do that you love. Work hard. And always, *always* remember your sense of humor! I have not always been able to laugh at myself, but it was something at which my father excelled. I remember his once trudging through an airport, luggage in tow, laboring to make a connecting flight home. He muttered to himself, "Flying

is for the birds!” — and, realizing just how true that was, laughed and regained his equanimity. Of all the advice he dispensed, perhaps his exhortation to remember one’s sense of humor is the most crucial. Doing so has helped me cope with difficult moments in my own life.

Strangely enough, I came across one of my father’s quotations about *his* father that sums up how I feel about *my* father:

Not having experience with many fathers, I didn’t realize how remarkable he was.

I will be forever grateful to my father for sharing his life with me — from the charming, silly, playful moments to the serious.

Michelle Feynman, 2014



Chronology

- 1918 Born in New York on May 11
- 1939 Graduates from MIT, begins graduate studies at Princeton
- 1940–41 Research assistant, Princeton University
- 1942 Receives PhD from Princeton
- 1942 Marries Arline Greenbaum
- 1943–45 Works on Manhattan Project, Los Alamos, New Mexico
- 1945 Arline dies
- 1945–50 Professor of theoretical physics, Cornell University
- 1950 Visiting professor at Caltech; takes a year teaching in Brazil
- 1950–59 Professor of theoretical physics at Caltech
- 1952 Marries Mary Louise Bell
- 1954 Wins Albert Einstein Award
- 1956 Divorces Mary Louise
- 1959 Gives lecture “There’s Plenty of Room at the Bottom”; offers two nanotechnology challenges
- 1959 Becomes the Richard Chase Tolman Professor of Theoretical Physics at Caltech
- 1960 Marries Gweneth Howarth
- 1961–63 Delivers freshman lectures on physics at Caltech that become The Feynman Lectures on Physics
- 1962 Wins the E. O. Lawrence Award
- 1962 Son, Carl Richard Feynman, born

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