The freedom of a curious character

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"So spoke and honest man, the outstanding intuitionist of our age and a prime example of what may lie in store for anyone who dares to follow the beat of a different drum"

–Nobel laureate Julian S. Schwinger in his obituary for Feynman in *Physics Today,* February 1989–

In his recent book *Feynman's Rainbow,* physicist Leonard Mlodinow remarks that anyone who ever met Richard Feynman and had the inclination to write, would have felt compelled to write something about him. Though I never met Feynman personally, I feel much the same way. Thus, a good place to start is to pose myself the question: Why Feynman? Certainly he was one of the most brilliant, original and idiosyncratic thinkers of the twentieth century, but not the only one. In fact, as is well known to all, the twentieth century was a prodigiously rich century in terms of eminent scientists. It suffices to mention that this century saw the genesis of two great theories, which together describe, explain and predict the workings of the known physical universe. On the one hand, relativity –mainly the creation of a single outstanding individual, Albert Einstein– explains the large-scale universe, in which gravity holds sway over the overwhelmingly vast realm of superclusters of galaxies, quasars, stars, black holes and planets, all embedded in the fabric of space-time. On the other hand, quantum mechanics is the theory which by far better accounts for the small-scale universe, namely, for the behavior of matter at its most fundamental level: molecules, atoms and subatomic particles. However, unlike relativity, quantum mechanics was the creation of many brilliant individual scientists, amongst whom the subject of this paper was but one contributor. More specifically, Feynman was the co-author (with both Schwinger and Tomonaga) of a rather esoteric theory called *quantum electrodynamics* (QED for short), which by means of very complex mathematics describes the interaction of light and matter. QED is one of the most precise theories known to mankind in terms of predictive power, and that's the work which earned Feynman a Nobel prize in physics in 1965, but I won't go into it. It is not my purpose here to describe Feynman's properly scientific work and achievements, as I lack the proper background in theoretical physics to do so. In what follows I will rather concentrate on Feynman the *man* rather than Feynman the *scientist*, and, more specifically, on Feynman as a *free man*, as the remarkable individual who always exercised freedom in his life and science, which for me, after all, is what makes Feynman so inspiring.

Richard Phillips Feynman was born in Brooklyn, New York City, in 1918. His mother Lucille recalled that Melville Feynman, a modest clerk who sold uniforms, said when she was pregnant: "If it's a son, he will be a scientist". Rather than a prophecy, though, it was Mel's deliberate goal to turn his son into a scientist, for he was the one who taught little Richard to think like one, and that's the reason why Feynman revered his father so much. But how to convey the gist of scientific thinking to a kid without teaching him abstract mathematics or burdening him with lots of (rather useless) information? By teaching him to look for patterns and getting him to think about *why* things happen and *how* things work, instead of learning

things by rote, was Mel's implicit answer to that question. Hence, what Mel taught his son was more a *methodology* to approach the world than actual facts or information about the world, a methodology which Feynman applied to everything, not just in his scientific work, but also in his everyday life. As Mel used to tell him in their field trips to the Catskill Mountains, there was no point in memorizing the characteristics and names of birds, for, after you know all that, you still don't know anything about birds. Why birds behave the way they do? Why their bodies are as they are? There you have really scientific questions, but of course Mel never told his son that; he just constantly poked his curiosity and imagination by posing interesting questions –rather than giving ready answers– to him. Only then come the facts, but behind those fun facts about the world there is a previous laborious process of reasoning and observation, and that's the main lesson which so successfully the father conveyed to his son.

There was also something else, and perhaps even more important: thinking about those things can be a very fun and delightful experience, a source of inner joy and utmost satisfaction. Getting to learn all those fascinating things *by yourself*, rather than knowing them second-hand, can be a highly stimulating, rewarding and perhaps unrivalled intellectual experience. Science is supposed to be fun, and if it ever loses that fun, then there is no worth in investing so much time and hard thinking in such a demanding enterprise. That was Feynman's approach, and years later he would tell his students: "Physics is like sex. Sure, it may give some practical results, but that's not why we do it". In science, curiosity and fun are everything; fame and honors mean nothing: they are just mere façade, uniforms, as Mel taught him, and Feynman also learned that lesson very well.

Equipped with Mel's teachings and an already notorious passion for science, the boy who fixed broken radio sets in New York went to the Massachusetts Institute of Technology in order to study pure mathematics. Soon, however, he switched to physics, for, after all, Feynman was a more pragmatic personality and realized that the use of higher math was just teaching higher math. But it was there at MIT that he discovered quantum mechanics, a whole new, strange and fascinating world to him, which would puzzle and amaze him for the rest of his life. The problem was, though, that only two professors at MIT, Slater and Morse, were familiar with the new physics by those days: so novel this theory was in America back then. So, he had to learn it all by himself. Well, not all by himself, but along with Welton, another gifted classmate with whom Feynman exchanged a notebook in which they "reconstructed" quantum mechanics in order to learn it. This was the very first instance of an approach that characterized Feynman across all of his scientific career: reconstructing things from first principles and deriving other scientists' results his own way. Otherwise he couldn't really feel he understood them, as he clearly expressed in a motto he wrote on the blackboard

many years later, when he was a senior professor: "What I cannot create, I do not understand". (With this same approach, he prepared for the Ph.D. examinations from Princeton University a few years after graduating from MIT: he inaugurated yet another blank notebook which he titled "Notebook of things I don't know about", in which he basically reconstructed, from first principles, all he had learned about physics through his undergrad and doctorate days.

Besides quantum mechanics, Feynman also made another important discovery back then: love. Since his childhood in Brooklyn he had met and been friends with a girl from his neighborhood, Arlene Greenbaum. And just as quantum mechanics, she was also his lifelong love, even though she died very soon from tuberculosis. During his undergrad and grad years, that already special friendship turned into love and our young scientist, allergic to ceremonies as he was and fearing his and her parents disapproval, decided to marry the young lady in secret, even though she was already sick. What follows is a critical episode in Feynman's life, when being only 24 and already married he was recruited to join one of the biggest collections of brilliant minds humankind has ever witnessed: the Manhattan Project, this is, the United States scientific and military effort to build an atomic bomb in order to prevent the Germans from doing so first.

In company of great mean despite his youth, another facet of Feynman's came into view: his disregard for authority when discussing scientific matters. In fact, later in his life Feynman defined science as "the belief in the ignorance of experts". At Los Alamos, he was appointed to work in the theoretical division under Hans Bethe (later known for discovering the source of energy of stars, what keeps them shining). But even exceedingly able scientists such as Bethe come up with bad ideas from time to time, and Feynman, his subordinate, didn't mind telling him so: "No, no, you're crazy, I'll rather go like this". As Feynman himself later recalled, that was precisely what Bethe was looking for: not just silent assent, but actually a test-bed for his own ideas. As a consequence, Feynman's position escalated until soon Oppenheimer sent him to supervise the uranium-producing facilities at Oak Ridge. This merciless attitude toward lousy ideas and sloppy thinking earned him the respect of his older and more reputable colleagues, among them the famous Bohr. Back in Princeton, another episode reminds us of his recklessness when discussing physics: being a doctorate student under Wheeler, Feynman was assigned to deliver his first seminar presentation in front of Einstein and Pauli. Understandably, this time Feynman got nervous, but once he started thinking and talking about his beloved physics, everything changed: he just focused on the problem at hand and completely forgot who was in front of him.

However, in spite of the fruitful scientific experience and the amusement provided now and then by fooling the censors at Los Alamos with his mischievous tricks and playing pranks on his colleagues, not everything was fun for Feynman at Los Alamos, for it was then that Arlene, his only true love besides physics, died in a sanatorium in Albuquerque. From then on, Feynman´s relationship towards women was going to change forever, as he never again knew a love like that. He didn't complain, though, but rather admitted that with Arlene he already had it all, so the rest of his life didn't have to be so good.

True enough, but only in terms of love. Nonetheless, in terms of scientific achievement and the satisfactions it brought, his career was only to begin. Immediately after the war ended and under recommendations from his former boss Bethe, Feynman accepted an appointment as professor of physics at Cornell University. This opened another important chapter in Feynman's life: teaching. Soon he discovered that by preparing his classes he could think about classical problems from fresh, new perspectives, and that often the student's questions allowed him to establish parallels and relations with the issues at the forefront of theoretical physics research. Furthermore, sometimes the student's questions could give rise to new problems and open novel areas of research. Hence, Feynman took his classes very seriously and assumed his role as a professor with devotion and dignity. Teaching was something he was always proud about, and given that he loved it he excelled in it and as a result his students revered him. Never did he accept a "happy" researcher position in which he was exempted from teaching duties, for according to the ever dignified professor it was teaching and students what kept life going, especially during dry spell periods in research. Perhaps as a testimony to that, both the Richard P. Feynman Chair in Theoretical Physics and the Feynman Award for Excellence in Teaching still exist to this day in Caltech. Notwithstanding the importance of his Cornell years, for it was there that he accomplished his most important scientific work on QED, I will jump forward to his Caltech years.

While it can be said that Cornell was the place where Feynman built his reputation as a scientist, it was at the California Institute of Technology where he became the public figure, beloved teacher and legend we remember today. Moreover, it was at Caltech that he spent the longer period of his career, for he remained there till the very end of his life. When Feynman first arrived in Pasadena in the late 1950's, Caltech didn't have the overwhelming reputation it has today as one of the top schools for the study of the physical sciences, but nonetheless it was well known that Caltech had been home to outstanding men of science, as it continues to be today: it was the place where Millikan had performed his experiments on the charge and mass of the electron and Richter had devised his famous scale for measuring the intensity of earthquakes. It was also there that Zwicky and Baade had explained supernovae and first

proposed the existence of neutron stars, and last but not least, the place where men like Einstein and Oppenheimer had lectured. Certainly an exciting place to work for the likes of Feynman, and it was this what attracted him. In turn, it was Feynman being there what later attracted the talented Murray Gell-Mann, who later became Feynman's closest intellectual rival –and casual collaborator– at Caltech.

Caltech seemed like the perfect place to do research, but in addition Feynman was also assigned the hard but welcome task to teach physics at its most elementary level: he was in charge of the introductory, first-year physics course mandatory for Caltech undergraduates. In facing the task before him, he started by disregarding the traditional way in which that course had been taught by other physics professors for years. They usually started with a review of the history of physics, from the incipient kinematics of Aristotle to Newton's mature dynamics. Not a very exciting place to start, thought Feynman. Why not starting with the new physics right away? Why not starting with the most remarkable discovery known to mankind, namely, that all things are made of incredibly small particles named atoms? Thus, starting from the atomic hypothesis, Feynman constructed his physics course from first principles, putting all his knowledge of theoretical physics –and the whole of science– to test. In fact, it is fair to say that in the process of preparing his classes for the Caltech juniors and sophomores during those two years, Feynman re-constructed the whole of physics bottom-up, his own way. His lectures were almost theatrical performances, conveying students not only the fun of physics, but also the rigour of scientific reasoning. For instance, Feynman used to hung heavy weights such as bowling balls and bricks from the roof of the auditorium and set them oscillating in a pendular motion such that they stopped just before reaching his face, in order to show students why he believed in the predictions of science: they worked and he was confident about his face not being smashed! As a result, his classes were amusing, for Feynman was much of a showman. At the same time, however, they were quite challenging: although his lectures were intended for first and second year students, what happened as the course evolved was that less students attended and more of his colleague professors at Caltech went there to listen to his classes and learn from him. Consequently, the legendary *Feynman Lectures on Physics* (the famous three "red books") have been described as a failure, as their level was too high for the intended audience. Even to this day, they continue to be a reference for many physics professors and advanced students worldwide.

Aside from his normal teaching, Feynman sometimes prepared "special" lectures just for the fun of it. An example is his lecture on the motion of the planets around the Sun, in which Feynman derived, his own way, a proof of Kepler's law of ellipses. The purpose was to re-derive what Edmond Halley once requested Issac Newton to do, namely, to show why,

assuming a centripetal force diminishing with distance (the inverse-square law), the planets moved in ellipses around the Sun. Feynman was not interested in following the conventional Newtonian demonstration as espoused in his *Principia*, but rather to rediscover it himself. The result is a brilliant lecture, in which Feynman reconstructs the proof and arrives at the same result Newton arrived to, not using calculus but only high-school-level Euclidean geometry! In addition to these special lectures, Feynman had a seminar called "Physics X", which was not addressed to Caltech students, but to people who wanted to go there, just for fun, to discuss physics. There was no class-plan or syllabus: any physics question was welcome and Feynman would try to answer it, out of improvisation. Again, some of his colleagues and students could not resist the temptation and attended these out-of-curriculum seminars, which they remember as one of their most rewarding intellectual experiences at Caltech. Perhaps there is no better testimony to the appreciation and admiration his students felt for this special teacher than the banner they hung from the roof of a building in the Caltech campus when Feynman died, which read: "We love you, Dick".

When it comes to his scientific work at Caltech, Feynman continued working on his QED, but also worked on other puzzling scientific problems of his day, such as superconductivity and superfluidity. It was there that he also devised his novel graphic approach to thinking and solving problems in quantum mechanics, what today are known as *Feynman diagrams*. With his colleague Gell-Mann he also worked on the theory of radioactive decay, this is, the theory which explains how atoms of a given element disintegrate into atoms of other elements and lighter fundamental particles, emitting energy in the process, known as radioactivity. To be fair, Gell-Mann was more than just another colleague to him: he was his foremost discussion partner, his friend and intellectual rival at the same time. As with opposite electric charges, Feynman and Gell-Mann attracted each other and kept in mutual balance by their opposing personalities and styles of doing physics, as well as by their cleverness. To be sure, they had some thing in common: both were born and grew up in New York City and had been very precocious in the intellectual sense, not to say they were truly gifted individuals. Both loved science and had chosen to study physics, but there the similarities end. Gell-Mann was more of a prodigy, the stereotypical nerdish "wonder boy", and he was very interested in a wide array of subjects as diverse as languages and ancient cultures, besides his interest and abilities in math and science. As a consequence, he boasted a vast knowledge about many non-scientific things; he certainly was a walking encyclopedia. On the other hand, Feynman was more like the unpolished, rough-hewn and seemingly uncultivated American, as his biographer Gleick characterizes him. He was interested in his science, his passion, and apparently nothing else. Along his life, he carefully avoided everything –and everyone– that

was not *interesting* to him because, he said, he had a limited intelligence and used it in a particular direction. Thus, Feynman focused all his energies and talent upon his beloved science and deliberately ignored many things, a characteristic which, coupled to his very informal manner of speech, sometimes made him appear as uneducated and brash, and even as an ignoramus to the polymath Gell-Mann. In turn, Feynman despised and made fun of the pedantic style of his colleague, not wasting an opportunity to tease him for what he saw as a display of unnecessary erudition with the only purpose of impressing people. Despite these differences, however, Feynman and Gell-Mann got along well and complemented each other. Their endless physics discussions, true bull sessions in which both men mutually challenged their ideas and pushed them to the limit were known in Caltech as "twisting the tail of the cosmos" and, of course, both profited from those sparkling exchanges. Today, Caltech owes much of its renown for having been the place were Feynman and Gell-Mann, the fox and the jaguar, the "twin titans" of physics, worked.

Later on, Gell-Mann moved on to the forefront of theoretical physics research. Back in the 1960's, and independently from his Caltech colleague Zweig, Gell-Mann had discovered what today we know as *quarks* (the name is Gell-Mann's), namely that hadrons –such as protons and neutrons– were in turn made up of even more fundamental triplets of particles. Feynman had also entertained a similar theory and had called them *partons*, but when new experimental evidence came from CERN in support of the existence of the Ω^- , a new fundamental particle predicted by Gell-Mann's theory, he endorsed it and had no problem giving full credit to his colleague. Less appealing to Feynman's taste and physical intuition was a theory which was born in the 1970's and soon came to dominate the field and attract the attention of many physicists, even to this day: string theory. This highly complex mathematical theory comes in several flavours, but the basic idea behind it is that the fundamental particles of matter are not point-like particles as traditionally conceived, but rather unimaginably small strings which can vibrate in several dimensions. One of the pioneers of this theory, Schwarz, was at Caltech at the time Feynman and Gell-Mann worked there, and the latter even supported him in his string theory research. Always skeptical, Feynman failed to be seduced by the new theory. No matter theories are beautiful or appealing in the mathematical sense, they have to give precise predictions, and one of the few predictions of this theory is that there is a bunch of additional dimensions lurking around, undetected to us. Feynman protested, as many other physicists continue to protest ever since: How are we going to detect those additional dimensions in order to verify the claims of string theory? It is a question that has not been answered, and though many physicists continue to have faith in string theory, many others are starting to doubt its *physical* validity and consider string theory as nothing but fancy

mathematics. Perhaps Feynman was right after all, or was Gell-Mann? Only time and Nature will tell: Feynman used to say it is Nature in the end which tells scientists what to do, and not the converse. And if you don't like the way things are, the way Nature works, "you can go to hell".

This takes us to one of the most interesting and fascinating aspects of Feynman: his relentless skepticism, utter honesty and impatience with all facets of human stupidity. "I was born not knowing –he once said– but had only had a little time to change that here and there". Getting knowledge is a tough business, for the easiest thing is to fool oneself. Feynman always kept that in mind, both in his science and in his life. He was always very critical, even of himself, and nothing escaped his skepticism. The mark of the scientist for him was the freedom to doubt, and this not only applies to science, but to all human enterprises. The scientist should always bear in mind "the great value of a satisfactory philosophy of ignorance and teach how doubt shouldn't be feared, but welcomed", no matter he is discussing science, politics or religion. As nothing is completely certain, Feynman thought (perhaps a lesson from quantum mechanics), it is better to speak of degrees of probability or likeliness of beliefs and learning how to live with uncertainty and doubt, instead of having total beliefs which may be wrong. In other words, he preferred to have partial beliefs which are approximately right than to have total beliefs which might be utterly wrong. For instance, he always thought the traditional religious picture of the universe as a stage arranged for God to watch men struggle between good and evil was inadequate given the facts of science, what we know about the universe and our place in it. He expressed it quite eloquently in an interview: "It doesn't seem to me that this fantastically marvelous universe, this tremendous range of time and space and different kinds of animals, and all the different planets, and all these atoms with all their motions, and so on, all this complicated thing can merely be a stage so that God can watch human beings struggle for good and evil, which is the view that religion has. The stage is too big for the drama". As a direct consequence of his science, Feynman was always an outspoken atheist and did not think science and religion could be compatible, but rather that their respective worldviews inevitably clashed in the head of the science student who has been raised in a religious environment. He was as dubious towards the pseudosciences, but in contrast to many other scientists who just disregard them hands off, he always tried to test his own beliefs –or rather disbeliefs– by subjecting himself to telepathy, telekinesis, ESP and sense-deprivation experiments, only to confirm they were bogus sciences. Knowing *why* things were true or false was always more important to Feynman than simply asserting they were true or false, and that involved checking his own beliefs and ideas, as well as other's. What he knew was less important and interesting than *how* he knew it. Thus, claiming to have knowledge

about something implied a greater responsibility than most people might think: avoiding fooling oneself first, in order not to fool others.

That was Richard Feynman: ever curious, ever skeptical –even about himself–and ever committed to the things that really moved or interested him in life, and in science as a considerable part and source of happiness thereof. As a scientist he learned how to cope with uncertainty, doubt and ignorance while bowing before the great mysteries of the universe and existence. As a gifted teacher, he was able to convey the passion of science, but also the painstaking effort and intellectual integrity and honesty that is behind the ultimate joy of scientific achievement, whether it be discovery or re-discovery. And as a man he loved life and truly enjoyed it until, after years of struggling with cancer, he decided he had lived fully and was ready to make his last "discovery". Aside from the scientific community, among which he was one of the brightest stars of the twentieth century, this curious character has inspired and continues to inspire many students worldwide. His unconventional and idiosyncratic approach is best described by Mlodinow, one of the lucky students who profited directly from Feynman's lessons in physics and in life: "He didn't seek the leadership role. He didn't gravitate to the sexy unified theories. For him satisfaction in discovery was there even if what you discover was already known by others. It was there even if all you are doing is re-deriving someone else's result you own way. And it was there even if your creativity is in playing with your child. It was self-satisfaction. Feynman's focus was internal, and his internal focus gave him freedom. Our culture is a culture that, by Feynman's characterization, is Greek. It is a culture of logic and proof, rules and order. In our culture people who live their lives like Feynman are considered eccentric, for Feynman was a Babylonian. For Feynman, both physics and life were ruled by intuition and inspiration, and a disdain for rules and customs. He ignored the conventional methods of physics, and invented his own, his sum over paths and his Feynman diagrams. He also ignored academic culture and invented his own, eating with the students in the Greasy, or working on his physics in strip clubs, or doing research less for reasons of ambition than for reasons of love. And if his behavior was not approved of, well, what did he care what other people thought?" In a world where uniformity and standardization rule over individuality, this is perhaps the best lesson the great Feynman has to offer.

By Juan Serrano*

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A FEYNMAN BIBLIOGRAPHY

Richard Feynman actually never wrote a book: what remains from him are recollections and transcriptions from his lectures and the anecdotes he told to his closest friends. Nevertheless, most of this lectures, both scientific and on other topics, have been preserved and collected in several volumes. A recent collection of his letters has also been published. There is also a movie (1996) called *Infinity* which centers on Feynman's relationship with Arlene.

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