

# ALL POSSIBLE PATHS

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*Richard Feynman*

RICHARD FEYNMAN'S CURIOUS LIFE

In 1968, I escaped from East Germany with a folding canoe, crossing the Black Sea from Northern Bulgaria to Turkey. Then I worked as a Ph.D. student at the Max-Planck-Institute in Munich. In the Fall of 1970, I went for 6 months to the Stanford Linear Accelerator Center (SLAC) in Palo Alto, California. Since at that time I collaborated with Murray Gell-Mann, I went twice a month for a few days to the California Institute of Technology (Caltech) in Pasadena, about 360 miles south from Palo Alto.

In Caltech I met Richard Feynman for the first time, and we discussed physics almost every day, in particular his parton model. He assumed that the nucleons consist of small pointlike constituents, which he called partons. With this idea he could describe the new experimental results, obtained since 1968 at SLAC.

I told Feynman that his partons should be the quarks, which his colleague Gell-Mann had introduced in 1964. However, Gell-Mann did not assume that the quarks are pointlike. The electric charges of the quarks are not  $(-1)$  or  $(+1)$  — as the charge of the electron or the proton are — instead they are  $(2/3)$  or  $(-1/3)$ . Using these charges of the quarks, Feynman and I derived specific relations for the cross sections. It turned out that these relations were correct, thus the partons should be just pointlike quarks. Originally Feynman did not like the quarks, but now he started to work on the new "quark parton model".

Much later, in 1974, Feynman and I tried to understand what happens if an electron and a positron annihilate at very high energies. One observed in this annihilation that many particles are produced, mostly mesons, which are unstable particles, composed of a quark and an antiquark. It was assumed that these particles are produced, because first a quark and an antiquark are produced, which then produce the observed particles. The energies of the two quarks are the same as the energy of the incoming electron.

Feynman and I had the idea that the sum of the energies of the particles, produced by a quark, should be equal to the energy of the original quark. Thus the produced particles should form a jet of particles. In the electron-positron-annihilation at high energies, one should observe two jets of particles. In 1978, these jets were observed at the German research centre, Deutsches Elektronen-Synchrotron (DESY) in Hamburg.

In Caltech, Feynman and Gell-Mann had one secretary, Helen Tuck, who worked at Caltech for 32 years. One day, Helen came to my office and asked me whether I knew how many languages Feynman can speak — she had to fill out a questionnaire for Feynman. I told her that he can speak English, Spanish and some German. Later she asked Gell-Mann the same question, but he told her: "As far as I know, Feynman cannot speak any language, except his funny New York dialect."

In 1972, I started to work as a research associate at Caltech. Gell-Mann and I introduced the theory of Quantum Chromodynamics (QCD), describing the interaction of the quarks with massless particles, which we called "gluons". Feynman was interested in this new theory, but he did not think that it was the right theory to describe the strong interactions. We always discussed this theory in the morning, when Feynman came to my office, but he always left at 11:30, since he knew that Gell-Mann would arrive at this time.

If the parton model of Feynman is correct, at high energies the sum of the momenta of all the partons should be equal to the momentum of the proton. At SLAC, one could measure the momenta of the partons, but it turned out that their momenta do not add up to the proton momentum. Only 45% of the proton momentum is carried by the partons.

I told Feynman that there is no problem if one assumes that the partons are quarks and gluons. The quarks provide 45% of the proton momentum; 55% is provided by the gluons, which have no electric charge, thus they cannot be observed at SLAC. Now Feynman was convinced that the theory of Quantum Chromodynamics is correct, and he started to give lectures on this theory at Caltech. He gave his last lecture on QCD only two weeks before he died — in February 1988.

In 1975, Feynman bought a Dodge Tradesman Maxivan and had it painted with Feynman diagrams. Once, we were going camping with Feynman and his wife in the Anza Borrego desert park near Palm Springs. Feynman drove his big camping car. On the way back, Feynman stopped at a gas station in Palm Springs. The guy at the station asked Feynman: "Why you have these Feynman Diagrams on your car?" Feynman told him, that he is Feynman, and the guy answered: "Well, in this case you do not have to pay for the gasoline."

Feynman had a house at the beach near Ensenada in Baja California, Mexico. He called the house "Casita Barranca". Feynman invited us to plan a visit to his house, and we went there several times. It was a beautiful house. Sitting on the side of a low beach cliff overlooking the Pacific Ocean, it had a private stairway from two intimate ocean front patios, allowing for immediate access to a sandy, solitary beach.

In 1976, I left Caltech and went to the European Research Laboratory CERN near Geneva, Switzerland. Often, I used my folding canoe on the Geneva lake. Feynman visited CERN regularly. In 1977, he came and insisted on seeing the canoe, which I had used to escape. Thus, I invited him to a boat ride in my canoe. When we left the shore at the beach of the United Nations east of Geneva, Feynman told me that in 1958, he was on this beach and met a young woman: Gweneth Howard. She was working as an au pair in Geneva. Feynman liked her and invited her to visit him in Pasadena. One year later, she came and worked in the house of Feynman. Soon they got married.

In 1977, I went as a professor to the new university in Wuppertal, Germany. I invited Feynman for a colloquium and he came in 1978. Since this was the first visit of Feynman in Germany, many students came to the colloquium, some from cities far away, e.g. Hamburg, Munich or Heidelberg. After a few days in Wuppertal, I went with Feynman on a ship on the Rhine river from Cologne to the south of Germany. This was a beautiful trip. We had good weather, and Feynman admired the many castles built on the mountains close to the river. In the evening, Feynman went to a conference in France.

In 1980, I moved to the university in Munich and to the Max-Planck Institute. I invited Feynman for a colloquium, and he came in 1983 for a few days. On the second day, we walked from the university to the English Garden. I showed him in particular the "Eisbach" river, which flows through the park. On the meadows near this river, many people were sunbathing.

I told Feynman to visit the big German museum the next day, one of the largest science museums in the world, and in the evening we were planning to have dinner in the beer garden at the Chinese tower in the English garden. On the next evening, I went to the English garden and found the table, where Feynman was sitting together with a beautiful young lady. I introduced myself and she told me that she had met Feynman in the morning on the meadow near the "eisbach" river. Thus, Feynman did not visit the German museum, but instead had a good time with the lady in the English garden.

Feynman went back to Pasadena the next day. A few days later Helen Tuck called me: "What happened in Munich? Feynman liked it very much and wants to go back to Munich. Why?" I told Helen that Feynman met a lady in Munich, but I did not know any details.

In 1985, I visited Caltech again. Feynman told me that he has written a new book, which had just appeared:

"Surely You're Joking, Mr. Feynman!"

Since I was leaving on this day, he gave me the book, which he had received in the morning. Back in Munich, I arranged that the book was translated. It was printed by the Piper Publishing Company after a few months and was a big success in Germany.

