Roy J. Glauber

What is it that makes a dedicated scientist out of a kid with an everyday background? Is it the ungovernable forces that seem to shape all our lives, or is it the development of our own curiosity and tastes that tips the balance of randomness? I've always been puzzled by those questions and can't claim to have found serious answers. Perhaps these recollections will reveal one, even if it escapes me as I write.

To be a traveling salesman in the 1920's gave one possession of a company-owned car, acquaintance with a potentially vast area of the country, and a slightly better income than one would earn within the tight confines of New York City. My father, having enjoyed some experience with that life before getting married in 1924, couldn't wait to get back on the road, a possibility he had to postpone for about three years until his wife and new-born son, at last aged two, were ready to travel. The itinerant life was a restless one and quite disconnected. After long hours spent driving through endless farmlands we would stay overnight at the houses of farmers who had hung the sign "Tourists-Vacancy" near the road – never two successive nights in the same house. That was long before the days of roadside motels. Even hotels were scarce in some of the small towns we visited. Rural electrification was not yet a reality and I became quite accustomed to the smells of illumination by kerosene and acetylene lamps, as well as all the odors of barnyards and outdoor plumbing.

The periods in which my father was visiting customers, in whatever small town we were passing through posed a problem for my mother. Trained as an elementary school teacher, but pregnant before she had begun teaching, she was determined to make these passages as instructive for me as she could. The most interesting place in each town, as well as I could make out, was the fire

department. We received guided tours of their living quarters and fire engines all over the Midwest. Where fire departments were lacking, visits to assorted courtrooms, police departments and even local lockups would do for my introduction to civics.

In one Cleveland hotel room when I was four, we actually had a radio. It occupied a wooden cabinet about the size of a steamer trunk. I remember insisting there must be a man inside it. He had given his name as Maurice Chevalier. Discovering that the cabinet top was hinged, I opened it and can still feel my bafflement at discovering within it only a few glowing radio tubes.

Life on the road. Standing on the bumper of my father's car, Ohio, 1930.
The 1929 market crash had an immediate impact for me. The company my father was working for failed and the car we had been using was repossessed. The result was my first ride on a train, an exciting experience that there was no occasion to repeat, once my father had another job and a most imposing new car, a Marmon, a kind of Cadillac of its day, and one of many brands destined for early extinction.

The arrival of a baby sister in 1931 and my need to begin school meant that we had somehow to settle down. My folks decided we would return to New York, but the only way to do it, under the circumstances, was for our family to move into a crowded apartment in upper Manhattan with my father's mother and aunt. It was quite a shock, moving there from the wide-open expanses of the middle west, to sit in the crowded classrooms of an ancient school building. I had had very little experience playing with other kids in the small towns we had visited, and had no idea how to deal with the crowds of kids who managed somehow to play on the concrete sidewalks and in the adjoining gutters.

My mother was talented at crafts of various sorts. She sewed and embroidered well and, though untrained, she sketched and painted quite skillfully. She encouraged me to draw as soon as I could hold pencils or crayons steadily. That was the beginning of my career as a creative artist, specializing in speeding trains, airplanes and the occasional dirigible. It was a necessary release from the need to get fresh air by playing on the sidewalks.

After one school year in Manhattan, we found an apartment in Sunnyside, an attractive area of Queens, and moved there in 1932. It was a kind of deliverance. The neighborhood was spacious and not yet fully built up. It consisted largely of modest single family houses that all had at least a small area devoted to yards or gardens. All the blocks of individual houses and even our apartment building had central areas of lawn with space for children to play – not withstanding all the "Please keep off the grass" signs. There were even vacant lots with tiny hills and semi-permanent puddles that lent excitement to the four daily treks to and from school.

Sunnyside's residents consisted mostly of young families, quite a few contending with the unemployment so widespread in those depression years. The building for Public School 150 however was clean, well lit, and quite new. Its teachers were mostly young and optimistic, a vigorous contrast to the atmosphere that prevailed more generally in the country. The school's annual Christmas play, written by the fifth and sixth graders in 1932 was entitled, "Santa's Depression." It depicted Santa Claus as being broke, and unable to afford to make his usual rounds, until everyone pitched in to help him out. In the same period there were demonstrations against foreclosures on home mortgages going on in the neighborhood streets. Those depression years cast a long shadow over the lives of children no less than their parents.

My earlier years had left me with no experience in sports of any kind so it wasn't easy discovering how to engage in outdoor exercise. Unlike Manhattan, however, Sunnyside had many residential streets with little traffic. The best solution to my exercise problem was roller skating – with steel-wheeled skates that clamped to one's everyday shoes. Those steel wheels were quite noisy rolling or scraping on concrete, notwithstanding their good ball bearings, and I wore down to those very bearings many a set of skate wheels, cruising the neighborhood streets.

Electricity mystified me throughout childhood and I vividly remember once at age seven trying to see what it was all about. Plugging lamp cords into wall sockets must lead to the flow of something through those wires, but whatever it was, one never got to see it before it was swallowed up by the lamp. One morning I awoke early, determined to catch sight of it. I screwed the wires of a short length of lamp cord into a male plug and inserted it into a wall socket, leaving free the frayed wires at the other end. There was a bright blue flash at that end, accompanied by a muffled bang. That was followed by silence, till my parents awoke and began wondering why none of the light switches seemed to be working. The fuse was easily replaced, but I never overcame my surprise that what passed so silently through slender wires could behave so aggressively.

My most interesting projects were the ones I could pursue indoors like building models of contemporary airplanes of all shapes and of ships and locomotives. I had no cash allowance to spend on such projects and so was wholly dependent on gifts of construction kits from uncles and aunts. When those were scarce, as they sometimes were, I ventured into other areas, attempting to use crate wood to construct the projects suggested in various instruction books written for young boys. The most interesting of these projects usually failed, and I began to conclude the authors could never themselves have really built the exciting things they were describing. Their version of a guitar, for example, fashioned from a cigar box and some cheese box wood never had the rigidity to permit stretching a guitar string tightly enough. My guitar looked a bit like one but couldn't sound a single note.

There were other failures, many of them, but each brought new experience in the use of hand tools. An uncle, to encourage this construction bent, presented me with a three-year subscription to Popular Mechanics magazine. That magazine, besides celebrating all of the mechanical wonders of the age, included brief plans for all sorts of home projects: door chimes, folding tables, towel racks, bookends and knife sharpeners. The subscription did a great deal to keep my interest in mechanical things alive, but I can't say I ever succeeded in building any of those worthy projects. And I doubt that anyone who didn't have a machine shop at his disposal ever did either.

All the sawing, drilling and sanding I was doing at home left little time for drawing and painting, but there was ample opportunity to pursue those interests in school. Tempera paints were available there, a certain amount of free time, and a good deal of encouragement from the teachers, who felt a need to keep the backs of their classrooms decorated with mural paintings executed by the kids. They were painted over large areas of brown wrapping paper that covered the rear blackboards. I enjoyed designing those huge works and loved the freedom painting them gave me from sitting at my classroom desk.

My cover for the PS 150, Queens, NY School Magazine, December 1935.
The school produced a magazine every term and when my design for the cover of the Christmas 1935 issue was accepted, I felt like the Michelangelo of the fifth grade. In fact I did have some involvement with sculpture as well. Small carvings in soap, greatly encouraged by the Procter and Gamble Corporation, were a medium of the day, and I made many of them, mostly of musicians playing instruments. But a more conventional medium was Plasticine clay, which remains permanently soft. Those sculptures tended not to last long, but we managed, with a teacher, to take a few to a real sculptor's studio, and I was fascinated there to learn to make plaster molds and permanent castings.

If I was fully determined in the fifth and sixth grades to become an artist of one sort or another, it was not without a certain note of caution. My uncle, Sam Adler, was a gifted artist who had not yet succeeded in selling any of his work, nor did those years seem to promise that he ever would. His advice to me was that becoming an artist was an excellent idea, provided my motivation was so strong as to leave no alternative. I began then to feel that my artwork was not spontaneous

enough, that if I were a true artist I shouldn't have to think so hard before even starting drawings; they should just pour out more instinctively. My involvement with art receded to a hobby.

The years in which the depression lingered must have been difficult ones for the owners of apartment buildings. Faced with many vacancies, they offered rent-free months and other incentives to new tenants, so there was always a certain degree of restlessness among the city's apartment dwellers. In 1936, when I was ten, my parents decided that the higher ground of the Bronx – and the top floor of a six story apartment house – would be a better place to live than the flat sea-level expanse of Long Island. A precipitous increase of the local population density went with that move, and it became once again impossible for me or my sister to spend much time outdoors, in the streets. My first salvation was reading. I visited the local public library regularly and began reading the great adventure stories of Jules Verne, Alexander Dumas and Walter Scott. The junior high school I went to seemed mired in a curriculum too timid to do anything serious, and altogether flat-footed at what it did undertake. Mathematics, I remember, consisted of memorizing the decimal equivalents of the familiar "business fractions" and doing compound interest calculations out longhand. I was so put off by those lessons I occasionally got failing grades. Our premature introduction to French required our memorizing a list of proverbs which didn't literally translate into their English counterparts.

That junior high school experience was typified by what was called "music appreciation" in the auditorium assemblies. The principal, a Mr. Snyder, had himself written words to accompany several dozen themes of the great works of music. Singing his rhyming words he evidently felt, set to the themes of the great composers, should imprint those masterpieces on our young memories. Indeed they did, but it was at the expense of burdening those themes permanently with his infernal doggerel.

But that school did offer my first exposure to science and it was exciting. We were shown how to coil wire around nails and make them into electromagnets with the current from dry cells. Those 6 volt dry cells, widely used to power doorbells, cost 25 cents in the local 5 and 10. From that time on I was never without them.

My ambition to be an artist was further dampened by an art appreciation course largely devoted to biographies of the less scandalous painters, and punctuated by black and white lantern slides of their masterpieces. That course also had a creative element devised to avoid, at all costs, creating any sort of untidiness in the classroom. I was encouraged to draw with pastel crayons, again on a large sheet of wrapping paper hung at the back of the classroom, while the other kids who felt less inclined toward art, were set to copying mounted cartoon panels on drawing paper. Neither the pastels for me, which were intended evidently to make the room look like an art class, nor the cartoon exercises for the other kids, seemed to have any instructive value.

My lingering interests in art presently became centered on puppetry and marionettes. The instructions I saw for making them in some magazine articles and a handbook seemed to offer an interesting combination of sculpture and construction. After fashioning several puppet heads of papier maché and painting them, I set about constructing their marionette bodies and string controls. When it came the turn of our class to present a play in the school auditorium I volunteered to produce a small troupe of marionettes and a stage appropriate for the class

presentation. Our decision to stage the fairy tale "Rumplestiltskin" turned out to set a more imposing task than I had imagined. Fortunately my mother came to my aid, offering not only to costume the marionettes but to help in constructing several. The task kept both of us busy for a solid month. The eventual presentation by the class, speaking for and operating the marionettes, must have been some sort of success since we had to repeat it several times. But I was ultimately embarrassed by the fact that so much of the work had been visibly my mother's, and resolved that any further projects of mine would be wholly independent.

When did my interest in science become more serious? It really wasn't too serious, I'd have to admit, until still another change of location. My parents, realizing in 1937 that the move to the Bronx had not been a success, decided to move to an apartment at the north end of Manhattan. We lived in a more spacious neighborhood there and across a peaceful street from Inwood Park – the only uncultivated area left in Manhattan. The school I attended there for the ninth grade, which was nominally the first year of high school, was materially less boring than the prior year's. Algebra was an altogether new beginning and even a redemption for mathematics. It was finally freed of all that dismal arithmetic. That was a joy more than sufficient to overcome the uselessness of so many of the procedures that the curriculum did include. Who, even in those days, could imagine seriously needing to carry out long division of lengthy polynomials, or see any need to teach that procedure to children? No one with experience beyond teacher training could have been responsible for that curriculum.

But general science was another of the subjects we studied, and the energy and enthusiasm of its young teachers more than made up for its attenuated subject matter. I had read an elementary book on astronomy by that time and had been taken by my Aunt Sarah on an exciting visit to the Hayden Planetarium. I found that I could easily visualize the diurnal motions of the stars, the monthly motion of the moon, and somewhat more sketchily the motions of the readily visible planets, Jupiter, Saturn and Venus. The images associated with astronomy quickly captured my imagination, and I began to read everything about it I could find.

The encyclopedia had some simplistic diagrams of how a telescope works, and they seemed to assure me that I could build one from some ordinary magnifying glasses I had accumulated. I did that and was amazed by the rainbow colored edges I saw on the image of the moon and presently dismayed by its overall fuzzy quality. It took a bit of reading to discover what the trouble was – chromatic aberration, endemic to all such primitive refractors. The cure – the only one accessible to me – would be to build a reflecting telescope. But that would be a long-term project, fortunately one that had already been pioneered by quite a few adult amateur astronomers. There was a book, in two volumes, in fact, that drew together the experiences of several amateurs and gave a good deal of guidance, if not detailed instruction, for grinding, polishing and figuring the mirror, and for constructing the remaining optical elements and the mounting. Going through the entire procedure required nine months of work. Coarse and fine grinding of the mirror took only a couple of weeks, but polishing and figuring it to its final shape consumed months. Building a stable yet flexible mounting for the telescope, one that would permit me to follow objects in the sky, compensating for the earth's rotation was another matter entirely. I had only a few hand tools appropriate to woodworking, and still no access to machine tools of any sort. Constructing the wooden cell to house the mirror involved strenuous use of a coping saw and a wood file for several days on end.

The steel polar axis for the equatorial mounting was originally the steering shaft of a Ford car. The proprietor of the junkyard I found it in was happy to give it to me free. But I had somehow to put a 41° bend into that shaft, to equal the latitude of New York. I drew an outline of the bend I needed on a sheet of asbestos and took it off together with the three foot shaft to a garage that I knew refashioned truck housings. The owner was tickled by the project, heated the shaft in his forge till it glowed brightly and pounded it into the precise shape I needed. It must have taken him a good three-quarters of an hour altogether, and I felt I owed him payment for his time. He thought the matter over, and I recall his smile as he said that would come to 25 cents. In fact I got a good deal of aid over those months from people who were pleased to help an ambitious kid with virtually no money to spend on his projects. My accumulated savings of $10 were no more than half spent during those nine months.

Stability of the telescope mounting demanded that it be fairly massive but not too heavy to be carried by hand. The only way I could use it, after all, was to carry it upstairs to the roof of the apartment building. A weight of 40 or 50 pounds seemed appropriate for the base of the mounting, and I would have to make it of cast concrete. A schoolmate kindly brought me a sack of cement and a bag of sand contributed by his father, a local contractor. I fashioned a mold of the appropriate shape from recycled box wood and filled it with the concrete mixture called for by the instructions on the cement sack. The only place available to me for the casting operation was the wooden floor of my bedroom, between my bed and work desk. I had taken some precautions against the leakage of a little water by covering the floor first with waxed paper and a layer of newspaper. My understanding of the setting of concrete was that some miracle of chemistry would incorporate all of the water into the finally hardened product, with none left to leak out onto the floor. That is how plaster of Paris had hardened. But the result was a memorable lesson. I couldn't say what fraction of the hardening was eventually due to drainage, but it must have been appreciable. I had to spend an entire day mopping up pools of water around the hardening mass. I suppose when concrete sidewalks harden their leakage just seeps into the ground below. In my case it would have been the apartment downstairs.

Observing with the telescope wasn't too easy either. In winter the apartment house roof was cold and often windy. Because of the city lights the sky was rarely dark enough to permit seeing the fainter objects, usually diffuse nebulae or distant galaxies. Still there were the thrilling topography of the moon, frequent views of the major planets and countless planetary nebulae, double stars, and clusters of all sorts. Lacking the means to find the fainter objects mechanically, I had to go about tracking them down by locating their positions on star maps relative to the brighter stars or objects easier to find. By putting in at least a little time on most clear nights I managed over the next year or two to find most of the hundred or so extended objects catalogued by the Italian astronomer Messier. I even managed to fashion a film holder and cardboard shutter for the telescope so that I took through it a sequence of moon pictures during the lunar eclipse of November 8, 1938.

The possibility of performing optical tests as exquisitely sensitive as the Foucault test of the telescope mirror's figure with even the most primitive sorts of equipment convinced me that optics was full of miracles. Some other miracles I had seen involved the mysteries of light polarization. The Polaroid Corporation was sponsoring an exhibit I had visited at the Museum of Science and Industry at Rockefeller Center that showed, among other things, the remarkable

colors that appeared in transparent materials like cellophane when seen between crossed sheets of Polaroid film. How could I procure any of the magical Polaroid film? That seemed hopeless for a 12-year old, but I had heard of the possibility of light polarization by reflection. The best reflectors for the purpose would be smooth and black – to avoid the complications of transmission. My father, who at that time in 1937 was selling jewelry displays made of just such black glass, found me several rectangular pieces of the right size. I was able then to mount all the optical elements, including a 25 watt light bulb within a cigar box and use the device to reveal the same sorts of polarization phenomena I had seen at the museum. Seeing the unseen in that way turned out to be as much of a thrill as any I had with the telescope.

In the late 30's an organization with the imposing name The American Institute of the City of New York began organizing activities for young people interested in science. They held science congresses during the Christmas vacations and science fairs during the spring school break, both at the Museum of Natural History. The science congresses were patterned after professional scientific meetings, and split just as incoherently into many sessions, according to fields and specialties. Each session had several ten minute talks presented by the kids as contributed papers. One of those presentations in 1937 was my own description of the plans for the forthcoming 200-inch telescope at Mt. Palomar. It was a visionary image that kept my spirits up while I was having troubles of my own building my 6-inch diameter telescope. The sponsoring Institute saw to it that our talks were attended by at least a sprinkling of mature scientists whom they could somehow persuade to volunteer. I was flattered that my own talk was attended, if only briefly, by Dr. Clyde Fisher, the curator of the Hayden Planetarium. One of his assistant lecturers, Dorothy Bennett, stayed for the whole ten minutes and dropped a suggestion to me that added immensely to my experience over the next four years.

Dorothy Bennett was something of a wonder. Seeking a career in New York, she had arrived there as a fresh graduate of the University of Minnesota just in time for the economic debacle of 1929. With boundless energy and no prior acquaintance with astronomy she found a position working on the plans for the City's new planetarium. One of her many inspirations was to begin in 1930 a citywide astronomy club for kids of high school age. It met on Saturday evenings biweekly, in an imposing auditorium on the top floor of the Roosevelt Memorial building, adjacent to the Planetarium. There the kids, who came in by subway from the far reaches of the city, heard invited lectures by real astronomers. It was that club that Miss Bennett suggested I try attending. I was indeed excited by it and caught up in it from the first meeting I went to. It then formed a large part of my life till I went off to college.

Watched over by Dorothy in a kind of godmotherly role, the Junior Astronomy Club actually had a permanent office in a former watchman's apartment in the basement of the Roosevelt Memorial. There it held committee meetings, originated large mailings to the membership and ground out its monthly mimeographed publication, the Junior Astronomy News. I rushed to take part in all of those programs, ceaselessly amazed that the club could manage all of its activities on dues that only came to 25 cents per year. The secret of that miracle was that Dorothy had assigned to the club the royalties of a book she had inspired, *The Handbook of the Heavens*, and the proceeds from the sales of a rotating star map, a planisphere she designed. Enough copies of those publications had been sold to keep the club afloat for over ten years. Dorothy left the

planetarium for a position in the publishing industry in 1939, entrusting supervision of our club to a group of its older alumni, who carried on the tradition for quite a few years more.

I often wondered what happened to Dorothy in the years after that. She didn't just vanish into the publishing world, I found. Within a couple of years she had become the originator and editor of the Little Golden Books of Simon and Schuster. Those small paperbacks, devoted at first to assorted topics in natural science or history, became one of the wonders of the publishing industry. They were colorfully illustrated and were sold in vast numbers at newsstands and stores everywhere. Countless kids must have owed their knowledge of fossils, seashells, or trees to those books and to Dorothy. When eventually the publishers decided to extend their franchise into more commercial and less educational material, Dorothy left them and took up a succession of new careers in archaeology and ethnography. Her adventures extended to many other novel areas of public education.

In September 1938 a new high school was opened by the City, with the declared intention of providing a more extensive background in science. That school, the Bronx High School of Science was to have an entrance examination and a freshly chosen staff of young teachers. It was established however in an old building still used as an annex for a traditional local school, and three years had to pass before its growing student body had displaced the more disaffected population originally present. It was interesting being a pioneer in this way, but not without problems. Although the two populations didn't overlap in classes they did – and experienced friction – everywhere else.

My choice of this high school required long trolley car rides between upper Manhattan and the Bronx, but it proved fortunate in several respects. The kids were better informed about most things than average high school kids, and were often interesting to talk to. Not many of them entertained ambitions of becoming scientists however. They were there, mainly, it seemed, in search of somewhat higher educational standards. The lawyers, doctors and businessmen who emerged from my cohort, in fact, greatly outnumbered the handful of eventual scientists. Although all high schools offered some elective courses, it would have been difficult in most of them, to take both a science and a math course in each year. If we were able to do that, it was at the expense of studying Latin or taking a second modern language course. I was more than pleased at the time by those omissions, but have come to regret them since.

Whatever may have been the weaknesses of the school's physical plant or its curriculum, the faculty members seemed to make up for them. They were mostly young, energetic and unjaded. We seemed to have the depression years to thank for that. Most of the teachers had graduated from the tuition-free city colleges during the early 30's and, seeing no future in continuing their studies, had taken refuge in positions with the school system. The subjects they taught, like European history and economics, seemed to have real substance, for a change, and mathematics stood out among them. It was the real thing, not just an introduction one would have to repeat and improve upon in college. When algebra became more serious in the second year of high school it became more interesting. My teacher in intermediate algebra, Samuel Altwerger, appreciating my involvement with astronomy and my growing enthusiasm for mathematics, suggested that it might be a good idea for me to learn calculus. He assured me I could learn it just by reading a textbook. He gave me one small book for that purpose and borrowed a larger

one for me from the library. I found, to my surprise, that he was right. I had no trouble with these and absorbed an understanding of elementary calculus quickly. In fact that was well before I really needed calculus, but the experience marked a kind of turning point for me. I had never felt inclined toward mathematics before, but what I had learned by the time I reached college permitted me to skip several elementary courses there.

However much I came to like mathematics, my passion was still building optical instruments. I had been reading about the pivotal role played by spectroscopy in developing an understanding of atoms, and I resolved to build a spectroscope myself. Most of its parts would have to be made of metal, and that meant even more numbing use of hand files, this time not on wood, but brass. It wasn't difficult putting the spectroscope together. Neither its structure nor its optics presented other problems. But there was one central element missing. I had neither a prism nor a diffraction grating to use as the dispersive device that generates the spectrum. Fortunately the principal of the new high school, Dr. Morris Meister, had been given a replica diffraction grating as a graduation present, and he was happy to loan it to me. That spectroscope, entered in the 1939 science fair, won two prizes. I had very little chance to use it after that, since the American Institute exhibited it over many months in a display case at the New York World's Fair of 1939 and its repetition in 1940.

The Junior Astronomy Club also had an involvement in those World's Fairs. Part of the extensive Westinghouse exhibit was devoted to the scientific hobbies of kids of high school age. I was happy to organize demonstrations of the grinding of telescope mirrors for the exhibit and enlist a succession of our club members, each to spend a week or two on public display at the task. When my own turns came I became good friends with the young chemist who worked next to me, notwithstanding the shower of ashes his synthetic volcano blew over my optical surfaces. Young Frank Pierson never did become a chemist. He became a well-known screen writer and for several years president of the Academy of Motion Picture Arts and Sciences.

Taken at December 1940 Science Congress talk. At left is a 6 inch richest-field telescope f4, much more portable than my original f8, in the center is the diffraction grating spectroscope, at right a photomicrographic camera, with odd bits of paraphernalia in the foreground.

In the Science Congress of 1939, I gave a talk that presented some of the photographs I had managed to take through my telescope, my spectroscope, and through a borrowed microscope. It won one of the prizes, a visit to the Westinghouse Corporation in Pittsburgh, Pennsylvania, where I had a chance to visit their “atom smasher”, a vertically mounted Van de Graaf generator, and to talk briefly with a couple of real scientists, including a well known theorist, E. U. Condon. Then, as a climax to the trip, I was ushered into the office of the president of the corporation. He promptly drew from his top desk drawer a tattered old pocket notebook. It was his official record, he explained, of the hours he had worked for the company at the turn of the century for a wage of only a few cents an hour.

The junior year of high school meant starting to think about going to college. The teacher assigned as my guidance counselor, thinking perhaps of the experience of his colleagues, assured me that there were too few positions available anywhere for astronomers or physicists, and that I would be best off going to an engineering school. He felt I should apply to a range of them, but he saw Rensselaer Polytech as the ideal compromise. The father of my best friend, a Harvard graduate himself, gave me rather different advice. Disappointed at the unlikelihood of his own son’s admission to Harvard, he guessed that I might make it. More to the point, he suggested that scholarship support could be available. Neither my parents nor I would otherwise have been so presumptuous as to imagine that large a leap in social status. I did fill out the lengthy Harvard applications, however, and take the several required examinations. The application for the scholarship awarded by the New York Harvard Club involved a searching interview conducted in a large, oak-paneled room by a dean and half a dozen club member contributors. I was eventually admitted to a number of colleges, including Rensselaer , but without scholarship aid. Harvard, on the other hand, granted me a Harvard Club scholarship, while making it clear that there were many more exams to take before I would be declared admitted.

SPECIAL JOINT MEETING

NEW YORK ELECTRICAL SOCIETY

and

The American Institute Science & Engineering Clubs

TO-MORROW'S SCIENTISTS

Chairman: IRWIN ARIAS, *American Institute Science Laboratory*

Speakers:

PATRICK CARNER, *Hunter High School*

ROY GLAUBER, *Bronx High School of Science*

BARUCH BLUMBERG, *Far Rockaway High School*

WILLIAM C. DIEFENBACH, *Stuyvesant High School*

By cooperation with The American Institute of New York City, all our speakers are doing special work at the Science Laboratory.

A demonstration meeting to see and hear how youth is preparing for the problems confronting the fields of science and engineering.

Wednesday
May 28, 1941
8:00 p.m.

The speakers are representative of young people and illustrate how they are preparing themselves to formulate attacks on problems, how to design, construct, operate and evaluate results from laboratory research equipment. Also the development of sound techniques and the ability to demonstrate and explain the use and value of their studies.

May 1941 announcement of talks at the Electrical Engineering Auditorium by four high school students. My talk was about photographs I had taken with the instruments I had shown at the 1940 Science Congress. The talk by Baruch Blumberg dealt with a model refrigerator he had constructed. He didn’t continue with physics, however, and switched to medicine, winning the

Nobel Prize in 1976 for the discovery of the hepatitis B virus. The chairman, Irwin Arias, also turned out to be a distinguished hepatologist.
Beginning at Harvard in the fall of 1941 meant suddenly being treated like a member of the gentry. We had waiter service at our dining tables and daily printed menus listing alternative dishes. Of course, some fraction of the waiters were fellow classmates, working for board. Our society was stratified in many other ways as well. The rents for the dormitory rooms were graded according to their location, with the result that the scholarship students were clustered in the less desirable areas. They never got to meet the occupants of the higher priced real estate. I scarcely minded any of that. I had come from a different world than those normal Harvard students. College was for them primarily a social experience, overlaid by a burden of course work. For me, on the other hand, having skipped a couple of grades along the way, and some two years younger than most of my classmates, it was the other way around. I enjoyed a few social contacts, but worked hard at my studies, finding them demanding at times, but on the whole well planned and satisfying.

That freshman year was punctuated on December 7 by the Japanese attack on Pearl Harbor and by the entry the next day of the U.S. into the war in Europe as well as the Pacific. The next few months saw significant changes in our lives as students. The rather searching physics course I was taking had been planned as the first half of a two year cycle. Because faculty members were departing for war work the remaining year-long course would not be offered as planned. It would instead be packed into the second semester of the first-year course. That proved to be quite a tall order but a fast way of learning.

The entire school then began operating during the summer and accelerating its course programs with the thought of providing as much education as possible before the young men left for the armed forces. In the meantime Harvard's dining halls lost their graciousness and were transformed into the cafeteria-style mess halls they have been ever since. The draft age, then 21, was presently lowered to 18 and the university began losing students in large numbers. With its faculty depleted the Physics Department announced that its graduate courses were shortly to be given for the last time "for the duration." That announcement made it a good idea to jump directly into the graduate courses, skipping the intermediate ones which had looked neither demanding nor very interesting anyway. It was with the war thus cracking the whip that I managed to assimilate most of the courses of a graduate school education by the time I turned 18 in September 1943. At that point I felt ready for war work myself and filled out a questionnaire sent out by an agency called the National Roster of Scientific Personnel. Its purpose was to ascertain scientific training and try to place people accordingly.

The armed forces by that time had become vastly larger than the country's immediate needs. The Army developed what it called a Specialized Training Program, in effect for storage of its legions in the universities for a year or so, until they would be needed in the invasion of Europe. The program exposed a large population of draftees to college courses for the first time and was a productive experiment in education. I was given a position teaching elementary physics in the program and had my hands full doing that along with taking a full program of courses of my own.

Then one day in October 1943, a stranger in a dark suit appeared in the Physics Department office evidently asking for me. He introduced himself as a Mr. Trytten from Washington, D.C. and asked to speak privately to me. We withdrew to a faculty meeting room in which the blinds were never raised. Closing the door, he asked if I would be interested in joining a new project that was engaged in interesting work. That it was "out west" was the most he would tell me about either the location of the place or what it was doing. It sounded fascinating nonetheless, and I found the security questionnaires he put before me easy to fill out. Having so little prior history helped. His seeking me out seemed to relate to my having filled out the National Roster blanks. It was then a matter of several weeks before my security clearance had been completed and I was instructed to send whatever belongings I needed to the now famous Post Office Box 1663, Santa Fe, New Mexico. In my case it was a trunk sent not by mail but by Railway Express. There were many occasions, then and later to imagine what a capacious P.O. box that one must be.

I could find many tiny hints at what was going on out there, all of them questionable and several, as it later became clear, completely wrong. The most solid hint was in fact a negative one. For about two years after the discovery of uranium fission in 1939 there had been occasional notes in the New York Times speculating on the possibility of starting a chain reaction. They had stopped appearing, it was hard to say just when, but at least two years earlier. So I had no idea whether it had become a dead issue, or my offer of a position implied some real progress toward a chain reaction.

The train ride from New York to Lamy, New Mexico, the stop for Santa Fe, consumed two and a half days. A driver from Los Alamos had come to the station principally to meet a short man in a black overcoat, but took me along, stopping first at an unassuming project office in Santa Fe, where I learned that the man in the overcoat was John von Neumann, a legendary mathematician.

The ride from Santa Fe up to "the Hill" was an experience I shall never forget. First there was the breathtaking scenery of the canyons of the Pajarito Plateau. Then there was my fellow passenger, John Von Neumann, who engaged in a lively conversation for most of the trip with the driver, whom I learned only later was a mathematician who had worked with "Johnny" earlier. With a thought perhaps of maintaining security, they discussed some calculations underway using the most outlandish mathematical terminology, and describing mathematical errors in physical terms that I knew represented physical impossibilities. The ride was an incredible mixture of visual thrills and intellectual enigmas.

I was astonished, shortly after arrival at the project, to be told that the chain reaction had long since been achieved in Chicago and the present intention was to construct a reaction fast enough to be a bomb. It was disturbing news and I recoiled from it at first, but the challenges and uncertainties involved helped reconcile me to it. More importantly, I felt, as everyone else on the project did, that whatever these uncertainties might be, the Germans, possessing the same understanding we had, were likely to be working on the bomb as well. And if they reached that goal before we did they would not be sentimental about using it to stave off eventual defeat. That fear applied only to the known expertise of the Germans. The conflict with Japan didn't appear to motivate anyone's involvement in the project.

The project was only a few months old when I joined it but most of its eventual leaders were already there. Not many were yet well-known. They were remarkably youthful. Oppenheimer in his late thirties was one of the oldest. He had a universal understanding of the work and an eloquence in describing it that kept us spellbound. Hans Bethe, the leader of the theoretical division, had a penetrating understanding that seemed capable of formulating absolutely anything quantitatively and evaluating it effortlessly, an aura he maintained even many years later. Feynman was there as leader of a small theoretical group. He was often cantankerously teasing the security people. His lectures were always offbeat performances demonstrating novel approaches to problems in ways devoted as much to entertainment as to the technical message. There were others, too many to mention, and among them as an occasional visitor, Niels Bohr, whom we called Nicholas Baker for obvious reasons, together with his son Aage.

Overwhelmed by these giants, my own position in the Theory Division at age 18 was a modest one. There were many problems in neutron diffusion such as finding the critical mass that required more careful formulations than had been carried out in the earliest projections. I worked on those for the better part of the two years I spent at Los Alamos and wrote three lengthy secret papers on those subjects.

There were many delays before the Trinity Test of the bomb in July 1945 and with them the uncertainty of how well it would work grew steadily. Unable to secure a position among the experimenters at Alomogordo, I had to be content with watching for the flash from the top of Sandia Peak near Albuquerque. I saw the flash indeed and some of the glow that followed from a distance of over a hundred miles. The test was followed by some tense days, leading up to August 6, when the use of the bomb at Hiroshima was announced. One thing the portentous announcement meant was a certain release from secrecy. We could now resume contact with the outside world. We could say, if only in general terms what we had been working on. But there were no celebrations of any sort until the war was over a few days later.

Resuming the life of an undergraduate at Harvard early in 1946 proved surprisingly difficult, even though I needed only a few credits to graduate. Having had a team of assistants to do calculations for me at Los Alamos didn't make it any easier, I found, to do my own homework back at school, particularly when I felt I had moved beyond all that. Fortunately that time was brief, and then I became a graduate student. But I had already taken most of the graduate courses on offer, and so was largely left on my own, being allowed to register, in effect, for independent reading and research. The principal reason for my remaining at Harvard was the addition of Julian Schwinger to the faculty. I had met him during a brief appearance he made at Los Alamos, late in 1945, and was immediately so impressed with his knowledge and his incredibly informative lecturing style that I felt he was unique among teachers and would be the ideal thesis advisor as well. I became friendly with Julian over the next three years and was never less than amazed by his ability to construct elegant mathematical structures that would permit him to see further than any of his contemporaries. There were times in those postwar years when it seemed he was responsible for most of the progress in theoretical physics, and very likely would be for years to come. His lectures were brilliantly delivered and notes on them were highly prized and reproduced wherever they could be found. Many students crowded in to work with him, however, and he limited the time he spent with them, so they didn't always produce great theses. Though nominally registered to work with Julian, I actually worked by myself and produced in

1949 a quantum field theoretical thesis that was useful to my later development but scarcely much better than the others of the day.

Life with Wolfgang Pauli; a Spring 1950 outing. Prepared to photograph Pauli kicking the ball into the lake, as he had done earlier, I stood to one side, carefully aiming the camera at him. Pauli indeed kicked the ball, and I managed to snap the shutter just before the camera hit me squarely in the face.

Robert Oppenheimer, who seemed to know more of me than I had imagined, invited me to spend my first postdoctoral year in Princeton at the Institute for Advanced Study. The group of 20 or so postdocs who gathered there included quite a few eventual leaders of the postwar generation of theorists. None had a stable position anywhere else and so the atmosphere was quite competitive. In the first term of 1950, Wolfgang Pauli was scheduled to visit the Institute. Following the advice of friends who had worked in Zürich, I arranged with Pauli to return with him to Zürich and work with him until the fall of that year when I would return to Princeton and the Institute. Having a few months to live in Zürich and to travel over Europe was the principal experience of that encounter. Pauli at age 50 had relaxed into the role of a critic and was no longer inspiring much research. He did retain a mordant sense of humor, however, and was forever doing his best to tease me. Teasing others as well, if not insulting them outright, he was always interesting to be around.

At the Les Houches Summer School, July 1954. Don Hughes spoke about neutron physics, Fermi about pion scattering, and I lectured on particle collision theory.
After another year I spent at the Institute, Oppy found me a teaching position. It was only a temporary one, replacing Feynman at Caltech. Feynman was to spend the year in Brazil, where by his own account, he worked hard on the bongo drums, and Caltech needed someone to teach quantum mechanics. The chemistry department out there, under Linus Pauling, seemed to be an exceptionally active one. My research for the year was devoted to resolving a puzzle they had encountered in studying electron diffraction by molecules. Solving the problem didn't interest me in molecules very much, but it did involve me deeply in scattering problems in which the incident particles were of wavelength much smaller than the ranges of interactions. Those problems, I understood, would become steadily more important in nuclear physics as accelerator energies were increased. I continued studying those problems then when I was invited back to Harvard in the fall of 1952 and for some years after that. The result was a species of nuclear diffraction theory analogous in some ways to optical diffraction theory, but generalized to include inelastic collisions between incident particles and complex nuclear systems. The theory is even used these days to treat the high-energy collisions of pairs of heavy nuclei.

Once I was back at Harvard I began to climb the academic ladder of professorial positions and was able to direct the thesis work of a number of gifted students. Theoretical physicists weren't nearly as specialized in those days as they are now. All of theory was considered one's province and so those theses ranged over half a dozen fields, as did my own work.

The late 50's proved to be an exciting time for many reasons. A radically new light source, the laser, was being developed and there were questions in the air regarding the quantum structure of its output. That was particularly so in view of the surprising discovery of quantum correlations in ordinary light by Hanbury Brown and Twiss. A second source of excitement, all my own, was that I had met the young woman I was to marry, Cynthia Rich, and had been going out with her since 1957. We married in July 1960, bought a contemporary house a year later, and settled into quite a happy life together. That was the period in which I began to work on quantum optics with a surmise that the Hanbury Brown-Twiss correlation would be found absent from a stable laser beam, and then followed it with a sequence of more general papers on photon statistics and the meaning of coherence.

Our first child, a son Jeffrey, arrived in 1963. I remember feeling his arrival was a kind of redemption, a species of renewal for which I was more than grateful at age 38. I was doing a good deal of traveling in those days, particularly during vacations, and it always amazed me how transportable the baby was. We had no trouble taking him on short domestic trips anywhere, but thinking back on my own experience perhaps, waited till he was nearly 4 before taking him on a longer trip to Geneva for a sabbatical at CERN. My work in this period gravitated back to high-energy collision theory, since experiments had begun to reveal many of the results my diffractive multiple scattering theory had predicted.

Spreading the gospel at a July 1977 summer school organized by F. T. Arecchi at Villa le Pianore, Versilia, Italy. The message considerably outlasted the moustache.

Our second child, a daughter Valerie, didn't arrive until 1970, and by that time our placid and comfortable academic life had been roiled up in many ways. Years of demonstrations against the Vietnam War, the anguish of the black liberation movement, and finally the bitter recriminations of militant feminism had left the world of our university seriously fragmented. My wife, joining with the militants, decided that the days of traditional marriage were over, and that her own should be one of the first to go. The law, she found, would permit her to end it, of her own choice, while retaining custody of the children. Devastated by her decision, I simply couldn't believe she would hew to it, and it took some time to try to reach a settlement. By that time, indeed, she no longer sought active custody of the children, and having taken care of them earlier, I proceeded thereafter to raise them as a single father. It was a time-consuming occupation, but an immensely rewarding one, and I managed fortunately to remain involved and reasonably productive in my work. I'm sure there is some number of papers I never got to write as a result, but raising those children and seeing them succeed was not an experience I would trade for the missing papers or any sort of recognition. Both Jeff and Val have families of their own now and are busy raising my grandchildren. I envy them that privilege, and wish I had the opportunity to be raising them all myself.

Professor Glauber died in Cambridge, MA, on 26 December 2018.