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God's Pickpockets: [Dr. Abraham Pais]

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RESEARCH PROFILES

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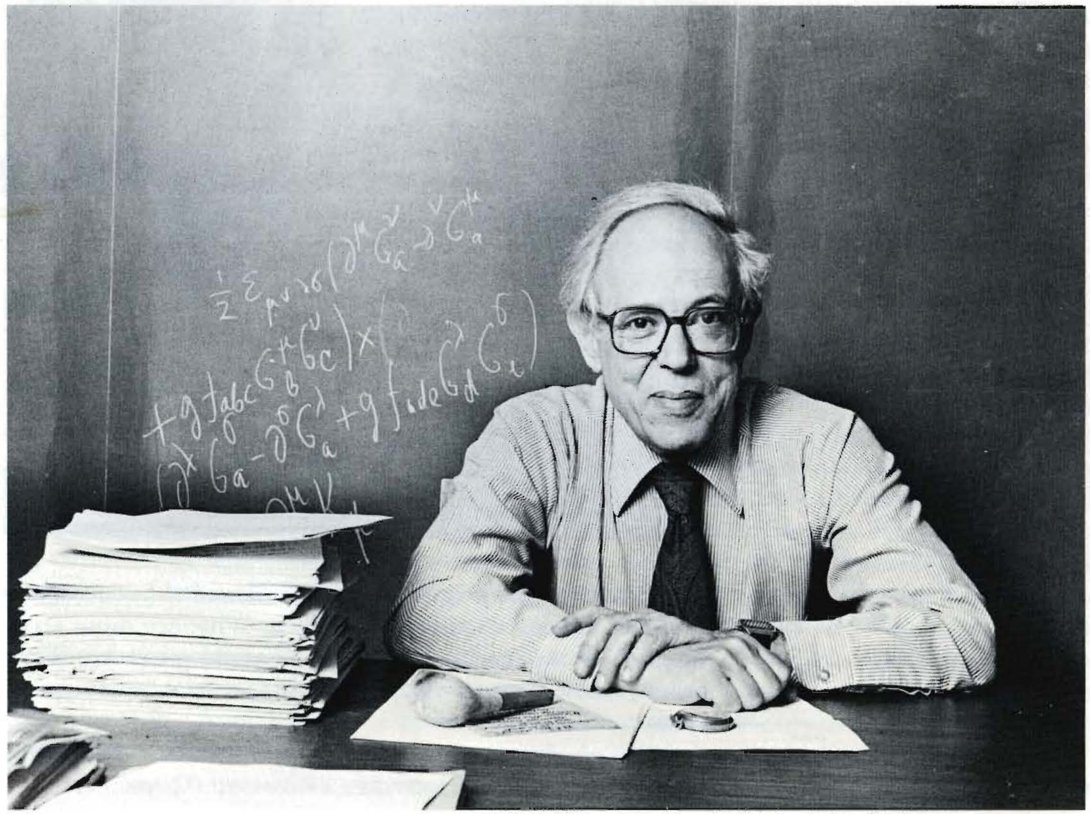
"All this is a dream. Still examine it by a few experiments. Nothing is too wonderful to be true if it is consistent with the laws of nature and in such things as these, experiment is the best test of consistency."

FARADAY'S DIARY
March 19, 1849

God's Pickpockets

Abraham Pais



"Scientists are like pickpockets," says Professor Abraham Pais. "God has all the secrets in his pockets, and we try to pick them. You make an assumption in science—and it *is* an assumption—that there are fundamental laws you can find out. You have an idea you think can be proved and you try to prove it. Depending on how it goes, you make a step forward or you make a fool of yourself. Nature doesn't care whether you're right or wrong. Nature is the way it is, and you had better be smart enough to get a little glimpse."

How does Dr. Pais think the pickpockets are doing? "Extraordinarily well," he says. "In the past 100 years or so, the glimpses science has gotten into nature are awesome. What we have learned has completely changed our view of the universe."

What twentieth century science has learned, above all, is that nothing in the universe is what it seems. Time and space are relative. Solid matter is not solid. Within its molecules, submicroscopic atoms are whirling, attracting and repelling one another and in the process exchanging minute packets of energy: quanta. Mass itself is a form of energy, tightly bound.

Dr. Pais is a theoretical physicist. His tools are primarily mathematical. For the past twenty years he has been a member of the faculty of The Rockefeller University. For more than forty years he has been delving into the atoms of matter. There, over the years, physicists have found an un-

George Uhlenbeck (seated) and Dr. Pais

suspected terrain populated by infinitesimal particles—a "particle jungle," as they wryly call it. What are these creatures? How do they work in nature's grand plan? Are there other creatures yet to be discovered? Can science devise the means to find out?

Although elementary-particle exploration is Dr. Pais's first love, of late his career has taken a new turn. Three years ago, he put aside the doing of science to write a book about the man who, more than any other, presaged this century of science. This past fall ***Subtle is the Lord... The Science and the Life of Albert Einstein*** was published by Oxford University Press. "I wrote it," Dr. Pais explains, "because there were some things I thought could be said about the development of twentieth century physics that had not been said and I thought I would try to say them." It is also a friend's tribute. During the last nine years of Einstein's life, at the Institute for Advanced Study in Princeton where Dr. Pais was then a member, the young man and the "beautiful old man" took walks together and talked about "physics, politics, the bomb, the Jewish destiny," their conversations peppered with an occasional Jewish joke Dr. Pais collected for Einstein's delectation. Of the book, a New York Times reviewer wrote: "It is a work against which future scientific biographies will be measured."

FROM AMSTERDAM TO A BAR ON BROADWAY

When "Bram" Pais was in high school in Holland in the early 1930s, physics ranked a poor fourth in his enthusiasms behind mathematics, chemistry, and water polo. The order of preference changed abruptly when, as an undergraduate at the University of Amsterdam, he attended a lecture by a visiting physicist who talked about current problems in experimental and theoretical physics. "I didn't understand at least 78 percent of what the man was saying," he recalls, "but as I listened it became perfectly clear that I now knew what I was going to do for the rest of my life."

The lecturer was George Uhlenbeck. A decade before, while a graduate student at Leiden, he and another student, Samuel Goudsmit, had discovered the spin of the electron. (Late nineteenth century physicists had learned that the "indivisible" atom was divisible; that it contained at least one subatomic particle, the electron.) The discovery by Uhlenbeck and Goudsmit of the electron's intrinsic angular momentum, the spin, is a cornerstone of modern atomic theory.

In 1938, when Dr. Pais finished his bachelor's degrees (he in fact got two, in mathematics and physics, with minors in chemistry and astronomy), he went off to the University of Utrecht to do graduate work with Dr. Uhlenbeck. A year later, Europe was at war. Dr. Uhlenbeck returned to the United States, to the University of Michigan where he had taught earlier and where Dr. Goudsmit was also teaching. Shortly after, Dr. Uhlenbeck became head of a division of the Radiation Laboratory at MIT and worked on the development of radar. Immediately following the American occupation of West Germany, Dr. Goudsmit, who died in 1978, was to lead a now-legendary mission to determine what progress the Germans were making on an atomic bomb.

At Utrecht, Dr. Pais, studying under León Rosenfeld, who was Dr. Uhlenbeck's successor as professor in theoretical physics, had determined that if he was going to survive the war he was going "to do it with a doctorate." The occupying Nazi forces, progressing in measured steps toward the "final solution" of the Dutch Jews, had decreed that they could no longer receive academic degrees after July 14, 1941. Dr. Pais got his on July 9. Immediately after, he went into hiding, moving from place to place in Amsterdam. Of his large family, whose roots in Holland he has since traced back almost 300 years, only his parents, also in hiding, survived. The Gestapo caught up with him in 1945 and he was imprisoned. "Why they didn't execute me, as they did so many others in the prison, I don't know," he says, "but just before V-E Day those of us still alive were freed."

In hiding he had done physics, some of which he was able to get to the outside. His work attracted the attention of the great Danish physicist Niels Bohr, one of the fathers of quantum theory, which explains the structure of atoms. Quantum field theory attempts to explain how matter and light are described by fields that are subject to quantum rules. These fields account for nature's fundamental forces. (Physicists today recognize four forces: gravity, which holds us to the earth and keeps the sun in orbit; the weak interactions, responsible, among other things, for beta-radioactivity—the slow leak of electrons from certain species of atoms; the electromagnetic force, which binds electrons to their nuclei; and the strong force gripping together the nuclear particles.) The major quest of modern physics is for an overarching theory encompassing relativity, quantum mechanics, and the four forces.

When the war ended, Dr. Pais got a fellowship to the Niels Bohr Institute in Copenhagen. He learned Danish and, for nine months as Bohr's assistant, had "an absolutely wonderful time." Bohr's kindness and that of his family to a young newcomer, his deep concern about the atomic "bum" (as Bohr pronounced it), and his accounts of philosophical differences with Einstein are memories Dr. Pais cherishes.

Dr. Pais went to the Institute of Advanced Study in 1946, also on a fellowship, expecting to stay briefly and return to Copenhagen. One night, shortly after his arrival, Robert Oppenheimer invited him for a drink after a physics meeting in New York. Dr. Pais recalls with amusement that his future was decided in a bar on Broadway. "Oppenheimer told me he had been offered the directorship of the institute and asked if I would stay to help him build up physics there. I agreed."

INTO THE PARTICLE JUNGLE

It is the job of theoretical physicists to make schemes to explain, classify, and predict the structure and behavior of matter. Perhaps the most far-reaching example of conceptual elegance achieved in the early days of modern physics is the theory of quantum electrodynamics. Invented in the 1920s by Paul Dirac, Werner Heisenberg, and Wolgang Pauli, it explains, among other things, how photons, which are particles of light, interact with electrons. (The realization that light could behave as discrete particles began with Einstein who thought of it as his "truly revolutionary" idea.)

Electrons are negatively charged and move in waves around the atom's dense central core, the nucleus. By the 1930s scientists had found within the nucleus two kinds of particles, protons and neutrons, collectively called baryons (meaning heavy particles). "Through the forties," says Dr. Pais, "we had the idea that maybe the electron and the baryons were the ultimate building blocks of matter. Then a sequence of discoveries began that had not been dreamt of in anybody's philosophy. We found that there are not just two baryons, but a whole family of them."

Cosmic rays from outer space, colliding with the earth's atoms and releasing particles, revealed to physicists the first new baryons, which live only trillionths of a second. By the 1950s, experimental high-energy physicists were able to build accelerators with which such very small and short-lived particles could be studied under controlled conditions. "It is a rule of physics," Dr. Pais explains, "that the smaller the object one wants to look at, the higher must be the energy of the projectiles with which one bombards that object." In accelerator laboratories, particles are spun to very high speed and bombarded with other particles. As they crash, smaller particles are ejected and scatter, leaving a trail of "footprints," which can be photographed and analyzed.

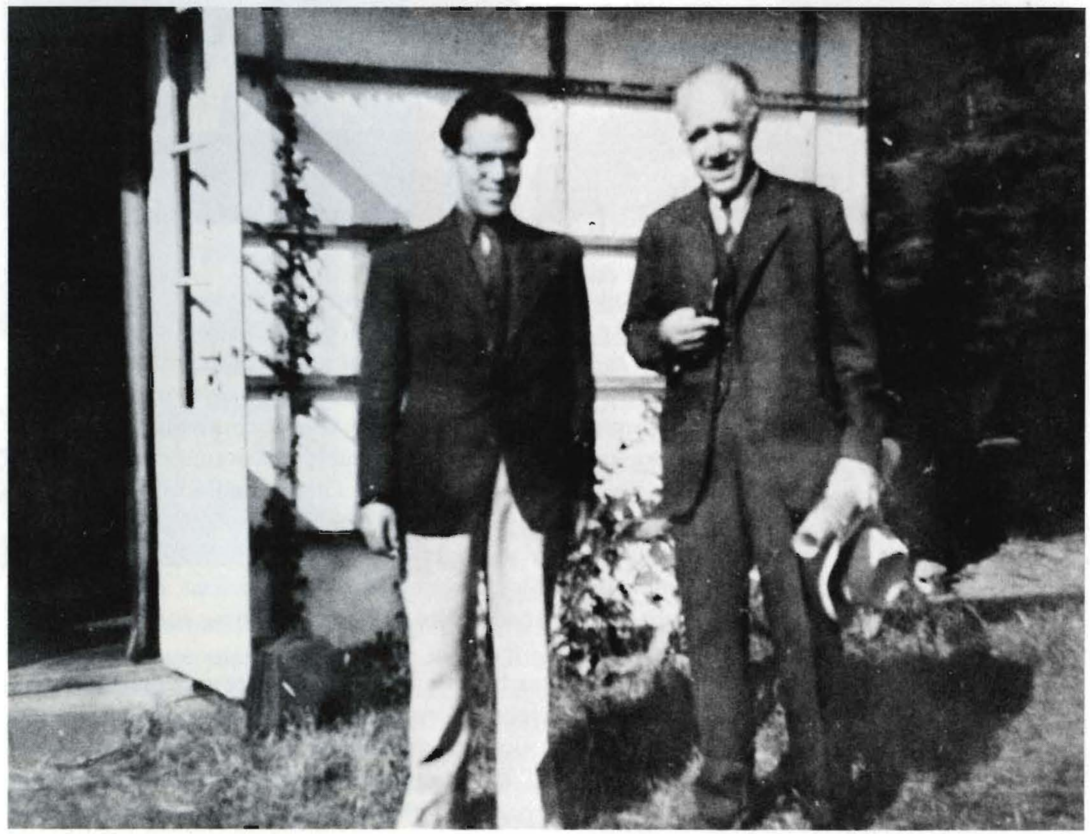
As the number of baryons and other nuclear particles such as mesons kept growing, physicists grouped them under the general category called hadrons. Then they began to wonder if hadrons, like electrons and photons, were truly fundamental particles.

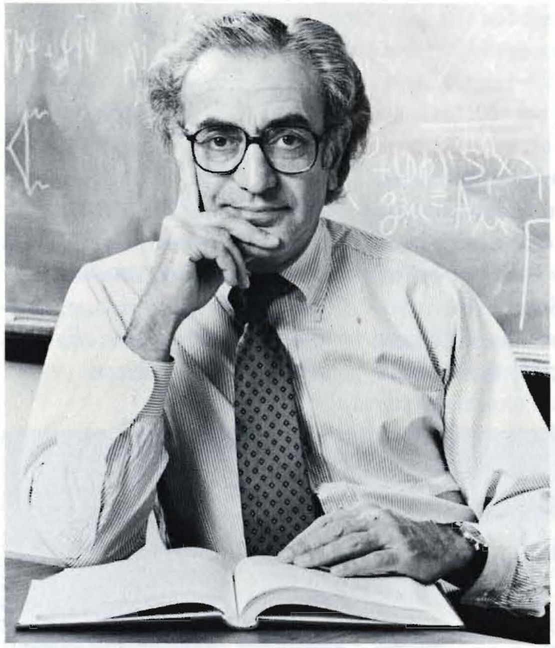
"The modern period of growth, confusion, and advancement in particle physics," says physicist Sam Bard Treiman, "began with the great quantitative triumph of quantum field theory as applied to electromagnetic forces and phenomena, and the excitement generated by the onset of discovery of hordes of new subnuclear particles—Pi-mesons, K-mesons, Lambda particles, and on and on to this day. The former triumph strengthened our belief in the general principle of quantum field theory. The new and unexpected particles were a signal that a correct, all-encompassing theory of the strong, weak, and electromagnetic forces was nowhere in sight. The phenomena themselves had first to be sorted and patterns searched for. Early on, Bram Pais made several central contributions."

Dr. Treiman, chairman of the physics department of Princeton University, has been one of Dr. Pais's closest collaborators for a quarter of a century. "To account for the puzzling observation that some of the new particles could be produced copiously (indicating strong interaction) in high-energy collisions, though they decay very slowly, as if subject only to weak forces, Bram introduced the notion of 'associated production'; that is, the notion that some of the new particles interact strongly only when pairs of them are involved, but weakly when acting alone. This observation broke a logjam of understanding and led to the discovery of new kinds of quantum numbers and to a first round of organization.

"With Murray Gell-Mann," Dr. Treiman continues, "Bram fixed his attention on a special subset of particles, the neutral

Dr. Pais and Niels Bohr at Tisvilde, Denmark, in August 1946. They are standing in front of the small cottage, near Bohr's country house, that served as his workroom.





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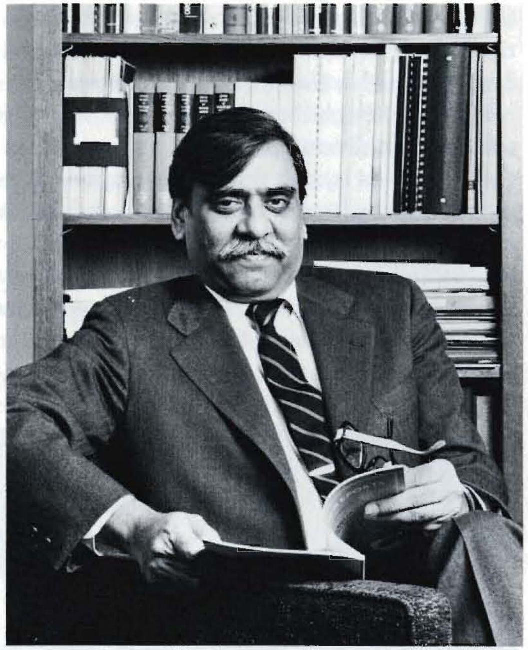

M.A.B. Bég

K-meson—K_0 and $K_{\bar{0}}$. They noticed some peculiar features that were special to this system, features that were both striking in their own right and that could be used as diagnostic tools for the study of important issues of particle physics. The interference predictions were amply confirmed by experiments, and the diagnostics, suitably elaborated, led in 1974 to the discovery, by Fitch and Cronin, of violation of the invariance for the reversal of time in certain fundamental laws of nature. (The discovery led to a Nobel Prize to Fitch and Cronin in 1980.) On a number of occasions in later years, Bram has returned to the K-mesons to mine further riches of understanding."

Physicists now believe that all of the strongly produced particles—the hadrons—are made up of a more limited variety of more basic objects named (in a borrowing from James Joyce) "quarks." During the past decade and a half, the quark picture of hadronic matter has taken firm root and new field theories have emerged as serious models of the real world. "As ever," says Dr. Treiman, "Bram Pais has been in the forefront, especially in pursuit of the unification of strong, weak, and electromagnetic forces."

Dr. Pais never returned to Copenhagen for any length of time, but Niels Bohr visited occasionally at the Institute for Advanced Study. Dr. Pais's favorite story concerns an event that occurred on a spring morning in 1948. "Bohr came into my office," he recounts, "and started as follows: 'Du er så klog...(you are so wise...)'. I began to laugh—no formality or solemnity was called for in the contact with Bohr—and said, 'All right, I understand.' Bohr would like me to come down to his office and talk. At that time he used Einstein's own office in Fuld Hall. Einstein himself worked in the small, assistant's office adjoining; he had a dislike of the big one which he did not use anyway. After we had entered, Bohr asked me to sit down and soon started to pace furiously around the oblong table in the center of the room. He then asked me if I could put down a few sentences as they would emerge during his pacing. It should be explained that at such sessions he never had a full sentence ready. He would often dwell on one word, coax it, implore it, to find the continuation. This could go on for many minutes. At that moment the word was 'Einstein.' There Bohr was, almost running around the table and repeating, 'Einstein...Einstein....' It would have been a curious sight for someone not familiar with Bohr. After a little while he walked to the window and gazed out, repeating every now and then, 'Einstein...Einstein....'

"At that moment the door opened very softly, and Einstein tiptoed in. He signaled to me with a finger on his lips to be very quiet, his urchin smile on his face. He was to explain a few minutes later the reason for his behavior. Einstein was not allowed by his doctor to buy any tobacco. However, the doctor had not forbidden him to steal tobacco, and this was precisely what he now set out to do. Always on tiptoe, he made a beeline for Bohr's tobacco pot which stood on the table at which I was sitting. Meanwhile Bohr, unaware, was standing at the window muttering 'Einstein...Einstein...' I was at a loss as to what to do, especially because at that moment I had not the faintest idea what Einstein was up to. Then Bohr, with a firm 'Einstein,' turned around. There they were, face-to-face, as if Bohr had summoned him forth. It is an understatement to say that Bohr was speechless. I myself, who had seen it coming, had felt distinctly uncanny. A moment later the spell was broken when Einstein explained his mission, and soon we were all bursting with laughter."

DOES THE MOON EXIST?

In 1963 Dr. Pais was invited to join The Rockefeller University and establish a high-energy physics group. The invitation came from the late Detlev Bronk, then president, who had spurred the transition of The Rockefeller Institute for Medical Research into a graduate "university of the sciences," as he called it. Dr. Pais had been suggested to Bronk by George Uhlenbeck, who had come to Rockefeller two years earlier to start, together with Mark Kac and the late Theodore Berlin, a physics and mathematics group. After the war, the former teacher and student had worked together again at the Institute for Advanced Study where Dr. Uhlenbeck went twice on sabbatical leave from the University of Michigan.

Dr. Uhlenbeck, now emeritus but still at work almost every day in his Rockefeller office, says, "In Ann Arbor I often would give lectures about Pais's work on the particles." He pulls down dog-eared notebooks from the shelf over his desk and points to entries in them: "Pais on the V-particles (1952)," "Further Development of the Pais Ideas (1953)," "Theoretical Views of the New Particles—Gell-Mann and Pais (1954)," and one that reads, "the idea of Pais is to seek a connection between the stability laws and the symmetry laws of the internal dynamics of the particles (1955)."

Among those Dr. Pais brought to Rockefeller are Professors M.A.B. Bég and Nicola Khuri. Together they created a group with international distinction which has in turn trained a new generation of physicists. Dr. Pais was also instrumental in bringing an experimental physics faculty to the University under the leadership of Professor Rodney Cool. In 1980 Dr. Pais was named Detlev W. Bronk Professor.

The introduction to *Subtle is the Lord* begins with one of the walks that Dr. Pais and Albert Einstein took together. Dr. Pais tells how, on that occasion, "Einstein suddenly stopped, turned to me, and asked me if I really believed that the moon exists only if I look at it. The nature of our conversation was not particularly metaphysical. Rather, we were discussing the quantum theory, in particular what is doable and knowable in the sense of physical observation. The twentieth century physicist does not, of course, claim to have the definitive answer to this question. He does know, however, that the answer given by his nineteenth century ancestors will no longer do. They were almost exactly right, to be sure, as far as conditions of everyday life are concerned, but their answer cannot be extrapolated to things moving nearly as fast as light, or to things that are as small as atoms, or—in some respects—to things that are as heavy as stars. We now know better than before that what man can do under the best of circumstances depends on a careful specification of what those circumstances are. That, in very broad terms, is the lesson of the theory of relativity, which Einstein created, and of quantum mechanics, which he eventually accepted as, in his words, the most successful theory of our period but which, he believed, was nonetheless only provisional in character."

Some years ago, while still deep in the exploration of the particle jungle, Dr. Pais wrote: "It is a basic creed of physics, as of other sciences, that nature's ultimate design is simple. If something doesn't look simple it usually means that we have not reached the bottom of it. No one can *prove* that nature must be forever simple, but this drive to simplicity has been an unfailing guide for 300 years of development in physics. We must continue to follow its lead." □

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