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Chapter Six

LATE-NIGHT THOUGHTS OF THE GREATEST PHYSICIST

The light from the upstairs corner room at the back cast a soft, yellowish glow on the backyard of the white clapboard house at 112 Mercer Street. At 11 o'clock on a late-spring evening the normal flow of traffic on this fairly busy residential street slowed considerably, making the neighborhood a good place for quiet contemplation. And that was exactly what the saintly looking white-haired gentleman in the rumpled dark-blue sweater sitting in the corner room was doing, as he leaned back and stared at the reflection of the desk lamp in the window. At the moment he was contemplating with nostalgic satisfaction the year 1905, which in the world of science had come to be known as the *annus mirabilis,* the year of miracles. Albert Einstein was thinking of the strange path his life had taken over nearly half a century,

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from his position as an examiner at the Swiss Patent Office in Berne in that year, to this study on Mercer Street today.

In that one unbelievable year, Einstein had published five articles in the journal *Annalen der Physik,* three of which pioneered three entirely new branches of physics, one of these papers being the surface reason quoted by the Nobel committee when they awarded him the prize in physics 18 years later, namely, the photoelectric effect, another of the papers being the one that began the theory of relativity. Very likely no physicist will ever again approach this feat. And this outpouring of genius sprang from a complete outsider to the profession, a mere patent examiner in a small town in Switzerland. Even Hollywood would turn down this story as being literally "incredible." And the most incredible part is that the man to whom it had happened was now nearly a complete outcast from the very community of physicists that had considered him their standard bearer and intellectual leader. What a wry cosmic joke, he thought. Having rebelled against authority his entire life, he was now paying for these sins by being an authority himself!

But the greatest scientist since Newton, and certainly the one scientist everyone in the world would recognize on sight, was now totally stumped. And he had been stumped for more than 20 years. His greatest creation, the general theory of relativity, linked space, time, and matter into one seamless theory—for *macro*scopic-sized objects like planets and galaxies. Yet just a few years later, an equally compelling theory of *micro*scopic-sized objects, electrons and photons and other fundamental particles—the quantum theory—burst onto the intellectual scene, in large part also due to Einstein's work. Unlike relativity theory, quantum theory was resolutely statistical. Electrons have only a certain *likelihood* of being found in a particular location until a measurement of their position is taken. General relativity, on the other hand, was purely clas-

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sical; that is, objects moved in accordance with the rigidly deterministic laws of Newtonian mechanics. It was a completely consistent theory of the gravitational field. The quantum theory, however, gave a full account of light, hence was a theory of the electromagnetic field. How to bring these two fundamentally different sets of phenomena—gravity and electromagnetism—together into a single coherent theory, the unified field theory. That was the Holy Grail to which he had dedicated the past two decades of his life.

To make matters even worse in Einstein's view, the standard interpretation of the quantum theory postulated that observable quantities themselves, such as energy, momentum, and even time, are somehow created through the very process of observation and do not have an existence independent of who or what is doing the observing. A physicist of the old school, Einstein simply could not accept a Nature that was so capricious. "God is subtle," he often said, "but he is not malicious." The quantum theory must somehow be fundamentally incomplete, he thought. Another part of his job as a physicist was to find the holes in the theory—and plug them.

Staring at the paper on his desk, covered with arcane mathematical scribbles that only a mathematician or theoretical physicist could love, he angrily swept it aside as yet another blind alley in his Sisyphean quest for the elusive unified field. Yet once more he leaned back in his chair and wondered: Could Nature be *so* subtle and deep that it is really beyond the power of the primitive human brain to ever truly understand it? Is the scheme of Nature too complex in some fundamental way for the monkey brain we have inherited to fully comprehend its workings? But Einstein thought that to fall into such a belief is to concede the game before the first point is even played. Staring absently at the book-covered wall of his study and the clutter on his desk, he reached for the tobacco tin and began stuffing his pipe as he pondered the thought

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experiment he had concocted with Nathan Rosen and Boris Podolsky more than a decade ago to focus on the inherent inconsistencies of the mysterious quantum.

A naïve realist at heart, Einstein clung to the classical view that a particle, be it a billiard ball, a planet, or an electron, had well-defined properties like position and momentum at every single moment. *Au contraire,* said the quantum theorists from Copenhagen, Paris, Brussels, and Berlin. The very idea of a well-defined position at all times is an illusion stemming from an overdose of experience with macroscopic-sized objects like planets, tables, and chairs. In the microscopic realm of the quantum, an object like an electron has *no* properties whatsoever until it is actually observed. Then it acquires a position, a spin, or a momentum, depending on the nature of the measurement. So in an ontological sense, the properties are brought into existence by the act of measurement, by an observation.

Even worse, thought Einstein, the conventional wisdom of the quantum theorist is that before a measurement is made, all one can say about a property like the position of a particle such as an electron is that there is a certain probability that the electron will be found in such-and-such a location when the measurement is actually taken. One can say no more. In short, Nature is statistical, not deterministic. We can speak only of the likelihood of an event, not its certainty. I'll go to my grave, Einstein thought, resisting such a view of Nature. If this is the best that quantum theory can offer to explain the deep reality of the material world, then the theory must be fundamentally incomplete. Somewhere, somehow, the theory must be completed. Then all this nonsense about probabilities, unobserved particles, and so forth will vanish just like the mythical luminiferous aether, he believed. There must be hidden variables that the theory does not include, but whose values enable us to speak with certainty about properties of

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particles—even when no one is looking.

So what can one *really* know about an electron? Are the limits imposed by Heisenberg's Uncertainty Principle true limits built into the fabric of Nature? Or are they simply limits imposed by an incomplete theory, having nothing whatsoever to do with the way Nature is truly put together? Einstein, with his collaborators Rosen and Podolsky, created an experiment to bring this "limits" question into sharper focus.

Suppose, they said, you have a particle system composed of two electrons, with opposite spins, UP and DOWN, say. Then the total spin of the overall system is zero. Now, according to the quantum theorists from Copenhagen like Niels Bohr and Werner Heisenberg, neither electron can be said to have a definite spin, UP or DOWN, until it is measured, at which moment it immediately *acquires* one spin or the other. Before the measurement forces an UP or DOWN spin on it, the electron is in a nether state without either spin.

So, said Einstein and his collaborators, without having first determined the spin of either electron by observing it, let one of them be transported to the other side of the galaxy. Once it reaches its destination, let that electron's spin be measured by an observer. Suppose that measurement gives the spin as UP. Since the total spin in the system must be zero, then at the very instant you measure UP on the "traveling" electron, you immediately know—without making a measurement—that the stay-at-home electron's spin is DOWN. In fact, if you do then measure the stay-at-home electron's spin, you will unfailingly observe that it's spin *is* DOWN. So you have acquired knowledge of the stationary electron's spin without any measurement at all! This is the paradox. How did that information get across the galaxy so fast? Faster than the speed of light, actually, if the spin DOWN was not already inherent in the stationary electron. This was the puzzle that Einstein, Podolsky, and Rosen (EPR) posed to the quantum theorists.

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The EPR paper divided the community of physicists into two camps: The first group is bothered by EPR. The second group is not, but is also divided into two subgroups. The first subgroup explains why it is not bothered, although the explanations tend to miss the point of EPR entirely or contain physical assertions that can be shown to be completely false. The other subgroup does not explain why it is not bothered; it just isn't. Some in this group claim that Einstein's close friend and debating partner, Niels Bohr, settled the whole thing—but they're not entirely sure how.

Ja, Einstein thought. Our idea really set the cat among the pigeons. Once those two electrons are "entangled" with opposite spins using the very rules the quantum theorists advocate, the problems start. After all, he argued to himself, if, without in any way disturbing the system of electrons it is possible to predict with certainty the value of the spin, then there exists an element of physical reality corresponding to the spin. In other words, if it's possible to deduce the spin of one particle by measuring the spin of its twin, both spins must already exist as elements of reality. Einstein then recalled how the original EPR paper used the properties of position and momentum instead of spin, which was a refinement introduced recently by the very clever young physicist David Bohm. But in either case, the idea of being able to know with certainty the state of one electron by measuring the state of the other is a total violation of Heisenberg's Uncertainty Principle, the bedrock upon which quantum theory rests. There simply *must* be something wrong with this theory! Einstein shouted silently to himself for the thousandth time.

Fortuitously, perhaps, at that very moment his thoughts were diverted from this negative turn by a soft knock on his study door. "*Komm,*" he said softly, as the door opened, revealing his wife, Elsa, with a tray in her hand. Remaining in the doorway—since it was a long-standing rule in the Einstein

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household that no one, but no one, ever entered his study—Elsa told him, "You need a rest, Albert. I've brought you a nice glass of warm milk and a biscuit. I will leave it on the bedside table in your room."

Einstein looked up from his desk at his caring, supportive wife, his large, sad, brown eyes communicating to her his disappointment at another night of fruitless labor. He had married his first cousin, Elsa, after a tempestuous first marriage to a fellow student in Zurich, the melancholic Mileva, who bore him two sons. While no one could say his union with Elsa was one of great passion, it was a marriage of great mutual respect, basically a platonic relationship based on friendship that gave both what they needed most: for him, a peaceful home life in which to conduct his work; for her, the mission to serve as support for a great man.

"It's very kind of you, Elsa. I will soon be off to bed. Please don't worry yourself about me. I'll not stay up very much later. I promise."

Nodding, Elsa turned and quietly closed the study door behind her, leaving Einstein to his dreams and reflections. Taking up his pipe to discard the plug of tobacco in the trash bin beneath the desk, Einstein's ruminations turned once again to the role fate had played in bringing him to Princeton.

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In the winter of 1932 Einstein visited the California Institute of Technology (Caltech) in Pasadena to deliver a series of lectures. Unknown to him, less than two years earlier the Bamberger family, wealthy New Jersey department store magnates, had provided an extremely generous endowment for the establishment of an "institute for advanced study" in Princeton, New Jersey, and commissioned the educator, Abraham Flexner, to make it a reality. Flexner also happened to be in

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Pasadena at the same time as Einstein and made a call on the great physicist to get his opinion on how to develop the new institute. As fate would have it, at that very time the political situation in Germany was going from bad to worse, and just a few months earlier Einstein had been the focus of a vicious attack on "Jewish physics" by sychophants of the Nazi regime whose vitriolic aim was to try to discredit scientific work done by any Jewish researchers. As a result, Einstein decided that he would have to leave Germany and was thus sensitized to opportunities abroad. Of course, there was no shortage of opportunities for the world's greatest scientist. But it had to be the *right* opportunity.

As soon as he heard about the new institute, Einstein liked the idea. So he listened quite closely to Flexner as the two of them strode back and forth across the small Caltech campus discussing various aspects of the new institute's formation. Just before the end of Flexner's short stay in California, Einstein saw him again and they agreed to meet the following spring when they would both be in Oxford.

Six months later, on a sunny day in May, Flexner and Einstein were strolling across the grounds of Christ Church College in Oxford when Flexner decided to roll the dice. He said straight out that if Einstein was interested in joining the new Institute, he was welcome under whatever terms he cared to name. Not a man to make a hasty decision, Einstein hesitated. He remembered that he had already turned down an offer from Princeton University back in 1927. But conditions had changed. Maybe it was now time to reconsider crossing the Atlantic—for good. Yet again the two men agreed to meet, this time at Einstein's summer home in Caputh, Germany, the very next month. Flexner stayed for eight hours that day, and left with Einstein's answer: "I am fire and flame for it," he told Flexner. And so it came to pass that on June 4, 1932, Einstein became the first faculty member of the fledgling Institute for

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Advanced Study. Overnight, the IAS was on the worldwide intellectual map with a vengeance. Instant respectability!

How droll, Einstein chuckled to himself, that his relations with Flexner soured almost immediately. First, there was the fight to persuade Flexner to accept his assistant, Walther Mayer, on equal terms as an Institute Professor. I almost had to resign before I even took up the position in Princeton, Einstein recalled, just to show Flexner how important Mayer was to my work.

The next crisis came from Flexner's pathological need to keep the whole faculty, especially his star scientist, isolated from the real world. Einstein remembered how Flexner went so far as to intercept his letters, telegrams, even an invitation to the White House! It got so bad that at one point Einstein wrote letters to close friends in which he wrote the return address as "Concentration Camp, Princeton."

But Einstein had the last laugh—a big one. By early 1939 he had had enough of Flexner's pettiness and meddling in his affairs. And so had many of the other faculty members. So a *coup d'état* was hatched with, of all people, Einstein as the ringleader. What a glorious moment that was, thought Einstein, replaying the episode in his mind. The plot to unseat Flexner was hatched at a meeting, Einstein presiding, at the Nassau Tavern, a block from the Princeton University campus. But who would have ever expected otherwise? After all, here was one of the great rebels of all time. A man who championed the rights of individuals against repressive political regimes. A man who defied the demigods of his own profession to create and walk a path that no man had walked before. Who better to be the moving force behind the removal of the dictatorial Flexner? Ah, those were the days, he laughed, before the war cast its long shadow over most of the world.

The furrows in Einstein's leonine brow were particularly evident when he reflected on his role in encouraging

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President Roosevelt to develop the atomic bomb. It pained him deeply that many people thought his famous formula $E = mc^2$, expressing the vast amount of energy contained in particulate matter, was an essential aspect of "the bomb." As a long-time pacifist and vehement supporter of the peaceful resolution of conflict, Einstein would have been the last to advocate nuclear force—if he had seen any alternative to halt the Nazi movement for world domination. But even in such an emotionally charged environment, he doubted that the letter he signed, at the instigation of his friend Leo Szilard, and sent to President Franklin D. Roosevelt, was a deciding factor in the establishment of the Manhattan Project, which would translate his formula into an actual weapon. Many other forces were at work at the time, all pushing in this same direction, and the biggest effect Einstein believed his letter could have had was to advance the timing of the project by a few weeks.

When the first bomb was dropped on Hiroshima, he thought, "Oh, horrible!" Nothing would ever convince him that this act was forgivable in either moral or military terms. But the bomb was a reality. So what should he do? What should anyone do? He campaigned long and hard for a world state. He sadly felt that in the end, the result of these untiring efforts was to make him even more distrustful of both the United States and the Soviet Union. The times in America now were just not right for such ideas, he concluded. These were times for very conservative views of the sort advocated by Johnny von Neumann, who stated that a preemptive strike on the Soviet Union was *necessary.* In von Neumann's words, "If you say such a strike would be good but not until tomorrow, I say why not today?" I am just an old sinner, Einstein thought, lost in a world of ever-shifting values and desires. I've been put out to pasture in this village of demigods on stilts just to *be* here. I'm an icon, a landmark, but not a beacon. The

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world of today belongs to the separatists, the militarists, the rabble rousers, and the flag-waving nationalists.

Sometimes Einstein wondered why he became so caught up in these political and moral matters. He remembered a conversation he had had a few years earlier with his then assistant, Ernst Straus. Straus also wondered about the balance of time Einstein spent between the political and the scientific. Einstein recalled saying that, "Yes, we have to divide our time like that, between our politics and our equations. But to me our equations are far more important, for politics is only a matter of present concern. A mathematical equation stands forever." Whoever finds a thought that enables us to obtain a slightly deeper glimpse into the eternal secrets of nature has been given great grace, he believed, and this far transcends the merely personal or political.

Such thoughts are dangerous, he joked to himself. They brought back visions of the intense lobbying Johnny von Neumann had been doing recently to gather support for building his computing machine. Von Neumann's discussion with him about this machine some weeks earlier at the Institute had brought him face to face with an entirely different side of the scientific enterprise than he had previously encountered. Could such a device have any use in furthering his own work on the unified field theory? What could it mean to *anyone's* work at the Institute? Do such machines represent a new wave in the practice of science, as Johnny claims? Or are they simply glorified calculators? These questions intruded so forcefully on his thoughts this night that he finally threw down his fountain pen and gave them full rein.

It is ironic that von Neumann should concern himself with what, in essence, is an experimental activity, thought Einstein, since it doesn't seem to me that Johnny has the physicist's natural feeling for, and recourse to, experiment. While he certainly knows a good deal of physics, his interest in the

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physical always seems to center on the mathematical formalization of a physical situation, not the physics itself. Einstein thought that such an axiomatic approach to physical theories bore the same relation to physics as grammar bore to literature. So why was Johnny so deeply concerned with a problem in engineering?

Einstein had totally missed the point of what a computer is for. In statements on the relevance of such a device for his own work, he repeatedly joked that he didn't see how a calculator would get him any closer to the chimerical unified field theory he so diligently sought. Scientific knowledge of a type could, perhaps, be teased out of Nature's grasp by performing an especially lengthy or intricate calculation. And Johnny's machine would be of great value for that. But there's more to science than doing a calculation, thought Einstein, strangely oblivious to the lengthy calculations he himself had performed by hand to develop his own general theory of relativity.

Von Neumann might have been amused by Einstein's blindness to what he saw as the obvious virtues of computing machines. Von Neumann always thought that Einstein had a certain kind of contempt for other physicists, including even the very best and most famous ones, because he had been lionized and even deified so much. After all, no one ever tried to invent something that would improve or rival or change the general theory of relativity. Von Neumann also felt that Einstein didn't think much of others as possible rivals in the physics of the twentieth century. So why should he think much of the ideas of an outsider like von Neumann about a device that he would prefer to replace with a fountain pen?

Can a machine stand in for the human mind? Can a machine think creative thoughts, creative enough to crack the puzzle of the unified field? Einstein felt that he must take up those questions with Gödel on their walk tomorrow. He leaned back in his chair, stretched his arms, and considered

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how Gödel might react to the idea of a machine that thinks like a man.

Einstein knew from von Neumann that two researchers at the University of Chicago, Warren McCulloch and Walter Pitts, had constructed a mathematical model of the neuronal structure making up the brain, showing that it was equivalent in its information-processing capability to a computing machine. This result caused von Neumann, along with others, to wonder whether a computing machine might one day surpass even the cognitive abilities of the human brain. Einstein scoffed at such hubris. Where is the human spirit in such a network of neurons? Where is the creative drive, the soul? It's inconceivable, he thought, that a box of metal, glass, wires, and electronic tubes could in any way duplicate the brain. Perhaps I should give my active support to von Neumann's project, just so that he can build this machine and discover this self-evident fact for himself. How can someone as smart and perceptive as Johnny be so blind as to believe that the human mind is nothing more than a machine? Kurt will have a good laugh over this when I speak to him about it tomorrow, he chuckled to himself, as he envisioned Gödel's incredulous look when faced with this astounding claim.

The thought of Gödel brought back images of the emotional stress this business of his promotion to Professor was visiting upon his friend. Einstein thought again of the unpleasantness with Flexner over the appointment of his assistant, Walther Mayer, to a full-fledged professorship at the Institute. In that instance, he was able to use his leverage on Flexner to push through the position for Mayer. Gödel's case should actually be much easier, Einstein thought, since no one disputed the brilliance of his work, quite unlike the meagre corpus he had been able to present in support of Mayer's candidacy for the faculty. But I have no influence any longer on those who will decide Gödel's fate, he ruefully acknowledged. I'm sim-

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ply an icon, useful to the Institute for my name and face, but completely cut off from the mainstream of all its intellectual and professional activities.

Einstein was continually puzzled by the energy and enthusiasm that people put into trying to exert power over others, pursue material gain, and generally involve themselves in the ephemeral affairs of everyday life. In spirit, if not in intellect, he was the most Platonistic of men, believing that, while the world is definitely "out there," the life of the mind completely transcends it. The whole point of science for him was summed up in his belief, along with Schopenhauer's, that one of the strongest motives that lead men to art and science is escape from everyday life with its painful crudity and hopeless dreariness, from the fetters of one's own ever-shifting desires. A finely tempered nature longs to escape from the personal life into the world of objective perception and thought. And with this uplifting manifesto on his mind, he gathered himself up from the desk and laid down his pipe. Turning out the light, he left his study to go to bed and thought yet again, tomorrow is another day. Maybe, just maybe, it will be *the* day . . . .

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