CHAPTER ONE

THE LIGHT-BEAM RIDER

"I promise you four papers," the young patent examiner wrote his friend. The letter would turn out to bear some of the most significant tidings in the history of science, but its momentous nature was masked by an impish tone that was typical of its author. He had, after all, just addressed his friend as "you frozen whale" and apologized for writing a letter that was "inconsequential babble." Only when he got around to describing the papers, which he had produced during his spare time, did he give some indication that he sensed their significance.[1]

"The first deals with radiation and the energy properties of light and is very revolutionary," he explained. Yes, it was indeed revolutionary. It argued that light could be regarded not just as a wave but also as a stream of tiny particles called quanta. The implications that would eventually arise from this theory—a cosmos without strict causality or certainty—would spook him for the rest of his life.

"The second paper is a determination of the true sizes of atoms." Even though the very existence of atoms was still in dispute, this was the most straightforward of the papers, which is why he chose it as the safest bet for his latest attempt at a doctoral thesis. He was in the process of revolutionizing physics, but he had been repeatedly thwarted in his efforts to win an academic job or even get a doctoral degree, which he hoped might get him promoted from a third- to a second-class examiner at the patent office.

The third paper explained the jittery motion of microscopic particles in liquid by using a statistical analysis of random collisions. In the process, it established that atoms and molecules actually exist.

"The fourth paper is only a rough draft at this point, and is an electrodynamics of moving bodies which employs a modification of the theory of space and time." Well, that was certainly more than inconsequential babble. Based purely on thought experiments—performed in his head rather than in a lab—he had decided to discard Newton's concepts of absolute space and time. It would become known as the Special Theory of Relativity.

What he did not tell his friend, because it had not yet occurred to him, was that he would produce a fifth paper that year, a short addendum to the fourth, which posited a relationship between energy and mass. Out of it would arise the best-known equation in all of physics: $E=mc^2$.

Looking back at a century that will be remembered for its willingness to break classical bonds, and looking ahead to an era that seeks to nurture the creativity needed for scientific innovation, one person stands out as a paramount icon of our age: the kindly refugee from oppression whose wild halo of hair, twinkling eyes, engaging humanity, and extraordinary brilliance made his face a symbol and his name a synonym for genius. Albert Einstein was a locksmith blessed with imagination and guided by a faith in the harmony of nature's handiwork. His fascinating story, a testament to the connection between creativity and freedom, reflects the triumphs and tumults of the modern era.

Now that his archives have been completely opened, it is possible to explore how the private side of Einstein—his nonconformist personality, his instincts as a rebel, his curiosity, his passions and detachments—intertwined with his political side and his scientific side. Knowing about the man helps us understand the wellsprings of his science, and vice versa. Character and imagination and creative genius were all related, as if part of some unified field.

Despite his reputation for being aloof, he was in fact passionate in both his personal and scientific pursuits. At college he fell madly in love with the only woman in his physics class, a dark and intense Ser-

bian named Mileva Marić. They had an illegitimate daughter, then married and had two sons. She served as a sounding board for his scientific ideas and helped to check the math in his papers, but eventually their relationship disintegrated. Einstein offered her a deal. He would win the Nobel Prize someday, he said; if she gave him a divorce, he would give her the prize money. She thought for a week and accepted. Because his theories were so radical, it was seventeen years after his miraculous outpouring from the patent office before he was awarded the prize and she collected.

Einstein's life and work reflected the disruption of societal certainties and moral absolutes in the modernist atmosphere of the early twentieth century. Imaginative nonconformity was in the air: Picasso, Joyce, Freud, Stravinsky, Schoenberg, and others were breaking conventional bonds. Charging this atmosphere was a conception of the universe in which space and time and the properties of particles seemed based on the vagaries of observations.

Einstein, however, was not truly a relativist, even though that is how he was interpreted by many, including some whose disdain was tinged by anti-Semitism. Beneath all of his theories, including relativity, was a quest for invariants, certainties, and absolutes. There was a harmonious reality underlying the laws of the universe, Einstein felt, and the goal of science was to discover it.

His quest began in 1895, when as a 16-year-old he imagined what it would be like to ride alongside a light beam. A decade later came his miracle year, described in the letter above, which laid the foundations for the two great advances of twentieth-century physics: relativity and quantum theory.

A decade after that, in 1915, he wrested from nature his crowning glory, one of the most beautiful theories in all of science, the general theory of relativity. As with the special theory, his thinking had evolved through thought experiments. Imagine being in an enclosed elevator accelerating up through space, he conjectured in one of them. The effects you'd feel would be indistinguishable from the experience of gravity.

Gravity, he figured, was a warping of space and time, and he came up with the equations that describe how the dynamics of this curvature

result from the interplay between matter, motion, and energy. It can be described by using another thought experiment. Picture what it would be like to roll a bowling ball onto the two-dimensional surface of a trampoline. Then roll some billiard balls. They move toward the bowling ball not because it exerts some mysterious attraction but because of the way it curves the trampoline fabric. Now imagine this happening in the four-dimensional fabric of space and time. Okay, it's not easy, but that's why we're no Einstein and he was.

The exact midpoint of his career came a decade after that, in 1925, and it was a turning point. The quantum revolution he had helped to launch was being transformed into a new mechanics that was based on uncertainties and probabilities. He made his last great contributions to quantum mechanics that year but, simultaneously, began to resist it. He would spend the next three decades, ending with some equations scribbled while on his deathbed in 1955, stubbornly criticizing what he regarded as the incompleteness of quantum mechanics while attempting to subsume it into a unified field theory.

Both during his thirty years as a revolutionary and his subsequent thirty years as a resister, Einstein remained consistent in his willingness to be a serenely amused loner who was comfortable not conforming. Independent in his thinking, he was driven by an imagination that broke from the confines of conventional wisdom. He was that odd breed, a reverential rebel, and he was guided by a faith, which he wore lightly and with a twinkle in his eye, in a God who would not play dice by allowing things to happen by chance.

Einstein's nonconformist streak was evident in his personality and politics as well. Although he subscribed to socialist ideals, he was too much of an individualist to be comfortable with excessive state control or centralized authority. His impudent instincts, which served him so well as a young scientist, made him allergic to nationalism, militarism, and anything that smacked of a herd mentality. And until Hitler caused him to revise his geopolitical equations, he was an instinctive pacifist who celebrated resistance to war.

His tale encompasses the vast sweep of modern science, from the infinitesimal to the infinite, from the emission of photons to the expansion of the cosmos. A century after his great triumphs, we are still

living in Einstein's universe, one defined on the macro scale by his theory of relativity and on the micro scale by a quantum mechanics that has proven durable even as it remains disconcerting.

His fingerprints are all over today's technologies. Photoelectric cells and lasers, nuclear power and fiber optics, space travel, and even semiconductors all trace back to his theories. He signed the letter to Franklin Roosevelt warning that it may be possible to build an atom bomb, and the letters of his famed equation relating energy to mass hover in our minds when we picture the resulting mushroom cloud.

Einstein's launch into fame, which occurred when measurements made during a 1919 eclipse confirmed his prediction of how much gravity bends light, coincided with, and contributed to, the birth of a new celebrity age. He became a scientific supernova and humanist icon, one of the most famous faces on the planet. The public earnestly puzzled over his theories, elevated him into a cult of genius, and canonized him as a secular saint.

If he did not have that electrified halo of hair and those piercing eyes, would he still have become science's preeminent poster boy? Suppose, as a thought experiment, that he had looked like a Max Planck or a Niels Bohr. Would he have remained in their reputational orbit, that of a mere scientific genius? Or would he still have made the leap into the pantheon inhabited by Aristotle, Galileo, and Newton?[2]

The latter, I believe, is the case. His work had a very personal character, a stamp that made it recognizably his, the way a Picasso is recognizably a Picasso. He made imaginative leaps and discerned great principles through thought experiments rather than by methodical inductions based on experimental data. The theories that resulted were at times astonishing, mysterious, and counterintuitive, yet they contained notions that could capture the popular imagination: the relativity of space and time, $E=mc^2$, the bending of light beams, and the warping of space.

Adding to his aura was his simple humanity. His inner security was tempered by the humility that comes from being awed by nature. He could be detached and aloof from those close to him, but toward mankind in general he exuded a true kindness and gentle compassion.

Yet for all of his popular appeal and surface accessibility, Einstein

also came to symbolize the perception that modern physics was something that ordinary laymen could not comprehend, "the province of priest-like experts," in the words of Harvard professor Dudley Herschbach.[3] It was not always thus. Galileo and Newton were both great geniuses, but their mechanical cause-and-effect explanation of the world was something that most thoughtful folks could grasp. In the eighteenth century of Benjamin Franklin and the nineteenth century of Thomas Edison, an educated person could feel some familiarity with science and even dabble in it as an amateur.

A popular feel for scientific endeavors should, if possible, be restored given the needs of the twenty-first century. This does not mean that every literature major should take a watered-down physics course or that a corporate lawyer should stay abreast of quantum mechanics. Rather, it means that an appreciation for the methods of science is a useful asset for a responsible citizenry. What science teaches us, very significantly, is the correlation between factual evidence and general theories, something well illustrated in Einstein's life.

In addition, an appreciation for the glories of science is a joyful trait for a good society. It helps us remain in touch with that childlike capacity for wonder, about such ordinary things as falling apples and elevators, that characterizes Einstein and other great theoretical physicists.[4]

That is why studying Einstein can be worthwhile. Science is inspiring and noble, and its pursuit an enchanting mission, as the sagas of its heroes remind us. Near the end of his life, Einstein was asked by the New York State Education Department what schools should emphasize. "In teaching history," he replied, "there should be extensive discussion of personalities who benefited mankind through independence of character and judgment."[5] Einstein fits into that category.

At a time when there is a new emphasis, in the face of global competition, on science and math education, we should also note the other part of Einstein's answer. "Critical comments by students should be taken in a friendly spirit," he said. "Accumulation of material should not stifle the student's independence." A society's competitive advantage will come not from how well its schools teach the multiplication

and periodic tables, but from how well they stimulate imagination and creativity.

Therein lies the key, I think, to Einstein's brilliance and the lessons of his life. As a young student he never did well with rote learning. And later, as a theorist, his success came not from the brute strength of his mental processing power but from his imagination and creativity. He could construct complex equations, but more important, he knew that math is the language nature uses to describe her wonders. So he could visualize how equations were reflected in realities—how the electromagnetic field equations discovered by James Clerk Maxwell, for example, would manifest themselves to a boy riding alongside a light beam. As he once declared, "Imagination is more important than knowledge."[6]

That approach required him to embrace nonconformity. "Long live impudence!" he exulted to the lover who would later become his wife. "It is my guardian angel in this world." Many years later, when others thought that his reluctance to embrace quantum mechanics showed that he had lost his edge, he lamented, "To punish me for my contempt for authority, fate made me an authority myself."[7]

His success came from questioning conventional wisdom, challenging authority, and marveling at mysteries that struck others as mundane. This led him to embrace a morality and politics based on respect for free minds, free spirits, and free individuals. Tyranny repulsed him, and he saw tolerance not simply as a sweet virtue but as a necessary condition for a creative society. "It is important to foster individuality," he said, "for only the individual can produce the new ideas."[8]

This outlook made Einstein a rebel with a reverence for the harmony of nature, one who had just the right blend of imagination and wisdom to transform our understanding of the universe. These traits are just as vital for this new century of globalization, in which our success will depend on our creativity, as they were for the beginning of the twentieth century, when Einstein helped usher in the modern age.