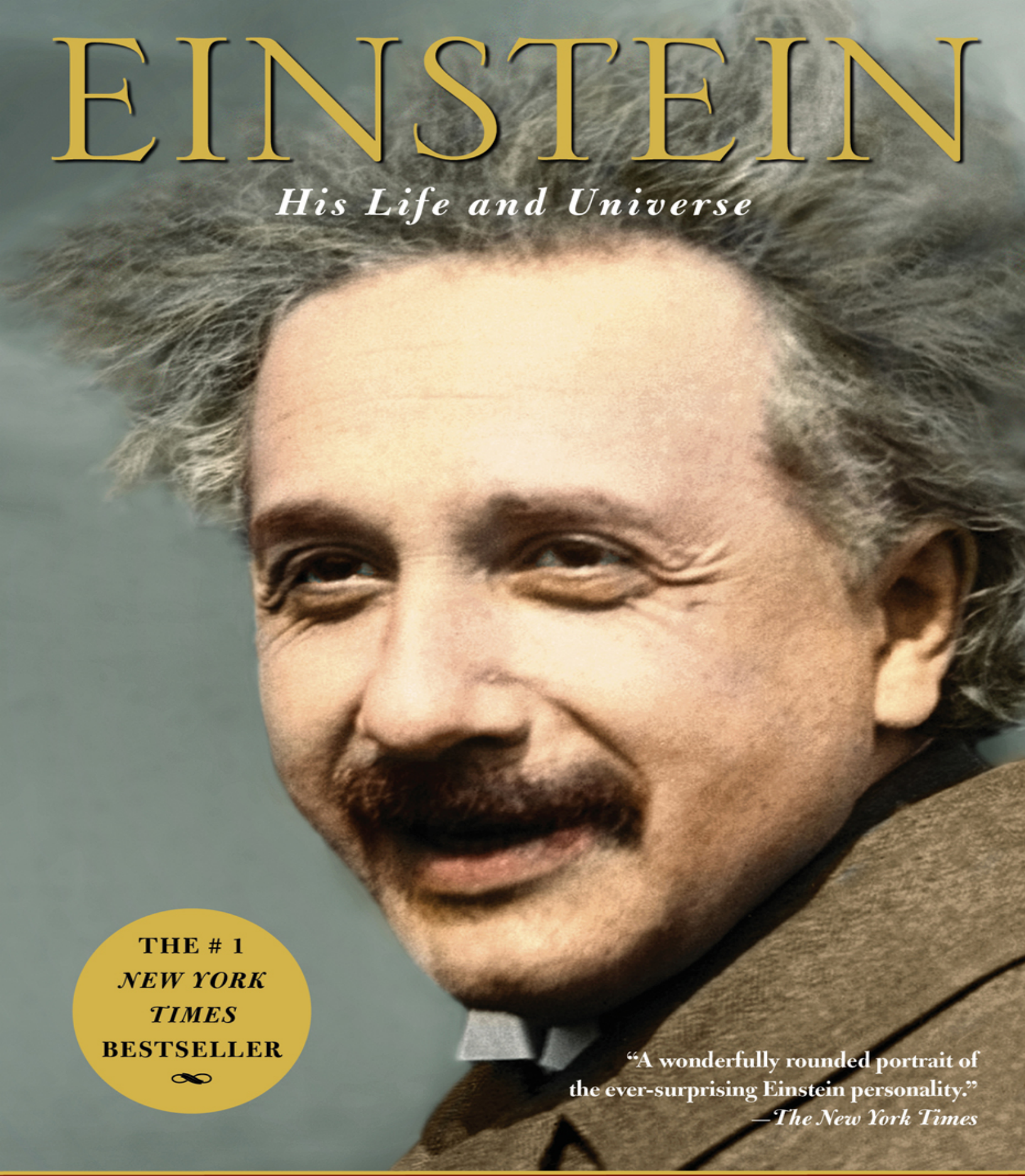
EINSTEIN

His Life and Universe



THE # 1
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"A wonderfully rounded portrait of the ever-surprising Einstein personality."
—*The New York Times*

WALTER ISAACSON

AUTHOR OF *BENJAMIN FRANKLIN* AND *STEVE JOBS*

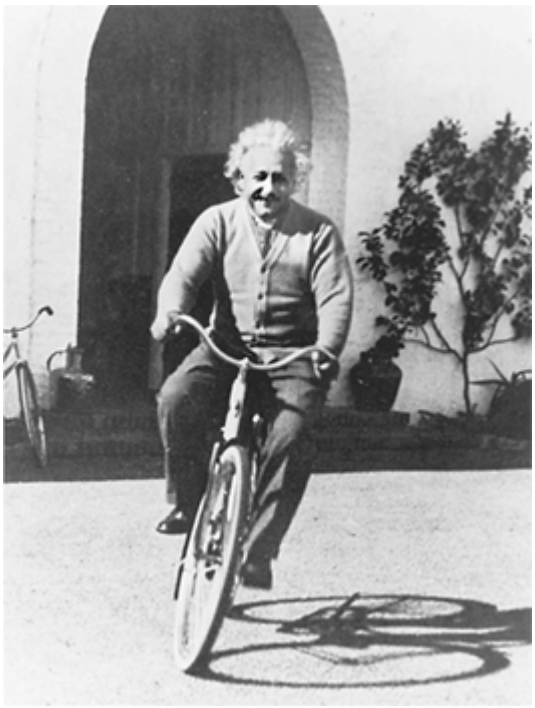
EINSTEIN

HIS LIFE AND UNIVERSE

WALTER ISAACSON

SIMON & SCHUSTER PAPERBACKS
NEW YORK LONDON TORONTO SYDNEY

To my father,
the nicest, smartest, and most moral man I know



In Santa Barbara, 1933

Life is like riding a bicycle.

To keep your balance you must keep moving.

—Albert Einstein, in a letter to his son Eduard, February 5, 1930[1]

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Krauss helped me enlist a protégé of his at Case, Craig J. Copi, who teaches relativity there. I hired him to do a thorough checking of the science and math, and I am grateful for his diligent edits.

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explained Einstein's objections to quantum uncertainty. With his combination of erudition and humor, and his feel for the personalities involved, he made the process a great joy.

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In addition, I asked two teachers of high school physics to give the book a careful reading to make sure the science was correct, and also comprehensible to those whose last physics course was in high school. Nancy Stravinsky Isaacson taught physics in New Orleans until, alas, Hurricane Katrina gave her more free time. David Derbes teaches physics

at the University of Chicago Lab School. Their comments were very incisive and also aimed at the lay reader.

There is a corollary of the uncertainty principle that says that no matter how often a book is observed, some mistakes will remain. Those are my fault.

It also helped to have some nonscientific readers, who made very useful suggestions from a lay perspective on parts or all of the manuscript. These included William Mayer, Orville Wright, Daniel Okrent, Steve Weisman, and Strobe Talbott.

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The other truly valuable reader was my wife, Cathy, who read every page with her usual wisdom, common sense, and curiosity. And the valuable half-a-reader was my daughter, Betsy, who as usual read selected portions of my book. The surety with which she made her pronouncements made up for the randomness of her reading. I love them both dearly.

MAIN CHARACTERS

Michele Angelo Besso (1873–1955). Einstein's closest friend. An engaging but unfocused engineer, he met Einstein in Zurich, then followed him to work at the Bern patent office. Served as a sounding board for the 1905 special relativity paper. Married Anna Winteler, sister of Einstein's first girlfriend.

Niels Bohr (1885–1962). Danish pioneer of quantum theory. At Solvay conferences and subsequent intellectual trysts, he parried Einstein's enthusiastic challenges to his Copenhagen interpretation of quantum mechanics.

Max Born (1882–1970). German physicist and mathematician. Engaged in a brilliant, intimate correspondence with Einstein for forty years. Tried to convince Einstein to be comfortable with quantum mechanics; his wife, Hedwig, challenged Einstein on personal issues.

Helen Dukas (1896–1982). Einstein's loyal secretary, Cerberus-like guard, and housemate from 1928 until his death, and after that protector of his legacy and papers.

Arthur Stanley Eddington (1882–1944). British astrophysicist and champion of relativity whose 1919 eclipse observations dramatically confirmed Einstein's prediction of how much gravity bends light.

Paul Ehrenfest (1880–1933). Austrian-born physicist, intense and insecure, who bonded with Einstein on a visit to Prague in 1912 and became a professor in Leiden, where he frequently hosted Einstein.

Eduard Einstein (1910–1965). Second son of Mileva Marić and Einstein. Smart and artistic, he obsessed about Freud and hoped to be a psychiatrist, but he succumbed to his own schizophrenic demons in his twenties and was institutionalized in Switzerland for much of the rest of his life.

Elsa Einstein (1876–1936). Einstein's first cousin, second wife. Mother of Margot and Ilse Einstein from her first marriage to textile merchant Max Löwenthal. She and her daughters reverted to her maiden name, Einstein, after her 1908 divorce. Married Einstein in 1919. Smarter than she pretended to be, she knew how to handle him.

Hans Albert Einstein (1904–1973). First son of Mileva Marić and Einstein, a difficult role that he handled with grace. Studied engineering at Zurich Polytechnic. Married Frieda Knecht (1895–1958) in 1927. They had two sons, Bernard (1930–) and Klaus (1932–1938), and an adopted daughter, Evelyn (1941–). Moved to the United States in 1938 and eventually became a professor of hydraulic engineering at Berkeley. After Frieda's death, married Elizabeth Roboz (1904–1995) in 1959. Bernard has five children, the only known great-grandchildren of Albert Einstein.

Hermann Einstein (1847–1902). Einstein's father, from a Jewish family from rural Swabia. With his brother Jakob, he ran electrical companies

in Munich and then Italy, but not very successfully.

Ilse Einstein (1897–1934). Daughter of Elsa Einstein from her first marriage. Dallied with adventurous physician Georg Nicolai and in 1924 married literary journalist Rudolph Kayser, who later wrote a book on Einstein using the pseudonym Anton Reiser.

Lieserl Einstein (1902–?). Premarital daughter of Einstein and Mileva Marić. Einstein probably never saw her. Likely left in her Serbian mother's hometown of Novi Sad for adoption and may have died of scarlet fever in late 1903.

Margot Einstein (1899–1986). Daughter of Elsa Einstein from her first marriage. A shy sculptor. Married Russian Dimitri Marianoff in 1930; no children. He later wrote a book on Einstein. She divorced him in 1937, moved in with Einstein at Princeton, and remained at 112 Mercer Street until her death.

Maria "Maja" Einstein (1881–1951). Einstein's only sibling, and among his closest confidantes. Married Paul Winteler, had no children, and in 1938 moved without him from Italy to Princeton to live with her brother.

Pauline Koch Einstein (1858–1920). Einstein's strong-willed and practical mother. Daughter of a prosperous Jewish grain dealer from Württemberg. Married Hermann Einstein in 1876.

Abraham Flexner (1866–1959). American education reformer. Founded the Institute for Advanced Study in Princeton and recruited

Einstein there.

Philipp Frank (1884–1966). Austrian physicist. Succeeded his friend Einstein at German University of Prague and later wrote a book about him.

Marcel Grossmann (1878–1936). Diligent classmate at Zurich Polytechnic who took math notes for Einstein and then helped him get a job in the patent office. As professor of descriptive geometry at the Polytechnic, guided Einstein to the math he needed for general relativity.

Fritz Haber (1868–1934). German chemist and gas warfare pioneer who helped recruit Einstein to Berlin and mediated between him and Marić. A Jew who converted to Christianity in an attempt to be a good German, he preached to Einstein the virtues of assimilation, until the Nazis came to power.

Conrad Habicht (1876–1958). Mathematician and amateur inventor, member of the "Olympia Academy" discussion trio in Bern, and recipient of two famous 1905 letters from Einstein heralding forthcoming papers.

Werner Heisenberg (1901–1976). German physicist. A pioneer of quantum mechanics, he formulated the uncertainty principle that Einstein spent years resisting.

David Hilbert (1862–1943). German mathematician who in 1915 raced Einstein to discover the mathematical equations for general relativity.

Banesh Hoffmann (1906–1986). Mathematician and physicist who collaborated with Einstein in Princeton and later wrote a book about him.

Philipp Lenard (1862–1947). Hungarian-German physicist whose experimental observations on the photoelectric effect were explained by Einstein in his 1905 light quanta paper. Became an anti-Semite, Nazi, and Einstein hater.

Hendrik Antoon Lorentz (1853–1928). Genial and wise Dutch physicist whose theories paved the way for special relativity. Became a father figure to Einstein.

Mileva Marić (1875–1948). Serbian physics student at Zurich Polytechnic who became Einstein's first wife. Mother of Hans Albert, Eduard, and Lieserl. Passionate and driven, but also brooding and increasingly gloomy, she triumphed over many, but not all, of the obstacles that then faced an aspiring female physicist. Separated from Einstein in 1914, divorced in 1919.

Robert Andrews Millikan (1868–1953). American experimental physicist who confirmed Einstein's law of the photoelectric effect and recruited him to be a visiting scholar at Caltech.

Hermann Minkowski (1864–1909). Taught Einstein math at the Zurich Polytechnic, referred to him as a "lazy dog," and devised a mathematical formulation of special relativity in terms of four-dimensional spacetime.

Georg Friedrich Nicolai, born Lewinstein (1874–1964). Physician, pacifist, charismatic adventurer, and seducer. A friend and doctor of Elsa Einstein and probable lover of her daughter Ilse, he wrote a pacifist tract with Einstein in 1915.

Abraham Pais (1918–2000). Dutch-born theoretical physicist who became a colleague of Einstein in Princeton and wrote a scientific biography of him.

Max Planck (1858–1947). Prussian theoretical physicist who was an early patron of Einstein and helped recruit him to Berlin. His conservative instincts, both in life and in physics, made him a contrast to Einstein, but they remained warm and loyal colleagues until the Nazis took power.

Erwin Schrödinger (1887–1961). Austrian theoretical physicist who was a pioneer of quantum mechanics but joined Einstein in expressing discomfort with the uncertainties and probabilities at its core.

Maurice Solovine (1875–1958). Romanian philosophy student in Bern who founded the "Olympia Academy" with Einstein and Habicht. Became Einstein's French publisher and lifelong correspondent.

Leó Szilárd (1898–1964). Hungarian-born physicist, charming and eccentric, who met Einstein in Berlin and patented a refrigerator with him. Conceived the nuclear chain reaction and cowrote the 1939 letter Einstein sent to President Franklin Roosevelt urging attention to the possibility of an atomic bomb.

Chaim Weizmann (1874–1952). Russian-born chemist who emigrated to England and became president of the World Zionist Organization. In 1921, he brought Einstein to America for the first time, using him as the draw for a fund-raising tour. Was first president of Israel, a post offered upon his death to Einstein.

The Winteler family. Einstein boarded with them while he was a student in Aarau, Switzerland. Jost Winteler was his history and Greek teacher; his wife, Rosa, became a surrogate mother. Of their seven children, Marie became Einstein's first girlfriend; Anna married Einstein's best friend, Michele Besso; and Paul married Einstein's sister, Maja.

Heinrich Zangger (1874–1957). Professor of physiology at the University of Zurich. Befriended Einstein and Marić and helped mediate their disputes and divorce.

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 Serbian 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.