EINSTEIN

HIS LIFE AND UNIVERSE

WALTER ISAACSON

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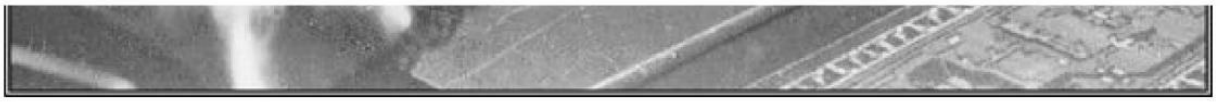

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First published in Great Britain in 2007
by Simon & Schuster UK Ltd
This edition published by Pocket Books, 2008
An imprint of Simon & Schuster UK Ltd
A CBS COMPANY
www.SimonandSchuster.com

Simon & Schuster UK Ltd
Africa House
64–78 Kingsway
London WC2B 6AH

Simon & Schuster Australia
Sydney

A CIP catalogue for this book is available from the British Library.

ISBN: 978-1-84739-054-7
ISBN: 978-1-8473-9589-4 (eBook)

Printed and bound in Great Britain by Cox & Wyman Ltd, Reading, Berks

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ACKNOWLEDGMENTS

Diana Kormos Buchwald, the general editor of Einstein's papers, read this book meticulously and made copious comments and corrections through many drafts. In addition, she helped me get early and complete access to the wealth of new Einstein papers that became available in 2006, and guided me through them. She was also a gracious host and facilitator during my trips to the Einstein Papers Project at Caltech. She has a passion for her work and a delightful sense of humor, which would have pleased her subject.

Two of her associates were also very helpful in guiding me through the newly available papers as well as untapped riches in the older archival material. Tilman Sauer, who likewise checked and annotated this book, in particular vetted the sections on Einstein's quest for the equations of general relativity and his pursuit of a unified field theory. Ze'ev Rosenkranz, the historical editor of the papers, provided insights on Einstein's attitudes toward Germany and his Jewish heritage. He was formerly curator of the Einstein archives at Hebrew University in Jerusalem.

Barbara Wolff, who is now at those archives at Hebrew University, did a careful fact-checking of every page of the manuscript, making fastidious corrections large and small. She warned that she has a reputation as a nitpicker, but I am very grateful for each and every nit she found. I also appreciate the encouragement given by Roni Grosz, the curator there.

Brian Greene, the Columbia University physicist and author of *The Fabric of the Cosmos,* was an indispensable friend and editor. He talked me through numerous revisions, honed the wording of the science passages, and read the final manuscript. He is a master of both science and language. In addition to his work on string theory, he and his wife, Tracy Day, are organizing an annual science festival in New York City, which will help spread the enthusiasm for physics so evident in his work and books.

Lawrence Krauss, professor of physics at Case Western Reserve and author of *Hiding in the Mirror,* also read my manuscript, vetted the sections on special relativity, general relativity, and cosmology, and offered many good suggestions and corrections. He, too, has an infectious enthusiasm for physics.

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.

Douglas Stone, professor of physics at Yale, also vetted the science in the book. A condensed matter theorist, he is writing what will be an important book on Einstein's contributions to quantum mechanics. In addition to checking my science sections, he helped me write the chapters on the 1905 light quanta paper, quantum theory, Bose-Einstein statistics, and kinetic theory.

Murray Gell-Mann, winner of the 1969 Nobel Prize in physics, was a delightful and passionate guide from the beginning to the end of this project. He helped me revise early drafts, edited and corrected the chapters on relativity and quantum mechanics, and helped draft sections that 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.

Arthur I. Miller, emeritus professor of history and philosophy of science at University College, London, is the author of *Einstein, Picasso* and of *Empire of the Stars.* He read and reread the versions of my scientific chapters and helped with numerous revisions, especially on special relativity (about which he wrote a pioneering book), general relativity, and quantum theory.

Sylvester James Gates Jr., a physics professor at the University of Maryland, agreed to read my manuscript when he came out to Aspen for a conference on Einstein. He did a comprehensive edit filled with smart comments and rephrasing of certain scientific passages.

John D. Norton, a professor at the University of Pittsburgh, has specialized in tracing Einstein's thought process as he developed both special and then general relativity. He read these sections of my book, made edits, and offered useful comments. I am also grateful for guidance from two of his fellow scholars specializing in Einstein's development of his theories: Jürgen Renn of the Max Planck Institute in Berlin and Michel Janssen of the University of Minnesota.

George Stranahan, a founder of the Aspen Center for Physics, also agreed to read and review the manuscript. He was particularly helpful in editing the sections on the light quanta paper, Brownian motion, and the history and science of special relativity.

Robert Rynasiewicz, a philosopher of science at Johns Hopkins, read many of the science chapters and made useful suggestions about the quest for general relativity.

N. David Mermin, professor of theoretical physics at Cornell and author of *It's About Time: Understanding Einstein's Relativity,* edited and made corrections to the final version of the introductory chapter and chapters 5 and 6 on Einstein's 1905

papers.

Gerald Holton, professor of physics at Harvard, has been one of the pioneers in the study of Einstein, and he is still a guiding light. I am deeply flattered that he was willing to read my book, make comments, and offer generous encouragement. His Harvard colleague Dudley Herschbach, who has done so much for science education, also was supportive. Both Holton and Herschbach made useful comments on my draft and spent an afternoon with me in Holton's office going over suggestions and refining my descriptions of the historical players.

Ashton Carter, professor of science and international affairs at Harvard, kindly read and checked an early draft. Columbia University's Fritz Stern, author of *Einstein's German World,* provided encouragement and advice at the outset. Robert Schulmann, one of the original editors at the Einstein Papers Project, did likewise. And Jeremy Bernstein, who has written many fine books on Einstein, warned me how difficult the science would be. He was right, and I am grateful for that as well.

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.

For twenty-five years, Alice Mayhew at Simon & Schuster has been my editor and Amanda Urban at ICM my agent. I can imagine no better partners, and they were again enthusiastic and helpful in their comments on the book. I also appreciate the help of Carolyn Reidy, David Rosenthal, Roger Labrie, Victoria Meyer, Elizabeth Hayes, Serena Jones, Mara Lurie, Judith Hoover, Jackie Seow, and Dana Sloan at Simon & Schuster. For their countless acts of support over the years, I am also grateful to Elliot Ravetz and Patricia Zindulka.

Natasha Hoffmeyer and James Hoppes translated for me Einstein's German correspondence and writing, especially the new material that had not yet been translated, and I appreciate their diligence. Jay Colton, who was photo editor for

Time's Person of the Century issue, also did a creative job tracking down pictures for this book.

I had two and a half other readers who were the most valuable of all. The first was my father, Irwin Isaacson, an engineer who instilled in me a love of science and is the smartest teacher I've ever had. I am grateful to him for the universe that he and my late mother created for me, and to my brilliant and wise stepmother, Julanne.

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 greatgrandchildren 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 bestknown 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.

CHAPTER TWO

CHILDHOOD

1879–1896

Maja, age 3, and Albert Einstein, 5

The Swabian

He was slow in learning how to talk. "My parents were so worried," he later recalled, "that they consulted a doctor." Even after he had begun using words, sometime after the age of 2, he developed a quirk that prompted the family maid to dub him "der Depperte," the dopey one, and others in his family to label him as "almost backwards." Whenever he had something to say, he would try it out on himself, whispering it softly until it sounded good enough to pronounce aloud. "Every sentence he uttered," his worshipful younger sister recalled, "no matter how routine, he repeated to himself softly, moving his lips." It was all very worrying, she

said. "He had such difficulty with language that those around him feared he would never learn."[1]

His slow development was combined with a cheeky rebelliousness toward authority, which led one schoolmaster to send him packing and another to amuse history by declaring that he would never amount to much. These traits made Albert Einstein the patron saint of distracted school kids everywhere.[2] But they also helped to make him, or so he later surmised, the most creative scientific genius of modern times.

His cocky contempt for authority led him to question received wisdom in ways that well-trained acolytes in the academy never contemplated. And as for his slow verbal development, he came to believe that it allowed him to observe with wonder the everyday phenomena that others took for granted. "When I ask myself how it happened that I in particular discovered the relativity theory, it seemed to lie in the following circumstance," Einstein once explained. "The ordinary adult never bothers his head about the problems of space and time. These are things he has thought of as a child. But I developed so slowly that I began to wonder about space and time only when I was already grown up. Consequently, I probed more deeply into the problem than an ordinary child would have."[3]

Einstein's developmental problems have probably been exaggerated, perhaps even by himself, for we have some letters from his adoring grandparents saying that he was just as clever and endearing as every grandchild is. But throughout his life, Einstein had a mild form of echolalia, causing him to repeat phrases to himself, two or three times, especially if they amused him. And he generally preferred to think in pictures, most notably in famous thought experiments, such as imagining watching lightning strikes from a moving train or experiencing gravity while inside a falling elevator. "I very rarely think in words at all," he later told a psychologist. "A thought comes, and I may try to express it in words afterwards."[4]

Einstein was descended, on both parents' sides, from Jewish tradesmen and peddlers who had, for at least two centuries, made modest livings in the rural villages of Swabia in southwestern Germany. With each generation they had become, or at least so they thought, increasingly assimilated into the German culture that they loved. Although Jewish by cultural designation and kindred instinct, they displayed scant interest in the religion or its rituals.

Einstein regularly dismissed the role that his heritage played in shaping who he became. "Exploration of my ancestors," he told a friend late in life, "leads nowhere."[5] That's not fully true. He was blessed by being born into an independent-minded and

intelligent family line that valued education, and his life was certainly affected, in ways both beautiful and tragic, by membership in a religious heritage that had a distinctive intellectual tradition and a history of being both outsiders and wanderers. Of course, the fact that he happened to be Jewish in Germany in the early twentieth century made him more of an outsider, and more of a wanderer, than he would have preferred— but that, too, became integral to who he was and the role he would play in world history.

Einstein's father, Hermann, was born in 1847 in the Swabian village of Buchau, whose thriving Jewish community was just beginning to enjoy the right to practice any vocation. Hermann showed "a marked inclination for mathematics,"[6] and his family was able to send him seventy-five miles north to Stuttgart for high school. But they could not afford to send him to a university, most of which were closed to Jews in any event, so he returned home to Buchau to go into trade.

A few years later, as part of the general migration of rural German Jews into industrial centers during the late nineteenth century, Hermann and his parents moved thirty-five miles away to the more prosperous town of Ulm, which prophetically boasted as its motto "Ulmenses sunt mathematici," the people of Ulm are mathematicians.[7]

There he became a partner in a cousin's featherbed company. He was "exceedingly friendly, mild and wise," his son would recall.[8] With a gentleness that blurred into docility, Hermann was to prove inept as a businessman and forever impractical in financial matters. But his docility did make him well suited to be a genial family man and good husband to a strong-willed woman. At age 29, he married Pauline Koch, eleven years his junior.

Pauline's father, Julius Koch, had built a considerable fortune as a grain dealer and purveyor to the royal Württemberg court. Pauline inherited his practicality, but she leavened his dour disposition with a teasing wit edged with sarcasm and a laugh that could be both infectious and wounding (traits she would pass on to her son). From all accounts, the match between Hermann and Pauline was a happy one, with her strong personality meshing "in complete harmony" with her husband's passivity.[9]

Their first child was born at 11:30 a.m. on Friday, March 14, 1879, in Ulm, which had recently joined, along with the rest of Swabia, the new German Reich. Initially, Pauline and Hermann had planned to name the boy Abraham, after his paternal grandfather. But they came to feel, he later said, that the name sounded "too Jewish."[10] So they kept the initial A and named him Albert Einstein.

Munich

In 1880, just a year after Albert's birth, Hermann's featherbed business foundered and he was persuaded to move to Munich by his brother Jakob, who had opened a gas and electrical supply company there. Jakob, the youngest of five siblings, had been able to get a higher education, unlike Hermann, and he had qualified as an engineer. As they competed for contracts to provide generators and electrical lighting to municipalities in southern Germany, Jakob was in charge of the technical side while Hermann provided a modicum of salesmanship skills plus, perhaps more important, loans from his wife's side of the family.[11]

Pauline and Hermann had a second and final child, a daughter, in November 1881, who was named Maria but throughout her life used instead the diminutive Maja. When Albert was shown his new sister for the first time, he was led to believe that she was like a wonderful toy that he would enjoy. His response was to look at her and exclaim, "Yes, but where are the wheels?"[12] It may not have been the most perceptive of questions, but it did show that during his third year his language challenges did not prevent him from making some memorable comments. Despite a few childhood squabbles, Maja was to become her brother's most intimate soul mate.

The Einsteins settled into a comfortable home with mature trees and an elegant garden in a Munich suburb for what was to be, at least through most of Albert's childhood, a respectable bourgeois existence. Munich had been architecturally burnished by mad King Ludwig II (1845–1886) and boasted a profusion of churches, art galleries, and concert halls that favored the works of resident Richard Wagner. In 1882, just after the Einsteins arrived, the city had about 300,000 residents, 85 percent of them Catholics and 2 percent of them Jewish, and it was the host of the first German electricity exhibition, at which electric lights were introduced to the city streets.

Einstein's back garden was often bustling with cousins and children. But he shied from their boisterous games and instead "occupied himself with quieter things." One governess nicknamed him "Father Bore." He was generally a loner, a tendency he claimed to cherish throughout his life, although his was a special sort of detachment that was interwoven with a relish for camaraderie and intellectual companionship. "From the very beginning he was inclined to separate himself from children his own age and to engage in daydreaming and meditative musing," according to Philipp Frank, a longtime scientific colleague.[13]

He liked to work on puzzles, erect complex structures with his toy building set,

play with a steam engine that his uncle gave him, and build houses of cards. According to Maja, Einstein was able to construct card structures as high as fourteen stories. Even discounting the recollections of a star-struck younger sister, there was probably a lot of truth to her claim that "persistence and tenacity were obviously already part of his character."

He was also, at least as a young child, prone to temper tantrums. "At such moments his face would turn completely yellow, the tip of his nose snow-white, and he was no longer in control of himself," Maja remembers. Once, at age 5, he grabbed a chair and threw it at a tutor, who fled and never returned. Maja's head became the target of various hard objects. "It takes a sound skull," she later joked, "to be the sister of an intellectual." Unlike his persistence and tenacity, he eventually outgrew his temper.[14]

To use the language of psychologists, the young Einstein's ability to systemize (identify the laws that govern a system) was far greater than his ability to empathize (sense and care about what other humans are feeling), which have led some to ask if he might have exhibited mild symptoms of some developmental disorder.[15] However, it is important to note that, despite his aloof and occasionally rebellious manner, he did have the ability to make close friends and to empathize both with colleagues and humanity in general.

The great awakenings that happen in childhood are usually lost to memory. But for Einstein, an experience occurred when he was 4 or 5 that would alter his life and be etched forever in his mind—and in the history of science.

He was sick in bed one day, and his father brought him a compass. He later recalled being so excited as he examined its mysterious powers that he trembled and grew cold. The fact that the magnetic needle behaved as if influenced by some hidden force field, rather than through the more familiar mechanical method involving touch or contact, produced a sense of wonder that motivated him throughout his life. "I can still remember—or at least I believe I can remember—that this experience made a deep and lasting impression on me," he wrote on one of the many occasions he recounted the incident. "Something deeply hidden had to be behind things."[16]

"It's an iconic story," Dennis Overbye noted in *Einstein in Love,* "the young boy trembling to the invisible order behind chaotic reality." It has been told in the movie *IQ,* in which Einstein, played by Walter Matthau, wears the compass around his neck, and it is the focus of a children's book, *Rescuing Albert's Compass,* by Shulamith Oppenheim, whose fatherinlaw heard the tale from Einstein in 1911.[17]

After being mesmerized by the compass needle's fealty to an unseen field, Einstein would develop a lifelong devotion to field theories as a way to describe nature. Field theories use mathematical quantities, such as numbers or vectors or tensors, to describe how the conditions at any point in space will affect matter or another field. For example, in a gravitational or an electromagnetic field there are forces that could act on a particle at any point, and the equations of a field theory describe how these change as one moves through the region. The first paragraph of his great 1905 paper on special relativity begins with a consideration of the effects of electrical and magnetic fields; his theory of general relativity is based on equations that describe a gravitational field; and at the very end of his life he was doggedly scribbling further field equations in the hope that they would form the basis for a theory of everything. As the science historian Gerald Holton has noted, Einstein regarded "the classical concept of the field the greatest contribution to the scientific spirit."[18]

His mother, an accomplished pianist, also gave him a gift at around the same time, one that likewise would last throughout his life. She arranged for him to take violin lessons. At first he chafed at the mechanical discipline of the instruction. But after being exposed to Mozart's sonatas, music became both magical and emotional to him. "I believe that love is a better teacher than a sense of duty," he said, "at least for me."[19]

Soon he was playing Mozart duets, with his mother accompanying him on the piano. "Mozart's music is so pure and beautiful that I see it as a reflection of the inner beauty of the universe itself," he later told a friend. "Of course," he added in a remark that reflected his view of math and physics as well as of Mozart, "like all great beauty, his music was pure simplicity."[20]

Music was no mere diversion. On the contrary, it helped him think. "Whenever he felt that he had come to the end of the road or faced a difficult challenge in his work," said his son Hans Albert, "he would take refuge in music and that would solve all his difficulties." The violin thus proved useful during the years he lived alone in Berlin, wrestling with general relativity. "He would often play his violin in his kitchen late at night, improvising melodies while he pondered complicated problems," a friend recalled. "Then, suddenly, in the middle of playing, he would announce excitedly, 'I've got it!' As if by inspiration, the answer to the problem would have come to him in the midst of music."[21]

His appreciation for music, and especially for Mozart, may have reflected his feel for the harmony of the universe. As Alexander Moszkowski, who wrote a biography

of Einstein in 1920 based on conversations with him, noted, "Music, Nature, and God became intermingled in him in a complex of feeling, a moral unity, the trace of which never vanished."[22]

Throughout his life, Albert Einstein would retain the intuition and the awe of a child. He never lost his sense of wonder at the magic of nature's phenomena—magnetic fields, gravity, inertia, acceleration, light beams—which grown-ups find so commonplace. He retained the ability to hold two thoughts in his mind simultaneously, to be puzzled when they conflicted, and to marvel when he could smell an underlying unity. "People like you and me never grow old," he wrote a friend later in life. "We never cease to stand like curious children before the great mystery into which we were born."[23]

School

In his later years, Einstein would tell an old joke about an agnostic uncle, who was the only member of his family who went to synagogue. When asked why he did so, the uncle would respond, "Ah, but you never know." Einstein's parents, on the other hand, were "entirely irreligious" and felt no compulsion to hedge their bets. They did not keep kosher or attend synagogue, and his father referred to Jewish rituals as "ancient superstitions."[24]

Consequently, when Albert turned 6 and had to go to school, his parents did not care that there was no Jewish one near their home. Instead he went to the large Catholic school in their neighborhood, the Petersschule. As the only Jew among the seventy students in his class, Einstein took the standard course in Catholic religion and ended up enjoying it immensely. Indeed, he did so well in his Catholic studies that he helped his classmates with theirs.[25]

One day his teacher brought a large nail to the class. "The nails with which Jesus was nailed to the cross looked like this," he said.[26] Nevertheless, Einstein later said that he felt no discrimination from the teachers. "The teachers were liberal and made no distinction based on denominations," he wrote. His fellow students, however, were a different matter. "Among the children at the elementary school, antiSemitism was prevalent," he recalled.

Being taunted on his walks to and from school based on "racial characteristics about which the children were strangely aware" helped reinforce the sense of being an outsider, which would stay with him his entire life. "Physical attacks and insults on the way home from school were frequent, but for the most part not too vicious. Nevertheless, they were sufficient to consolidate, even in a child, a lively sense of

being an outsider."[27]

When he turned 9, Einstein moved up to a high school near the center of Munich, the Luitpold Gymnasium, which was known as an enlightened institution that emphasized math and science as well as Latin and Greek. In addition, the school supplied a teacher to provide religious instruction for him and other Jews.

Despite his parents' secularism, or perhaps because of it, Einstein rather suddenly developed a passionate zeal for Judaism. "He was so fervent in his feelings that, on his own, he observed Jewish religious strictures in every detail," his sister recalled. He ate no pork, kept kosher dietary laws, and obeyed the strictures of the Sabbath, all rather difficult to do when the rest of his family had a lack of interest bordering on disdain for such displays. He even composed his own hymns for the glorification of God, which he sang to himself as he walked home from school.[28]

One widely held belief about Einstein is that he failed math as a student, an assertion that is made, often accompanied by the phrase "as everyone knows," by scores of books and thousands of websites designed to reassure underachieving students. It even made it into the famous "Ripley's Believe It or Not!" newspaper column.

Alas, Einstein's childhood offers history many savory ironies, but this is not one of them. In 1935, a rabbi in Princeton showed him a clipping of the Ripley's column with the headline "Greatest Living Mathematician Failed in Mathematics." Einstein laughed. "I never failed in mathematics," he replied, correctly. "Before I was fifteen I had mastered differential and integral calculus."[29]

In fact, he was a wonderful student, at least intellectually. In primary school, he was at the top of his class. "Yesterday Albert got his grades," his mother reported to an aunt when he was 7. "Once again he was ranked first." At the gymnasium, he disliked the mechanical learning of languages such as Latin and Greek, a problem exacerbated by what he later said was his "bad memory for words and texts." But even in these courses, Einstein consistently got top grades. Years later, when Einstein celebrated his fiftieth birthday and there were stories about how poorly the great genius had fared at the gymnasium, the school's current principal made a point of publishing a letter revealing how good his grades actually were.[30]

As for math, far from being a failure, he was "far above the school requirements." By age 12, his sister recalled, "he already had a predilection for solving complicated problems in applied arithmetic," and he decided to see if he could jump ahead by learning geometry and algebra on his own. His parents bought him the textbooks in advance so that he could master them over summer vacation. Not only did he learn

the proofs in the books, he tackled the new theories by trying to prove them on his own. "Play and playmates were forgotten," she noted. "For days on end he sat alone, immersed in the search for a solution, not giving up before he had found it."[31]

His uncle Jakob Einstein, the engineer, introduced him to the joys of algebra. "It's a merry science," he explained. "When the animal that we are hunting cannot be caught, we call it *X* temporarily and continue to hunt until it is bagged." He went on to give the boy even more difficult challenges, Maja recalled, "with good-natured doubts about his ability to solve them." When Einstein triumphed, as he invariably did, he "was overcome with great happiness and was already then aware of the direction in which his talents were leading him."

Among the concepts that Uncle Jakob threw at him was the Pythagorean theorem (the square of the lengths of the legs of a right triangle add up to the square of the length of the hypotenuse). "After much effort I succeeded in 'proving' this theorem on the basis of the similarity of triangles," Einstein recalled. Once again he was thinking in pictures. "It seemed to me 'evident' that the relations of the sides of the right-angled triangles would have to be completely determined by one of the acute angles."[32]

Maja, with the pride of a younger sister, called Einstein's Pythagorean proof "an entirely original new one." Although perhaps new to him, it is hard to imagine that Einstein's approach, which was surely similar to the standard ones based on the proportionality of the sides of similar triangles, was completely original. Nevertheless, it did show Einstein's youthful appreciation that elegant theorems can be derived from simple axioms—and the fact that he was in little danger of failing math. "As a boy of 12, I was thrilled to see that it was possible to find out truth by reasoning alone, without the help of any outside experience," he told a reporter from a high school newspaper in Princeton years later. "I became more and more convinced that nature could be understood as a relatively simple mathematical structure."[33]

Einstein's greatest intellectual stimulation came from a poor medical student who used to dine with his family once a week. It was an old Jewish custom to take in a needy religious scholar to share the Sabbath meal; the Einsteins modified the tradition by hosting instead a medical student on Thursdays. His name was Max Talmud (later changed to Talmey, when he immigrated to the United States), and he began his weekly visits when he was 21 and Einstein was 10. "He was a pretty, dark-haired boy," remembered Talmud. "In all those years, I never saw him reading any light literature. Nor did I ever see him in the company of schoolmates or other

boys his age."[34]

Talmud brought him science books, including a popular illustrated series called *People's Books on Natural Science,* "a work which I read with breathless attention," said Einstein. The twenty-one little volumes were written by Aaron Bernstein, who stressed the interrelations between biology and physics, and he reported in great detail the scientific experiments being done at the time, especially in Germany.[35]

In the opening section of the first volume, Bernstein dealt with the speed of light, a topic that obviously fascinated him. Indeed, he returned to it repeatedly in his subsequent volumes, including eleven essays on the topic in volume 8. Judging from the thought experiments that Einstein later used in creating his theory of relativity, Bernstein's books appear to have been influential.

For example, Bernstein asked readers to imagine being on a speeding train. If a bullet is shot through the window, it would seem that it was shot at an angle, because the train would have moved between the time the bullet entered one window and exited the window on the other side. Likewise, because of the speed of the earth through space, the same must be true of light going through a telescope. What was amazing, said Bernstein, was that experiments showed the same effect no matter how fast the source of the light was moving. In a sentence that, because of its relation to what Einstein would later famously conclude, seems to have made an impression, Bernstein declared, "Since each kind of light proves to be of exactly the same speed, the law of the speed of light can well be called the most general of all of nature's laws."

In another volume, Bernstein took his young readers on an imaginary trip through space. The mode of transport was the wave of an electric signal. His books celebrated the joyful wonders of scientific investigation and included such exuberant passages as this one written about the successful prediction of the location of the new planet Uranus: "Praised be this science! Praised be the men who do it! And praised be the human mind, which sees more sharply than does the human eye."[36]

Bernstein was, as Einstein would later be, eager to tie together all of nature's forces. For example, after discussing how all electromagnetic phenomena, such as light, could be considered waves, he speculated that the same may be true for gravity. A unity and simplicity, Bernstein wrote, lay beneath all the concepts applied by our perceptions. Truth in science consisted in discovering theories that described this underlying reality. Einstein later recalled the revelation, and the realist attitude, that this instilled in him as a young boy: "Out yonder there was this huge world, which exists independently of us human beings and which stands before us like a

great, eternal riddle."[37]

Years later, when they met in New York during Einstein's first visit there, Talmud asked what he thought, in retrospect, of Bernstein's work. "A very good book," he said. "It has exerted a great influence on my whole development."[38]

Talmud also helped Einstein continue to explore the wonders of mathematics by giving him a textbook on geometry two years before he was scheduled to learn that subject in school. Later, Einstein would refer to it as "the sacred little geometry book" and speak of it with awe: "Here were assertions, as for example the intersection of the three altitudes of a triangle in one point, which—though by no means evident—could nevertheless be proved with such certainty that any doubt appeared to be out of the question. This lucidity and certainty made an indescribable impression upon me." Years later, in a lecture at Oxford, Einstein noted, "If Euclid failed to kindle your youthful enthusiasm, then you were not born to be a scientific thinker."[39]

When Talmud arrived each Thursday, Einstein delighted in showing him the problems he had solved that week. Initially, Talmud was able to help him, but he was soon surpassed by his pupil. "After a short time, a few months, he had worked through the whole book," Talmud recalled. "He thereupon devoted himself to higher mathematics… Soon the flight of his mathematical genius was so high that I could no longer follow."[40]

So the awed medical student moved on to introducing Einstein to philosophy. "I recommended Kant to him," he recalled. "At that time he was still a child, only thirteen years old, yet Kant's works, incomprehensible to ordinary mortals, seemed to be clear to him." Kant became, for a while, Einstein's favorite philosopher, and his *Critique of Pure Reason* eventually led him to delve also into David Hume, Ernst Mach, and the issue of what can be known about reality.

Einstein's exposure to science produced a sudden reaction against religion at age 12, just as he would have been readying for a bar mitzvah. Bernstein, in his popular science volumes, had reconciled science with religious inclination. As he put it, "The religious inclination lies in the dim consciousness that dwells in humans that all nature, including the humans in it, is in no way an accidental game, but a work of lawfulness, that there is a fundamental cause of all existence."

Einstein would later come close to these sentiments. But at the time, his leap away from faith was a radical one. "Through the reading of popular scientific books, I soon reached the conviction that much in the stories of the Bible could not be true. The consequence was a positively fanatic orgy of freethinking coupled with the

impression that youth is intentionally being deceived by the state through lies; it was a crushing impression."[41]

As a result, Einstein avoided religious rituals for the rest of his life. "There arose in Einstein an aversion to the orthodox practice of the Jewish or any traditional religion, as well as to attendance at religious services, and this he has never lost," his friend Philipp Frank later noted. He did, however, retain from his childhood religious phase a profound reverence for the harmony and beauty of what he called the mind of God as it was expressed in the creation of the universe and its laws.[42]

Einstein's rebellion against religious dogma had a profound effect on his general outlook toward received wisdom. It inculcated an allergic reaction against all forms of dogma and authority, which was to affect both his politics and his science. "Suspicion against every kind of authority grew out of this experience, an attitude which has never again left me," he later said. Indeed, it was this comfort with being a nonconformist that would define both his science and his social thinking for the rest of his life.

He would later be able to pull off this contrariness with a grace that was generally endearing, once he was accepted as a genius. But it did not play so well when he was merely a sassy student at a Munich gymnasium. "He was very uncomfortable in school," according to his sister. He found the style of teaching—rote drills, impatience with questioning—to be repugnant. "The military tone of the school, the systematic training in the worship of authority that was supposed to accustom pupils at an early age to military discipline, was particularly unpleasant."[43]

Even in Munich, where the Bavarian spirit engendered a less regimented approach to life, this Prussian glorification of the military had taken hold, and many of the children loved to play at being soldiers. When troops would come by, accompanied by fifes and drums, kids would pour into the streets to join the parade and march in lockstep. But not Einstein. Watching such a display once, he began to cry. "When I grow up, I don't want to be one of those poor people," he told his parents. As Einstein later explained, "When a person can take pleasure in marching in step to a piece of music it is enough to make me despise him. He has been given his big brain only by mistake."[44]

The opposition he felt to all types of regimentation made his education at the Munich gymnasium increasingly irksome and contentious. The mechanical learning there, he complained, "seemed very much akin to the methods of the Prussian army, where a mechanical discipline was achieved by repeated execution of meaningless orders." In later years, he would liken his teachers to members of the military. "The

teachers at the elementary school seemed to me like drill sergeants," he said, "and the teachers at the gymnasium like lieutenants."

He once asked C. P. Snow, the British writer and scientist, whether he was familiar with the German word *Zwang*. Snow allowed that he was; it meant constraint, compulsion, obligation, coercion. Why? In his Munich school, Einstein answered, he had made his first strike against *Zwang*, and it had helped define him ever since.[45]

Skepticism and a resistance to received wisdom became a hallmark of his life. As he proclaimed in a letter to a fatherly friend in 1901, "A foolish faith in authority is the worst enemy of truth."[46]

Throughout the six decades of his scientific career, whether leading the quantum revolution or later resisting it, this attitude helped shape Einstein's work. "His early suspicion of authority, which never wholly left him, was to prove of decisive importance," said Banesh Hoffmann, who was a collaborator of Einstein's in his later years. "Without it he would not have been able to develop the powerful independence of mind that gave him the courage to challenge established scientific beliefs and thereby revolutionize physics."[47]

This contempt for authority did not endear him to the German "lieutenants" who taught him at his school. As a result, one of his teachers proclaimed that his insolence made him unwelcome in class. When Einstein insisted that he had committed no offense, the teacher replied, "Yes, that is true, but you sit there in the back row and smile, and your mere presence here spoils the respect of the class for me."[48]

Einstein's discomfort spiraled toward depression, perhaps even close to a nervous breakdown, when his father's business suffered a sudden reversal of fortune. The collapse was a precipitous one. During most of Einstein's school years, the Einstein brothers' company had been a success. In 1885, it had two hundred employees and provided the first electrical lights for Munich's Oktoberfest. Over the next few years, it won the contract to wire the community of Schwabing, a Munich suburb of ten thousand people, using gas motors to drive twin dynamos that the Einsteins had designed. Jakob Einstein received six patents for improvements in arc lamps, automatic circuit breakers, and electric meters. The company was poised to rival Siemens and other power companies then flourishing. To raise capital, the brothers mortgaged their homes, borrowed more than 60,000 marks at 10 percent interest, and went deeply in debt.[49]

But in 1894, when Einstein was 15, the company went bust after it lost

competitions to light the central part of Munich and other locations. His parents and sister, along with Uncle Jakob, moved to northern Italy—first Milan and then the nearby town of Pavia—where the company's Italian partners thought there would be more fertile territory for a smaller firm. Their elegant home was torn down by a developer to build an apartment block. Einstein was left behind in Munich, at the house of a distant relative, to finish his final three years of school.

It is not quite clear whether Einstein, in that sad autumn of 1894, was actually forced to leave the Luitpold Gymnasium or was merely politely encouraged to leave. Years later, he recalled that the teacher who had declared that his "presence spoils the respect of the class for me" had gone on to "express the wish that I leave the school." An early book by a member of his family said that it was his own decision. "Albert increasingly resolved not to remain in Munich, and he worked out a plan."

That plan involved getting a letter from the family doctor, Max Talmud's older brother, who certified that he was suffering from nervous exhaustion. He used this to justify leaving the school at Christmas vacation in 1894 and not returning. Instead, he took a train across the Alps to Italy and informed his "alarmed" parents that he was never going back to Germany. Instead, he promised, he would study on his own and attempt to gain admission to a technical college in Zurich the following autumn.

There was perhaps one other factor in his decision to leave Germany. Had he remained there until he was 17, just over a year away, he would have been required to join the army, a prospect that his sister said "he contemplated with dread." So, in addition to announcing that he would not go back to Munich, he would soon ask for his father's help in renouncing his German citizenship. [50]

Aarau

Einstein spent the spring and summer of 1895 living with his parents in their Pavia apartment and helping at the family firm. In the process, he was able to get a good feel for the workings of magnets, coils, and generated electricity. Einstein's work impressed his family. On one occasion, Uncle Jakob was having problems with some calculations for a new machine, so Einstein went to work on it. "After my assistant engineer and I had been racking our brain for days, that young sprig had got the whole thing in just fifteen minutes," Jakob reported to a friend. "You will hear of him yet."[51]

With his love of the sublime solitude found in the mountains, Einstein hiked for days in the Alps and Apennines, including an excursion from Pavia to Genoa to see

his mother's brother Julius Koch. Wherever he traveled in northern Italy, he was delighted by the non Germanic grace and "delicacy" of the people. Their "naturalness" was a contrast to the "spiritually broken and mechanically obedient automatons" of Germany, his sister recalled.

Einstein had promised his family that he would study on his own to get into the local technical college, the Zurich Polytechnic.* So he bought all three volumes of Jules Violle's advanced physics text and copiously noted his ideas in the margins. His work habits showed his ability to concentrate, his sister recalled. "Even in a large, quite noisy group, he could withdraw to the sofa, take pen and paper in hand, set the inkstand precariously on the armrest, and lose himself so completely in a problem that the conversation of many voices stimulated rather than disturbed him."[52]

That summer, at age 16, he wrote his first essay on theoretical physics, which he titled "On the Investigation of the State of the Ether in a Magnetic Field." The topic was important, for the notion of the ether would play a critical role in Einstein's career. At the time, scientists conceived of light simply as a wave, and so they assumed that the universe must contain an all-pervasive yet unseen substance that was doing the rippling and thus propagating the waves, just as water was the medium rippling up and down and thus propagating the waves in an ocean. They dubbed this the ether, and Einstein (at least for the time being) went along with the assumption. As he put it in his essay, "An electric current sets the surrounding ether in a kind of momentary motion."

The fourteen-paragraph handwritten paper echoed Violle's textbook as well as some of the reports in the popular science magazines about Heinrich Hertz's recent discoveries about electromagnetic waves. In it, Einstein made suggestions for experiments that could explain "the magnetic field formed around an electric current." This would be interesting, he argued, "because the exploration of the elastic state of the ether in this case would permit us a look into the enigmatic nature of electric current."

The high school dropout freely admitted that he was merely making a few suggestions without knowing where they might lead. "As I was completely lacking in materials that would have enabled me to delve into the subject more deeply than by merely meditating about it, I beg you not to interpret this circumstance as a mark of superficiality," he wrote.[53]

He sent the paper to his uncle Caesar Koch, a merchant in Belgium, who was one of his favorite relatives and occasionally a financial patron. "It is rather naïve and imperfect, as might be expected from such a young fellow like myself," Einstein

confessed with a pretense of humility. He added that his goal was to enroll the following fall at the Zurich Polytechnic, but he was concerned that he was younger than the age requirement. "I should be at least two years older."[54]

To help him get around the age requirement, a family friend wrote to the director of the Polytechnic, asking for an exception. The tone of the letter can be gleaned from the director's response, which expressed skepticism about admitting this "so-called 'child prodigy.'" Nevertheless, Einstein was granted permission to take the entrance exam, and he boarded the train for Zurich in October 1895 "with a sense of well-founded diffidence."

Not surprisingly, he easily passed the section of the exam in math and science. But he failed to pass the general section, which included sections on literature, French, zoology, botany, and politics. The Polytechnic's head physics professor, Heinrich Weber, suggested that Einstein stay in Zurich and audit his classes. Instead, Einstein decided, on the advice of the college's director, to spend a year preparing at the cantonal school in the village of Aarau, twenty-five miles to the west.[55]

It was a perfect school for Einstein. The teaching was based on the philosophy of a Swiss educational reformer of the early nineteenth century, Johann Heinrich Pestalozzi, who believed in encouraging students to visualize images. He also thought it important to nurture the "inner dignity" and individuality of each child. Students should be allowed to reach their own conclusions, Pestalozzi preached, by using a series of steps that began with handson observations and then proceeded to intuitions, conceptual thinking, and visual imagery.[56] It was even possible to learn—and truly understand—the laws of math and physics that way. Rote drills, memorization, and force-fed facts were avoided.

Einstein loved Aarau. "Pupils were treated individually," his sister recalled, "more emphasis was placed on independent thought than on punditry, and young people saw the teacher not as a figure of authority, but, alongside the student, a man of distinct personality." It was the opposite of the German education that Einstein had hated. "When compared to six years' schooling at a German authoritarian gymnasium," Einstein later said, "it made me clearly realize how much superior an education based on free action and personal responsibility is to one relying on outward authority."[57]

The visual understanding of concepts, as stressed by Pestalozzi and his followers in Aarau, became a significant aspect of Einstein's genius. "Visual understanding is the essential and only true means of teaching how to judge things correctly,"

Pestalozzi wrote, and "the learning of numbers and language must be definitely subordinated."[58]

Not surprisingly, it was at this school that Einstein first engaged in the visualized thought experiment that would help make him the greatest scientific genius of his time: he tried to picture what it would be like to ride alongside a light beam. "In Aarau I made my first rather childish experiments in thinking that had a direct bearing on the Special Theory," he later told a friend. "If a person could run after a light wave with the same speed as light, you would have a wave arrangement which could be completely independent of time. Of course, such a thing is impossible."[59]

This type of visualized thought experiments—*Gedankenexperiment*—became a hallmark of Einstein's career. Over the years, he would picture in his mind such things as lightning strikes and moving trains, accelerating elevators and falling painters, two-dimensional blind beetles crawling on curved branches, as well as a variety of contraptions designed to pinpoint, at least in theory, the location and velocity of speeding electrons.

While a student in Aarau, Einstein boarded with a wonderful family, the Wintelers, whose members would long remain entwined in his life. There was Jost Winteler, who taught history and Greek at the school; his wife, Rosa, soon known to Einstein as Mamerl, or Mama; and their seven children. Their daughter Marie would become Einstein's first girlfriend. Another daughter, Anna, would marry Einstein's best friend, Michele Besso. And their son Paul would marry Einstein's beloved sister, Maja.

"Papa" Jost Winteler was a liberal who shared Einstein's allergy to German militarism and to nationalism in general. His edgy honesty and political idealism helped to shape Einstein's social philosophy. Like his mentor, Einstein would become a supporter of world federalism, internationalism, pacifism, and democratic socialism, with a strong devotion to individual liberty and freedom of expression.

More important, in the warm embrace of the Winteler family, Einstein became more secure and personable. Even though he still fancied himself a loner, the Wintelers helped him flower emotionally and open himself to intimacy. "He had a great sense of humor and at times could laugh heartily," recalled daughter Anna. In the evenings he would sometimes study, "but more often he would sit with the family around the table."[60]

Einstein had developed into a head-turning teenager who possessed, in the words of one woman who knew him, "masculine good looks of the type that played havoc at the turn of the century." He had wavy dark hair, expressive eyes, a high forehead,

and jaunty demeanor. "The lower half of his face might have belonged to a sensualist who found plenty of reasons to love life."

One of his schoolmates, Hans Byland, later wrote a striking description of "the impudent Swabian" who made such a lasting impression. "Sure of himself, his gray felt hat pushed back on his thick, black hair, he strode energetically up and down in the rapid, I might say crazy, tempo of a restless spirit which carries a whole world in itself. Nothing escaped the sharp gaze of the large bright brown eyes. Whoever approached him was captivated by his superior personality. A mocking curl of his fleshy mouth with its protruding lower lip did not encourage Philistines to fraternize with him."

Most notably, Byland added, young Einstein had a sassy, sometimes intimidating wit. "He confronted the world spirit as a laughing philosopher, and his witty sarcasm mercilessly castigated all vanity and artificiality."[61]

Einstein fell in love with Marie Winteler at the end of 1895, just a few months after he moved in with her parents. She had just completed teacher training college and was living at home while waiting to take a job in a nearby village. She was just turning 18, he was still 16. The romance thrilled both families. Albert and Marie sent New Year's greetings to his mother; she replied warmly, "Your little letter, dear Miss Marie, brought me immense joy."[62]

The following April, when he was back home in Pavia for spring break, Einstein wrote Marie his first known love letter:

> Beloved sweetheart!
>
> Many, many thanks sweetheart for your charming little letter, which made me endlessly happy. It was so wonderful to be able to press to one's heart such a bit of paper which two so dear little eyes have lovingly beheld and on which the dainty little hands have charmingly glided back and forth. I was now made to realize, my little angel, the meaning of homesickness and pining. But love brings much happiness—much more so than pining brings pain…
>
> My mother has also taken you to her heart, even though she does not know you; I only let her read two of your charming little letters. And she always laughs at me because I am no longer attracted to the girls who were supposed to have enchanted me so much in the past. You mean more to my soul than the whole world did before.

To which his mother penned a postscript: "Without having read this letter, I send you cordial greetings!"[63]

Although he enjoyed the school in Aarau, Einstein turned out to be an uneven student. His admission report noted that he needed to do remedial work in

chemistry and had "great gaps" in his knowledge of French. By midyear, he still was required to "continue with private lessons in French & chemistry," and "the protest in French remains in effect." His father was sanguine when Jost Winteler sent him the midyear report. "Not all its parts fulfill my wishes and expectations," he wrote, "but with Albert I got used to finding mediocre grades along with very good ones, and I am therefore not disconsolate about them."[64]

Music continued to be a passion. There were nine violinists in his class, and their teacher noted that they suffered from "some stiffness in bowing technique here and there." But Einstein was singled out for praise: "One student, by the name of Einstein, even sparkled by rendering an adagio from a Beethoven sonata with deep understanding." At a concert in the local church, Einstein was chosen to play first violin in a piece by Bach. His "enchanting tone and incomparable rhythm" awed the second violinist, who asked, "Do you count the beats?" Einstein replied, "Heavens no, it's in my blood."

His classmate Byland recalled Einstein playing a Mozart sonata with such passion—"What fire there was in his playing!"—that it seemed like hearing the composer for the first time. Listening to him, Byland realized that Einstein's wisecracking, sarcastic exterior was a shell around a softer inner soul. "He was one of those split personalities who know how to protect, with a prickly exterior, the delicate realm of their intense personal life."[65]

Einstein's contempt for Germany's authoritarian schools and militarist atmosphere made him want to renounce his citizenship in that country. This was reinforced by Jost Winteler, who disdained all forms of nationalism and instilled in Einstein the belief that people should consider themselves citizens of the world. So he asked his father to help him drop his German citizenship. The release came through in January 1896, and for the time being he was stateless.[66]

He also that year became a person without a religious affiliation. In the application to renounce his German citizenship, his father had written, presumably at Albert's request, "no religious denomination." It was a statement Albert would also make when applying for Zurich residency a few years later, and on various occasions over the ensuing two decades.

His rebellion from his childhood fling with ardent Judaism, coupled with his feelings of detachment from Munich's Jews, had alienated him from his heritage. "The religion of the fathers, as I encountered it in Munich during religious instruction and in the synagogue, repelled rather than attracted me," he later explained to a Jewish historian. "The Jewish bourgeois circles that I came to know in

my younger years, with their affluence and lack of a sense of community, offered me nothing that seemed to be of value."[67]

Later in life, beginning with his exposure to virulent antiSemitism in the 1920s, Einstein would begin to reconnect with his Jewish identity. "There is nothing in me that can be described as a 'Jewish faith,'" he said, "however I am happy to be a member of the Jewish people." Later he would make the same point in more colorful ways. "The Jew who abandons his faith," he once said, "is in a similar position to a snail that abandons his shell. He is still a snail."[68]

His renunciation of Judaism in 1896 should, therefore, be seen not as a clean break but as part of a lifelong evolution of his feelings about his cultural identity. "At that time I would not even have understood what leaving Judaism could possibly mean," he wrote a friend the year before he died. "But I was fully aware of my Jewish origin, even though the full significance of belonging to Jewry was not realized by me until later."[69]

Einstein ended his year at the Aarau school in a manner that would have seemed impressive for anyone except one of history's great geniuses, scoring the second highest grades in his class. (Alas, the name of the boy who bested Einstein is lost to history.) On a 1 to 6 scale, with 6 being the highest, he scored a 5 or 6 in all of his science and math courses as well as in history and Italian. His lowest grade was a 3, in French.

That qualified him to take a series of exams, written and oral, that would permit him, if he passed, to enter the Zurich Polytechnic. On his German exam, he did a perfunctory outline of a Goethe play and scored a 5. In math, he made a careless mistake, calling a number "imaginary" when he meant "irrational," but still got a top grade. In physics, he arrived late and left early, completing the two-hour test in an hour and fifteen minutes; he got the top grade. Altogether, he ended up with a 5.5, the best grade among the nine students taking the exams.

The one section on which he did poorly was French. But his three-paragraph essay was, to those of us today, the most interesting part of all of his exams. The topic was "Mes Projets d'avenir," my plans for the future. Although the French was not memorable, the personal insights were:

> If I am lucky and pass my exams, I will enroll in the Zurich Polytechnic. I will stay there four years to study mathematics and physics. I suppose I will become a teacher in these fields of science, opting for the theoretical part of these sciences.
>
> Here are the reasons that have led me to this plan. They are, most of all, my personal talent for abstract and mathematical thinking… My desires have also led me to the same

decision. That is quite natural; everybody desires to do that for which he has a talent. Besides, I am attracted by the independence offered by the profession of science.[70]

In the summer of 1896, the Einstein brothers' electrical business again failed, this time because they bungled getting the necessary water rights to build a hydroelectric system in Pavia. The partnership was dissolved in a friendly fashion, and Jakob joined a large firm as an engineer. But Hermann, whose optimism and pride tended to overwhelm any prudence, insisted on opening yet another new dynamo business, this time in Milan. Albert was so dubious of his father's prospects that he went to his relatives and suggested that they not finance him again, but they did.[71]

Hermann hoped that Albert would someday join him in the business, but engineering held little appeal for him. "I was originally supposed to become an engineer," he later wrote a friend, "but the thought of having to expend my creative energy on things that make practical everyday life even more refined, with a bleak capital gain as the goal, was unbearable to me. Thinking for its own sake, like music!"[72] And thus he headed off to the Zurich Polytechnic.

CHAPTER THREE

THE ZURICH POLYTECHNIC

1896–1900

The Impudent Scholar

The Zurich Polytechnic, with 841 students, was mainly a teachers' and technical college when 17-year-old Albert Einstein enrolled in October 1896. It was less prestigious than the neighboring University of Zurich and the universities in Geneva and Basel, all of which could grant doctoral degrees (a status that the Polytechnic, officially named the Eidgenössische Polytechnische Schule, would attain in 1911 when it became the Eidgenössische Technische Hochschule, or ETH). Nevertheless, the Polytechnic had a solid reputation in engineering and science. The head of the physics department, Heinrich Weber, had recently procured a grand new building, funded by the electronics magnate (and Einstein Brothers competitor) Werner von Siemens. It housed showcase labs famed for their precision measurements.

Einstein was one of eleven freshmen enrolled in the section that provided training "for specialized teachers in mathematics and physics." He lived in student lodgings on a monthly stipend of 100 Swiss francs from his Koch family relatives. Each month he put aside 20 of those francs toward the fee he would eventually have to pay to become a Swiss citizen.[1]

Theoretical physics was just coming into its own as an academic discipline in the 1890s, with professorships in the field sprouting up across Europe. Its pioneer practitioners—such as Max Planck in Berlin, Hendrik Lorentz in Holland, and Ludwig Boltzmann in Vienna— combined physics with math to suggest paths where experimentalists had yet to tread. Because of this, math was supposed to be a major part of Einstein's required studies at the Polytechnic.

Einstein, however, had a better intuition for physics than for math, and he did not yet appreciate how integrally the two subjects would be related in the pursuit of new theories. During his four years at the Polytechnic, he got marks of 5 or 6 (on a 6-point scale) in all of his theoretical physics courses, but got only 4s in most of his

math courses, especially those in geometry. "It was not clear to me as a student," he admitted, "that a more profound knowledge of the basic principles of physics was tied up with the most intricate mathematical methods."[2]

That realization would sink in a decade later, when he was wrestling with the geometry of his theory of gravity and found himself forced to rely on the help of a math professor who had once called him a lazy dog. "I have become imbued with great respect for mathematics," he wrote to a colleague in 1912, "the subtler part of which I had in my simple-mindedness regarded as pure luxury until now." Near the end of his life, he expressed a similar lament in a conversation with a younger friend. "At a very early age, I made an assumption that a successful physicist only needs to know elementary mathematics," he said. "At a later time, with great regret, I realized that the assumption of mine was completely wrong."[3]

His primary physics professor was Heinrich Weber, the one who a year earlier had been so impressed with Einstein that, even after he had failed his entrance exam to the Polytechnic, he urged him to stay in Zurich and audit his lectures. During Einstein's first two years at the Polytechnic, their mutual admiration endured. Weber's lectures were among the few that impressed him. "Weber lectured on heat with great mastery," he wrote during their second year. "One lecture after another of his pleases me." He worked in Weber's laboratory "with fervor and passion," took fifteen courses (five lab and ten classroom) with him, and scored well in them all.[4]

Einstein, however, gradually became disenchanted with Weber. He felt that the professor focused too much on the historical foundations of physics, and he did not deal much with contemporary frontiers. "Anything that came after Helmholtz was simply ignored," one contemporary of Einstein complained. "At the close of our studies, we knew all the past of physics but nothing of the present and future."

Notably absent from Weber's lectures was any exploration of the great breakthroughs of James Clerk Maxwell, who, beginning in 1855, developed profound theories and elegant mathematical equations that described how electromagnetic waves such as light propagated. "We waited in vain for a presentation of Maxwell's theory," wrote another fellow student. "Einstein above all was disappointed."[5]

Given his brash attitude, Einstein didn't hide his feelings. And given his dignified sense of himself, Weber bristled at Einstein's ill-concealed disdain. By the end of their four years together they were antagonists.

Weber's irritation was yet another example of how Einstein's scientific as well as personal life was affected by the traits deeply bred into his Swabian soul: his casual

willingness to question authority, his sassy attitude in the face of regimentation, and his lack of reverence for received wisdom. He tended to address Weber, for example, in a rather informal manner, calling him "Herr Weber" instead of "Herr Professor."

When his frustration finally overwhelmed his admiration, Professor Weber's pronouncement on Einstein echoed that of the irritated teacher at the Munich gymnasium a few years earlier. "You're a very clever boy, Einstein," Weber told him. "An extremely clever boy. But you have one great fault: you'll never let yourself be told anything."

There was some truth to that assessment. But Einstein was to show that, in the jangled world of physics at the turn of the century, this insouciant ability to tune out the conventional wisdom was not the worst fault to have.[6]

Einstein's impertinence also got him into trouble with the Polytechnic's other physics professor, Jean Pernet, who was in charge of experimental and lab exercises. In his course Physical Experiments for Beginners, Pernet gave Einstein a 1, the lowest possible grade, thus earning himself the historic distinction of having flunked Einstein in a physics course. Partly it was because Einstein seldom showed up for the course. At Pernet's written request, in March 1899 Einstein was given an official "director's reprimand due to lack of diligence in physics practicum."[7]

Why are you specializing in physics, Pernet asked Einstein one day, instead of a field like medicine or even law? "Because," Einstein replied, "I have even less talent for those subjects. Why shouldn't I at least try my luck with physics?"[8]

On those occasions when Einstein did deign to show up in Pernet's lab, his independent streak sometimes got him in trouble, such as the day he was given an instruction sheet for a particular experiment. "With his usual independence," his friend and early biographer Carl Seelig reports, "Einstein naturally flung the paper in the waste paper basket." He proceeded to pursue the experiment in his own way. "What do you make of Einstein?" Pernet asked an assistant. "He always does something different from what I have ordered."

"He does indeed, Herr Professor," the assistant replied, "but his solutions are right and the methods he uses are of great interest."[9]

Eventually, these methods caught up with him. In July 1899, he caused an explosion in Pernet's lab that "severely damaged" his right hand and required him to go to the clinic for stitches. The injury made it difficult for him to write for at least two weeks, and it forced him to give up playing the violin for even longer. "My fiddle had to be laid aside," he wrote to a woman he had performed with in Aarau. "I'm sure it wonders why it is never taken out of the black case. It probably thinks it

has gotten a stepfather."[10] He soon resumed playing the violin, but the accident seemed to make him even more wedded to the role of theorist rather than experimentalist.

Despite the fact that he focused more on physics than on math, the professor who would eventually have the most positive impact on him was the math professor Hermann Minkowski, a squarejawed, handsome Russian-born Jew in his early thirties. Einstein appreciated the way Minkowski tied math to physics, but he avoided the more challenging of his courses, which is why Minkowski labeled him a lazy dog: "He never bothered about mathematics at all."[11]

Einstein preferred to study, based on his own interests and passions, with one or two friends.[12] Even though he was still priding himself on being "a vagabond and a loner," he began to hang around the coffeehouses and attend musical soirees with a congenial crowd of bohemian soul mates and fellow students. Despite his reputation for detachment, he forged lasting intellectual friendships in Zurich that became important bonds in his life.

Among these was Marcel Grossmann, a middleclass Jewish math wizard whose father owned a factory near Zurich. Grossmann took copious notes that he shared with Einstein, who was less diligent about attending lectures. "His notes could have been printed and published," Einstein later marveled to Grossmann's wife. "When it came time to prepare for my exams, he would always lend me those notebooks, and they were my savior. What I would have done without these books I would rather not speculate on."

Together Einstein and Grossmann smoked pipes and drank iced coffee while discussing philosophy at the Café Metropole on the banks of the Limmat River. "This Einstein will one day be a great man," Grossmann predicted to his parents. He would later help make that prediction true by getting Einstein his first job, at the Swiss Patent Office, and then aiding him with the math he needed to turn the special theory of relativity into a general theory.[13]

Because many of the Polytechnic lectures seemed out of date, Einstein and his friends read the most recent theorists on their own. "I played hooky a lot and studied the masters of theoretical physics with a holy zeal at home," he recalled. Among those were Gustav Kirchhoff on radiation, Hermann von Helmholtz on thermodynamics, Heinrich Hertz on electromagnetism, and Boltzmann on statistical mechanics.

He was also influenced by reading a lesser-known theorist, August Föppl, who in 1894 had written a popular text titled *Introduction to Maxwell's Theory of Electricity.*

As science historian Gerald Holton has pointed out, Föppl's book is filled with concepts that would soon echo in Einstein's work. It has a section on "The Electrodynamics of Moving Conductors" that begins by calling into question the concept of "absolute motion." The only way to define motion, Föppl notes, is relative to another body. From there he goes on to consider a question concerning the induction of an electric current by a magnetic field: "if it is all the same whether a magnet moves in the vicinity of a resting electric circuit or whether it is the latter that moves while the magnet is at rest." Einstein would begin his 1905 special relativity paper by raising this same issue.[14]

Einstein also read, in his spare time, Henri Poincaré, the great French polymath who would come tantalizingly close to discovering the core concepts of special relativity. Near the end of Einstein's first year at the Polytechnic, in the spring of 1897, there was a mathematics conference in Zurich where the great Poincaré was due to speak. At the last minute he was unable to appear, but a paper of his was read there that contained what would become a famous proclamation. "Absolute space, absolute time, even Euclidean geometry, are not conditions to be imposed on mechanics," he wrote.[15]

The Human Side

One evening when Einstein was at home with his landlady, he heard someone playing a Mozart piano sonata. When he asked who it was, his landlady told him that it was an old woman who lived in the attic next door and taught piano. Grabbing his violin, he dashed out without putting on a collar or a tie. "You can't go like that, Herr Einstein," the landlady cried. But he ignored her and rushed into the neighboring house. The piano teacher looked up, shocked. "Go on playing," Einstein pleaded. A few moments later, the air was filled with the sounds of a violin accompanying the Mozart sonata. Later, the teacher asked who the intruding accompanist was. "Merely a harmless student," her neighbor reassured her.[16]

Music continued to beguile Einstein. It was not so much an escape as it was a connection: to the harmony underlying the universe, to the creative genius of the great composers, and to other people who felt comfortable bonding with more than just words. He was awed, both in music and in physics, by the beauty of harmonies.

Suzanne Markwalder was a young girl in Zurich whose mother hosted musical evenings featuring mostly Mozart. She played piano, while Einstein played violin. "He was very patient with my shortcomings," she recalled. "At the worst he used to say, 'There you are, stuck like the donkey on the mountain,' and he would point

with his bow to the place where I had to come in." What Einstein appreciated in Mozart and Bach was the clear architectural structure that made their music seem "deterministic" and, like his own favorite scientific theories, plucked from the universe rather than composed. "Beethoven created his music," Einstein once said, but "Mozart's music is so pure it seems to have been ever-present in the universe." He contrasted Beethoven with Bach: "I feel uncomfortable listening to Beethoven. I think he is too personal, almost naked. Give me Bach, rather, and then more Bach."

He also admired Schubert for his "superlative ability to express emotion." But in a questionnaire he once filled out, he was critical about other composers in ways that reflect some of his scientific sentiments: Handel had "a certain shallowness"; Mendelssohn displayed "considerable talent but an indefinable lack of depth that often leads to banality"; Wagner had a "lack of architectural structure I see as decadence"; and Strauss was "gifted but without inner truth."[17]

Einstein also took up sailing, a more solitary pursuit, in the glorious Alpine lakes around Zurich. "I still remember how when the breeze dropped and the sails drooped like withered leaves, he would take out his small notebook and he would start scribbling," recalled Suzanne Markwalder. "But as soon as there was a breath of wind he was immediately ready to start sailing again."[18]

The political sentiments he had felt as a boy—a contempt for arbitrary authority, an aversion to militarism and nationalism, a respect for individuality, a disdain for bourgeois consumption or ostentatious wealth, and a desire for social equality—had been encouraged by his landlord and surrogate father in Aarau, Jost Winteler. Now, in Zurich, he met a friend of Winteler's who became a similar political mentor: Gustav Maier, a Jewish banker who had helped arrange Einstein's first visit to the Polytechnic. With support from Winteler, Maier founded the Swiss branch of the Society for Ethical Culture, and Einstein was a frequent guest at their informal gatherings in Maier's home.

Einstein also came to know and like Friedrich Adler, the son of Austria's Social Democratic leader, who was studying in Zurich. Einstein later called him the "purest and most fervent idealist" he had ever met. Adler tried to get Einstein to join the Social Democrats. But it was not Einstein's style to spend time at meetings of organized institutions.[19]

His distracted demeanor, casual grooming, frayed clothing, and forgetfulness, which were later to make him appear to be the iconic absentminded professor, were already evident in his student days. He was known to leave behind clothes, and sometimes even his suitcase, when he traveled, and his inability to remember his

keys became a running joke with his landlady. He once visited the home of family friends and, he recalled, "I left forgetting my suitcase. My host said to my parents, 'That man will never amount to anything because he can't remember anything.'"[20]

This carefree life as a student was clouded by the continued financial failings of his father, who, against Einstein's advice, kept trying to set up his own businesses rather than go to work for a salary at a stable company, as Uncle Jakob had finally done. "If I had my way, papa would have looked for salaried employment two years ago," he wrote his sister during a particularly gloomy moment in 1898 when his father's business seemed doomed to fail again.

The letter was unusually despairing, probably more than his parents' financial situation actually warranted:

> What depresses me most is the misfortune of my poor parents who have not had a happy moment for so many years. What further hurts me deeply is that as an adult man, I have to look on without being able to do anything. I am nothing but a burden to my family… It would be better off if I were not alive at all. Only the thought that I have always done what lay in my modest powers, and that I do not permit myself a single pleasure or distraction save for what my studies offer me, sustains me and sometimes protects me from despair.[21]

Perhaps this was all merely an attack of teenage angst. In any event, his father seemed to get through the crisis with his usual optimism. By the following February, he had won contracts for providing street lights to two small villages near Milan. "I am happy at the thought that the worst worries are over for our parents," Einstein wrote Maja. "If everyone lived such a way, namely like me, the writing of novels would never have been invented."[22]

Einstein's new bohemian life and old self-absorbed nature made it unlikely that he would continue his relationship with Marie Winteler, the sweet and somewhat flighty daughter of the family he had boarded with in Aarau. At first, he still sent her, via the mail, baskets of his laundry, which she would wash and then return. Sometimes there was not even a note attached, but she would cheerfully try to please him. In one letter she wrote of "crossing the woods in the pouring rain" to the post office to send back his clean clothes. "In vain did I strain my eyes for a little note, but the mere sight of your dear handwriting in the address was enough to make me happy."

When Einstein sent word that he planned to visit her, Marie was giddy. "I really thank you, Albert, for wanting to come to Aarau, and I don't have to tell you that I

will be counting the minutes until that time," she wrote. "I could never describe, because there are no words for it, how blissful I feel ever since the dear soul of yours has come to live and weave in my soul. I love you for all eternity, sweetheart."

But he wanted to break off the relationship. In one of his first letters after arriving at the Zurich Polytechnic, he suggested that they refrain from writing each other. "My love, I do not quite understand a passage in your letter," she replied. "You write that you do not want to correspond with me any longer, but why not, sweetheart?… You must be quite annoyed with me if you can write so rudely." Then she tried to laugh off the problem: "But wait, you'll get some proper scolding when I get home."[23]

Einstein's next letter was even less friendly, and he complained about a teapot she had given him. "The matter of my sending you the stupid little teapot does not have to please you at all as long as you are going to brew some good tea in it," she replied. "Stop making that angry face which looked at me from all the sides and corners of the writing paper." There was a little boy in the school where she taught named Albert, she said, who looked like him. "I love him ever so much," she said. "Something comes over me when he looks at me and I always believe that you are looking at your little sweetheart."[24]

But then the letters from Einstein stopped, despite Marie's pleas. She even wrote his mother for advice. "The rascal has become frightfully lazy," Pauline Einstein replied. "I have been waiting in vain for news for these last three days; I will have to give him a thorough talking-to once he's here."[25]

Finally, Einstein declared the relationship over in a letter to Marie's mother, saying that he would not come to Aarau during his academic break that spring. "It would be more than unworthy of me to buy a few days of bliss at the cost of new pain, of which I have already caused too much to the dear child through my fault," he wrote.

He went on to give a remarkably introspective—and memorable— assessment of how he had begun to avoid the pain of emotional commitments and the distractions of what he called the "merely personal" by retreating into science:

> It fills me with a peculiar kind of satisfaction that now I myself have to taste some of the pain that I brought upon the dear girl through my thoughtlessness and ignorance of her delicate nature. Strenuous intellectual work and looking at God's nature are the reconciling, fortifying yet relentlessly strict angels that shall lead me through all of life's troubles. If only I were able to give some of this to the good child. And yet, what a peculiar way this is to weather the storms of life—in many a lucid moment I appear to

myself as an ostrich who buries his head in the desert sand so as not to perceive the danger.[26]

Einstein's coolness toward Marie Winteler can seem, from our vantage, cruel. Yet relationships, especially those of teenagers, are hard to judge from afar. They were very different from each other, particularly intellectually. Marie's letters, especially when she was feeling insecure, often descended into babble. "I'm writing a lot of rubbish, isn't that so, and in the end you'll not even read it to the finish (but I don't believe that)," she wrote in one. In another, she said, "I do not think about myself, sweetheart, that's quite true, but the only reason for this is that I do not think at all, except when it comes to some tremendously stupid calculation that requires, for a change, that I know more than my pupils."[27]

Whoever was to blame, if either, it was not surprising that they ended up on different paths. After her relationship with Einstein ended, Marie lapsed into a nervous depression, often missing days of teaching, and a few years later married the manager of a watch factory. Einstein, on the other hand, rebounded from the relationship by falling into the arms of someone who was just about as different from Marie as could be imagined.

Mileva Marić

Mileva Marić was the first and favorite child of an ambitious Serbian peasant who had joined the army, married into modest wealth, and then dedicated himself to making sure that his brilliant daughter was able to prevail in the male world of math and physics. She spent most of her childhood in Novi Sad, a Serbian city then held by Hungary,[28] and attended a variety of ever more demanding schools, at each of which she was at the top of her class, culminating when her father convinced the allmale Classical Gymnasium in Zagreb to let her enroll. After graduating there with the top grades in physics and math, she made her way to Zurich, where she became, just before she turned 21, the only woman in Einstein's section of the Polytechnic.

More than three years older than Einstein, afflicted with a congenital hip dislocation that caused her to limp, and prone to bouts of tuberculosis and despondency, Mileva Marić was known for neither her looks nor her personality. "Very smart and serious, small, delicate, brunette, ugly," is how one of her female friends in Zurich described her.

But she had qualities that Einstein, at least during his romantic scholar years, found attractive: a passion for math and science, a brooding depth, and a beguiling

soul. Her deep-set eyes had a haunting intensity, her face an enticing touch of melancholy.[29] She would become, over time, Einstein's muse, partner, lover, wife, bête noire, and antagonist, and she would create an emotional field more powerful than that of anyone else in his life. It would alternately attract and repulse him with a force so strong that a mere scientist like himself would never be able to fathom it.

They met when they both entered the Polytechnic in October 1896, but their relationship took a while to develop. There is no sign, from their letters or recollections, that they were anything more than classmates that first academic year. They did, however, decide to go hiking together in the summer of 1897. That fall, "frightened by the new feelings she was experiencing" because of Einstein, Marić decided to leave the Polytechnic temporarily and instead audit classes at Heidelberg University.[30]

Her first surviving letter to Einstein, written a few weeks after she moved to Heidelberg, shows glimmers of a romantic attraction but also highlights her self-confident nonchalance. She addresses Einstein with the formal *Sie* in German, rather than the more intimate *du.* Unlike Marie Winteler, she teasingly makes the point that she has not been obsessing about him, even though he had written an unusually long letter to her. "It's now been quite a while since I received your letter," she said, "and I would have replied immediately and thanked you for the sacrifice of writing four long pages, would have also told of the joy you provided me through our trip together, but you said I should write to you someday when I happened to be bored. And I am very obedient, and I waited and waited for boredom to set in; but so far my waiting has been in vain."

Distinguishing Marić even more from Marie Winteler was the intellectual intensity of her letters. In this first one, she enthused over the lectures she had been attending of Philipp Lenard, then an assistant professor at Heidelberg, on kinetic theory, which explains the properties of gases as being due to the actions of millions of individual molecules. "Oh, it was really neat at the lecture of Professor Lenard yesterday," she wrote. "He is talking now about the kinetic theory of heat and gases. So, it turns out that the molecules of oxygen move with a velocity of over 400 meters per second, then the good professor calculated and calculated… and it finally turned out even though molecules do move with this velocity, they travel a distance of only 1/100 of a hairbreadth."

Kinetic theory had not yet been fully accepted by the scientific establishment (nor, for that matter, had even the existence of atoms and molecules), and Marić's letter indicated that she did not have a deep understanding of the subject. In

addition, there was a sad irony: Lenard would be one of Einstein's early inspirations but later one of his most hateful antiSemitic tormentors.

Marić also commented on ideas Einstein had shared in his earlier letter about the difficulty mortals have in comprehending the infinite. "I do not believe that the structure of the human brain is to be blamed for the fact that man cannot grasp infinity," she wrote. "Man is very capable of imagining infinite happiness, and he should be able to grasp the infinity of space—I think that should be much easier." There is a slight echo of Einstein's escape from the "merely personal" into the safety of scientific thinking: finding it easier to imagine infinite space than infinite happiness.

Yet Marić was also, it is clear from her letter, thinking of Einstein in a more personal way. She had even talked to her adoring and protective father about him. "Papa gave me some tobacco to take with me and I was supposed to hand it to you personally," she said. "He wanted so much to whet your appetite for our little land of outlaws. I told him all about you—you must absolutely come back with me someday. The two of you would really have a lot to talk about!" The tobacco, unlike Marie Winteler's teapot, was a present Einstein would likely have wanted, but Marić teased that she wasn't sending it. "You would have to pay duty on it, and then you would curse me."[31]

That conflicting admixture of playfulness and seriousness, of insouciance and intensity, of intimacy and detachment—so peculiar yet also so evident in Einstein as well—must have appealed to him. He urged her to return to Zurich. By February 1898, she had made up her mind to do so, and he was thrilled. "I'm sure you won't regret your decision," he wrote. "You should come back as soon as possible."

He gave her a thumbnail of how each of the professors was performing (admitting that he found the one teaching geometry to be "a little impenetrable"), and he promised to help her catch up with the aid of the lecture notes he and Marcel Grossmann had kept. The one problem was that she would probably not be able to get her "old pleasant room" at the nearby pension back. "Serves you right, you little runaway!"[32]

By April she was back, in a boarding house a few blocks from his, and now they were a couple. They shared books, intellectual enthusiasms, intimacies, and access to each other's apartments. One day, when he again forgot his key and found himself locked out of his own place, he went to hers and borrowed her copy of a physics text. "Don't be angry with me," he said in the little note he left her. Later that year, a similar note left for her added, "If you don't mind, I'd like to come over this evening

to read with you."[33]

Friends were surprised that a sensuous and handsome man such as Einstein, who could have almost any woman fall for him, would find himself with a short and plain Serbian who had a limp and exuded an air of melancholy. "I would never be brave enough to marry a woman unless she were absolutely healthy," a fellow student said to him. Einstein replied, "But she has such a lovely voice."[34]

Einstein's mother, who had adored Marie Winteler, was similarly dubious about the dark intellectual who had replaced her. "Your photograph had quite an effect on my old lady," Einstein wrote from Milan, where he was visiting his parents during spring break of 1899. "While she studied it carefully, I said with the deepest sympathy: 'Yes, yes, she certainly is a clever one.' I've already had to endure much teasing about this."[35]

It is easy to see why Einstein felt such an affinity for Marić. They were kindred spirits who perceived themselves as aloof scholars and outsiders. Slightly rebellious toward bourgeois expectations, they were both intellectuals who sought as a lover someone who would also be a partner, colleague, and collaborator. "We understand each other's dark souls so well, and also drinking coffee and eating sausages, etcetera," Einstein wrote her.

He had a way of making the *etcetera* sound roguish. He closed another letter: "Best wishes etc., especially the latter." After being apart for a few weeks, he listed the things he liked to do with her: "Soon I'll be with my sweetheart again and can kiss her, hug her, make coffee with her, scold her, study with her, laugh with her, walk with her, chat with her, and ad infinitum!" They took pride in sharing a quirkiness. "I'm the same old rogue as I've always been," he wrote, "full of whims and mischief, and as moody as ever!"[36]

Above all, Einstein loved Marić for her mind. "How proud I will be to have a little Ph.D. for a sweetheart," he wrote to her at one point. Science and romance seemed to be interwoven. While on vacation with his family in 1899, Einstein lamented in a letter to Marić, "When I read Helmholtz for the first time I could not —and still cannot—believe that I was doing so without you sitting next to me. I enjoy working together and I find it soothing and also less boring."

Indeed, most of their letters mixed romantic effusions with scientific enthusiasms, often with an emphasis on the latter. In one letter, for example, he foreshadowed not only the title but also some of the concepts of his great paper on special relativity. "I am more and more convinced that the electrodynamics of moving bodies as it is presented today does not correspond to reality and that it will

evidence that Wien ever wrote back.[42]

Einstein's next research proposal involved exploring the link between the ability of different materials to conduct heat and to conduct electricity, something that was suggested by the electron theory. Weber apparently did not like that idea either, so Einstein was reduced, along with Marić, to doing a study purely on heat conduction, which was one of Weber's specialties.

Einstein later dismissed their graduation research papers as being of "no interest to me." Weber gave Einstein and Marić the two lowest essay grades in the class, a 4.5 and a 4.0, respectively; Grossmann, by comparison, got a 5.5. Adding annoyance to that injury, Weber said that Einstein had not written his on the proper regulation paper, and he forced him to copy the entire essay over again.[43]

Despite the low mark on his essay, Einstein was able to eke by with a 4.9 average in his final set of grades, placing him fourth in his class of five. Although history refutes the delicious myth that he flunked math in high school, at least it does offer as a consolation the amusement that he graduated college near the bottom of his class.

At least he graduated. His 4.9 average was just enough to let him get his diploma, which he did officially in July 1900. Mileva Marić, however, managed only a 4.0, by far the lowest in the class, and was not allowed to graduate. She determined that she would try again the following year.[44]

Not surprisingly, Einstein's years at the Polytechnic were marked by his pride at casting himself as a nonconformist. "His spirit of independence asserted itself one day in class when the professor mentioned a mild disciplinary measure just taken by the school's authorities," a classmate recalled. Einstein protested. The fundamental requirement of education, he felt, was the "need for intellectual freedom."[45]

Throughout his life, Einstein would speak lovingly of the Zurich Polytechnic, but he also would note that he did not like the discipline that was inherent in the system of examinations. "The hitch in this was, of course, that one had to cram all this stuff into one's mind for the examinations, whether one liked it or not," he said. "This coercion had such a deterring effect that, after I had passed the final examination, I found the consideration of any scientific problems distasteful to me for an entire year."[46]

In reality, that was neither possible nor true. He was cured within weeks, and he ended up taking with him some science books, including texts by Gustav Kirchhoff and Ludwig Boltzmann, when he joined his mother and sister later that July for their summer holiday in the Swiss Alps. "I've been studying a great deal," he wrote

Marić, “mainly Kirchhoff’s notorious investigations of the motion of the rigid body.” He admitted that his resentment over the exams had already worn off. “My nerves have calmed down enough so that I’m able to work happily again,” he said. “How are yours?”[47]

CHAPTER FOUR

THE LOVERS

1900–1904

With Mileva and Hans Albert Einstein, 1904

Summer Vacation, 1900

Newly graduated, carrying his Kirchhoff and other physics books, Einstein arrived at the end of July 1900 for his family's summer vacation in Melchtal, a village nestled in the Swiss Alps between Lake Lucerne and the border with northern Italy. In tow was his "dreadful aunt," Julia Koch. They were met at the train station by his mother and sister, who smothered him with kisses, and then all piled into a carriage for the ride up the mountain.

As they neared the hotel, Einstein and his sister got off to walk. Maja confided

that she had not dared to discuss with their mother his relationship with Mileva Marić, known in the family as "the Dollie affair" after his nickname for her, and she asked him to "go easy on Mama." It was not in Einstein's nature, however, "to keep my big mouth shut," as he later put it in his letter to Marić about the scene, nor was it in his nature to protect Marić's feelings by sparing her all the dramatic details about what ensued.[1]

He went to his mother's room and, after hearing about his exams, she asked him, "So, what will become of your Dollie now?"

"My wife," Einstein answered, trying to affect the same nonchalance that his mother had used in her question.

His mother, Einstein recalled, "threw herself on the bed, buried her head in the pillow, and wept like a child." She was finally able to regain her composure and proceeded to go on the attack. "You are ruining your future and destroying your opportunities," she said. "No decent family will have her. If she gets pregnant you'll really be in a mess."

At that point, it was Einstein's turn to lose his composure. "I vehemently denied we had been living in sin," he reported to Marić, "and scolded her roundly."

Just as he was about to storm out, a friend of his mother's came in, "a small, vivacious lady, an old hen of the most pleasant variety." They promptly segued into the requisite small talk: about the weather, the new guests at the spa, the illmannered children. Then they went off to eat and play music.

Such periods of storm and calm alternated throughout the vacation. Every now and then, just when Einstein thought that the crisis had receded, his mother would revisit the topic. "Like you, she's a book, but you ought to have a wife," she scolded at one point. Another time she brought up the fact that Marić was 24 and he was then only 21. "By the time you're 30, she'll be an old witch."

Einstein's father, still working back in Milan, weighed in with "a moralistic letter." The thrust of his parents' views—at least when applied to the situation of Mileva Marić rather than Marie Winteler— was that a wife was "a luxury" affordable only when a man was making a comfortable living. "I have a low opinion of that view of a relationship between a man and wife," he told Marić, "because it makes the wife and the prostitute distinguishable only insofar as the former is able to secure a lifelong contract."[2]

Over the ensuing months, there would be times when it seemed as if his parents had decided to accept their relationship. "Mama is slowly resigning herself," Einstein wrote Marić in August. Likewise in September: "They seem to have

reconciled themselves to the inevitable. I think they will both come to like you very much once they get to know you." And once again in October: "My parents have retreated, grudgingly and with hesitation, from the battle of Dollie—now that they have seen that they'll lose it."[3]

But repeatedly, after each period of acceptance, their resistance would flare up anew, randomly leaping into a higher state of frenzy. "Mama often cries bitterly and I don't have a single moment of peace," he wrote at the end of August. "My parents weep for me almost as if I had died. Again and again they complain that I have brought misfortune upon myself by my devotion to you. They think you are not healthy."[4]

His parents' dismay had little to do with the fact that Marić was not Jewish, for neither was Marie Winteler, nor that she was Serbian, although that certainly didn't help her cause. Primarily, it seems, they considered her an unsuitable wife for many of the reasons that some of Einstein's friends did: she was older, somewhat sickly, had a limp, was plain looking, and was an intense but not a star intellectual.

All of this emotional pressure stoked Einstein's rebellious instincts and his passion for his "wild street urchin," as he called her. "Only now do I see how madly in love with you I am!" The relationship, as expressed in their letters, remained equal parts intellectual and emotional, but the emotional part was now filled with a fire unexpected from a self-proclaimed loner. "I just realized that I haven't been able to kiss you for an entire month, and I long for you so terribly much," he wrote at one point.

During a quick trip to Zurich in August to check on his job prospects, he found himself walking around in a daze. "Without you, I lack self-confidence, pleasure in my work, pleasure in life—in short, without you my life is not life." He even tried his hand at a poem for her, which began: "Oh my! That Johnnie boy! / So crazy with desire / While thinking of his Dollie / His pillow catches fire."[5]

Their passion, however, was an elevated one, at least in their minds. With the lonely elitism of young German coffeehouse denizens who have read the philosophy of Schopenhauer once too often, they unabashedly articulated the mystical distinction between their own rarefied spirits and the baser instincts and urges of the masses. "In the case of my parents, as with most people, the senses exercise a direct control over the emotions," he wrote her amid the family wars of August. "With us, thanks to the fortunate circumstances in which we live, the enjoyment of life is vastly broadened."

To his credit, Einstein reminded Marić (and himself) that "we mustn't forget that

parents' antipathy toward her. "What utterly depressed me was the fact that our separation had to come about in such an unnatural way, on account of slanders and intrigues," she wrote her friend. With an absentmindedness he was later to make iconic, Einstein left behind in Zurich his nightshirt, toothbrush, comb, hairbrush (back then he used one), and other toiletries. "Send everything along to my sister," he instructed Marić, "so she can bring them home with her." Four days later, he added, "Hold on to my umbrella for the time being. We'll figure out something to do with it later."[21]

Both in Zurich and then in Milan, Einstein churned out jobseeking letters, ever more pleading, to professors around Europe. They were accompanied by his paper on the capillary effect, which proved not particularly impressive; he rarely even received the courtesy of a response. "I will soon have graced every physicist from the North Sea to the southern tip of Italy with my offer," he wrote Marić.[22]

By April 1901, Einstein was reduced to buying a pile of postcards with postagepaid reply attachments in the forlorn hope that he would, at least, get an answer. In the two cases where these postcard pleas have survived, they have become, rather amusingly, prized collectors' items. One of them, to a Dutch professor, is now on display in the Leiden Museum for the History of Science. In both cases, the return-reply attachment was not used; Einstein did not even get the courtesy of a rejection. "I leave no stone unturned and do not give up my sense of humor," he wrote his friend Marcel Grossmann. "God created the donkey and gave him a thick skin."[23]

Among the great scientists Einstein wrote was Wilhelm Ostwald, professor of chemistry in Leipzig, whose contributions to the theory of dilution were to earn him a Nobel Prize. "Your work on general chemistry inspired me to write the enclosed article," Einstein said. Then flattery turned to plaintiveness as he asked "whether you might have use for a mathematical physicist." Einstein concluded by pleading: "I am without money, and only a position of this kind would enable me to continue my studies." He got no answer. Einstein wrote again two weeks later using the pretext "I am not sure whether I included my address" in the earlier letter. "Your judgment of my paper matters very much to me." There was still no answer.[24]

Einstein's father, with whom he was living in Milan, quietly shared his son's anguish and tried, in a painfully sweet manner, to help. When no answer came after the second letter to Ostwald, Hermann Einstein took it upon himself, without his son's knowledge, to make an unusual and awkward effort, suffused with heart-wrenching emotion, to prevail upon Ostwald himself:

To what extent did anti-Semitism play a role? Einstein came to believe that it was a factor, which led him to seek work in Italy, where he felt it was not so pronounced. "One of the main obstacles in getting a position is absent here, namely anti-Semitism, which in German-speaking countries is as unpleasant as it is a hindrance," he wrote Marić. She, in turn, lamented to her friend about her lover's difficulties. "You know my sweetheart has a sharp tongue and moreover he is a Jew."[27]

In his effort to find work in Italy, Einstein enlisted one of the friends he had made while studying in Zurich, an engineer named Michele Angelo Besso. Like Einstein, Besso was from a middle-class Jewish family that had wandered around Europe and eventually settled in Italy. He was six years older than Einstein, and by the time they met he had already graduated from the Polytechnic and was working for an engineering firm. He and Einstein forged a close friendship that would last for the rest of their lives (they died within weeks of each other in 1955).

Over the years, Besso and Einstein would share both the most intimate personal confidences and the loftiest scientific notions. As Einstein wrote in one of the 229 extant letters they exchanged, "Nobody else is so close to me, nobody knows me so well, nobody is so kindly disposed to me as you are."[28]

Besso had a delightful intellect, but he lacked focus, drive, and diligence. Like Einstein, he had once been asked to leave high school because of his insubordinate attitude (he sent a petition complaining about a math teacher). Einstein called Besso "an awful weakling… who cannot rouse himself to any action in life or scientific creation, but who has an extraordinarily fine mind whose working, though disorderly, I watch with great delight."

Einstein had introduced Besso to Anna Winteler of Aarau, Marie's sister, whom he ended up marrying. By 1901 he had moved to Trieste with her. When Einstein caught up with him, he found Besso as smart, as funny, and as maddeningly unfocused as ever. He had recently been asked by his boss to inspect a power station, and he decided to leave the night before to make sure that he arrived on time. But he missed his train, then failed to get there the next day, and finally arrived on the third day—"but to his horror realizes that he has forgotten what he's supposed to do." So he sent a postcard back to the office asking them to resend his instructions. It was the boss's assessment that Besso was "completely useless and almost unbalanced."

Einstein's assessment of Besso was more loving. "Michele is an awful schlemiel," he reported to Marić, using the Yiddish word for a hapless bumbler. One evening,

Besso and Einstein spent almost four hours talking about science, including the properties of the mysterious ether and "the definition of absolute rest." These ideas would burst into bloom four years later, in the relativity theory that he would devise with Besso as his sounding board. "He's interested in our research," Einstein wrote Marić, "though he often misses the big picture by worrying about petty considerations."

Besso had some connections that could, Einstein hoped, be useful. His uncle was a mathematics professor at the polytechnic in Milan, and Einstein's plan was to have Besso provide an introduction: "I'll grab him by the collar and drag him to his uncle, where I'll do the talking myself." Besso was able to persuade his uncle to write letters on Einstein's behalf, but nothing came of the effort. Instead, Einstein spent most of 1901 juggling temporary teaching assignments and some tutoring.[29]

It was Einstein's other close friend from Zurich, his classmate and math notetaker Marcel Grossmann, who ended up finally getting Einstein a job, though not one that would have been expected. Just when Einstein was beginning to despair, Grossmann wrote that there was likely to be an opening for an examiner at the Swiss Patent Office, located in Bern. Grossmann's father knew the director and was willing to recommend Einstein.

"I was deeply moved by your devotion and compassion, which did not let you forget your luckless friend," Einstein replied. "I would be delighted to get such a nice job and that I would spare no effort to live up to your recommendation." To Marić he exulted: "Just think what a wonderful job this would be for me! I'll be mad with joy if something should come of that."

It would take months, he knew, before the patent-office job would materialize, assuming that it ever did. So he accepted a temporary post at a technical school in Winterhur for two months, filling in for a teacher on military leave. The hours would be long and, worse yet, he would have to teach descriptive geometry, neither then nor later his strongest field. "But the valiant Swabian is not afraid," he proclaimed, repeating one of his favorite poetic phrases.[30]

In the meantime, he and Marić would have the chance to take a romantic vacation together, one that would have fateful consequences.

Lake Como, May 1901

"You absolutely must come see me in Como, you little witch," Einstein wrote Marić at the end of April 1901. "You'll see for yourself how bright and cheerful I've become and how all my brow-knitting is gone."

The family disputes and frustrating job search had caused him to be snappish, but he promised that was now over. "It was only out of nervousness that I was mean to you," he apologized. To make it up to her, he proposed that they should have a romantic and sensuous tryst in one of the world's most romantic and sensuous places: Lake Como, the grandest of the jewel-like Alpine finger lakes high on the border of Italy and Switzerland, where in early May the lush foliage bursts forth under majestic snow-capped peaks.

"Bring my blue dressing-gown so we can wrap ourselves up in it," he said. "I promise you an outing the likes of which you've never seen."[31] Marić quickly accepted, but then changed her mind; she had received a letter from her family in Novi Sad "that robs me of all desire, not only for having fun, but for life itself." He should make the trip on his own, she sulked. "It seems I can have nothing without being punished." But the next day she changed her mind again. "I wrote you a little card yesterday while in the worst of moods because of a letter I received. But when I read your letter today I became a bit more cheerful, since I see how much you love me, so I think we'll take that trip after all."[32]

And thus it was that early on the morning of Sunday, May 5, 1901, Albert Einstein was waiting for Mileva Marić at the train station in the village of Como, Italy, "with open arms and a pounding heart." They spent the day there, admiring its gothic cathedral and walled old town, then took one of the stately white steamers that hop from village to village along the banks of the lake.

They stopped to visit Villa Carlotta, the most luscious of all the famous mansions that dot the shore, with its frescoed ceilings, a version of Antonio Canova's erotic sculpture *Cupid and Psyche,* and five hundred species of plants. Marić later wrote a friend how much she admired "the splendid garden, which I preserved in my heart, the more so because we were not allowed to swipe a single flower."

After spending the night in an inn, they decided to hike through the mountain pass to Switzerland, but found it still covered with up to twenty feet of snow. So they hired a small sleigh, "the kind they use that has just enough room for two people in love with each other, and a coachman stands on a little plank in the rear and prattles all the time and calls you 'signora,'" Marić wrote. "Could you think of anything more beautiful?"

The snow was falling merrily, as far as the eye could see, "so that this cold, white infinity gave me the shivers and I held my sweetheart firmly in my arms under the coats and shawls covering us." On the way down, they stomped and kicked at the snow to produce little avalanches, "so as to properly scare the world below."[33]

he had used to explain the capillary effect in liquids and applied them to the diffusion of gas molecules. "I've got an extremely lucky idea, which will make it possible to apply our theory of molecular forces to gases as well," he wrote Marić. To Grossmann he noted, "I am now convinced that my theory of atomic attractive forces can also be extended to gases."[42]

Next he became interested in the conduction of heat and electricity, which led him to study Paul Drude's electron theory of metals. As the Einstein scholar Jürgen Renn notes, "Drude's electron theory and Boltzmann's kinetic theory of gas do not just happen to be two arbitrary subjects of interest to Einstein, but rather they share an important common property with several other of his early research topics: they are two examples of the application of atomistic ideas to physical and chemical problems."[43]

Drude's electron theory posited that there are particles in metal that move freely, as molecules of gas do, and thereby conduct both heat and electricity. When Einstein looked into it, he was pleased with it in parts. "I have a study in my hands by Paul Drude on the electron theory, which is written to my heart's desire, even though it contains some very sloppy things," he told Marić. A month later, with his usual lack of deference to authority, he declared, "Perhaps I'll write to Drude privately to point out his mistakes."

And so he did. In a letter to Drude in June, Einstein pointed out what he thought were two mistakes. "He will hardly have anything sensible to refute me with," Einstein gloated to Marić, "because my objections are very straightforward." Perhaps under the charming illusion that showing an eminent scientist his purported lapses is a good method for getting a job, Einstein included a request for one in his letter.[44]

Surprisingly, Drude replied. Not surprisingly, he dismissed Einstein's objections. Einstein was outraged. "It is such manifest proof of the wretchedness of its author that no further comment by me is necessary," Einstein said when forwarding Drude's reply to Marić. "From now on I'll no longer turn to such people, and will instead attack them mercilessly in the journals, as they deserve. It is no wonder that little by little one becomes a misanthrope."

Einstein also vented his frustration to Jost Winteler, his father figure from Aarau, in a letter that included his declaration about a blind respect for authority being the greatest enemy of truth. "He responds by pointing out that another 'infallible' colleague of his shares his opinion. I'll soon make it hot for the man with a masterly publication."[45]

night.[56]

Einstein's impatience with authority soon pitted him against the proprietor of the academy. He tried to cajole his tutee to move to Bern with him and pay him directly, but the boy's mother balked. Then Einstein asked Nüesch to give him his meal money in cash so that he would not have to eat with his family. "You know what our conditions are," Nüesch replied. "There is no reason to deviate from them."

A surly Einstein threatened to find new arrangements, and Nüesch backed down in a rage. In a line that could be considered yet another maxim for his life, Einstein recounted the scene to Marić and exulted, "Long live impudence! It is my guardian angel in this world."

That night, as he sat down for his last meal at the Nüesch household, he found a letter for him next to his soup plate. It was from his real-life guardian angel, Marcel Grossmann. The position at the patent office, Grossmann wrote, was about to be advertised, and Einstein was sure to get it. Their lives were soon to be "brilliantly changed for the better," an excited Einstein wrote Marić. "I'm dizzy with joy when I think about it," he said. "I'm even happier for you than for myself. Together we'd surely be the happiest people on the earth."

That still left the issue of what to do about their baby, who was due to be born in less than two months, by early February 1902. "The only problem that would remain to be solved would be how to keep our Lieserl with us," Einstein (who had begun referring to their unborn child as a girl) wrote to Marić, who had returned home to have the baby at her parents' house in Novi Sad. "I wouldn't want to have to give her up." It was a noble intention on his part, yet he knew that it would be difficult for him to show up for work in Bern with an illegitimate child. "Ask your Papa; he's an experienced man, and knows the world better than your overworked, impractical Johnnie." For good measure, he declared that the baby, when born, "shouldn't be stuffed with cow milk, because it might make her stupid." Marić's milk would be more nourishing, he said.[57]

Although he was willing to consult Marić's family, Einstein had no intention of letting his own family know that his mother's worst fears about his relationship—a pregnancy and possible marriage—were materializing. His sister seemed to realize that he and Marić were secretly planning to be married, and she told this to members of the Winteler family in Aarau. But none of them showed any sign of suspecting that a child was involved. Einstein's mother learned about the purported engagement from Mrs. Winteler. "We are resolutely against Albert's relationship

"Is she healthy, and does she cry properly?" Einstein wrote Marić. "What are her eyes like? Which one of us does she more resemble? Who is giving her milk? Is she hungry? She must be completely bald. I love her so much and don't even know her yet!" Yet his love for their new baby seemed to exist mainly in the abstract, for it was not quite enough to induce him to make the train trip to Novi Sad.[62]

Einstein did not tell his mother, sister, or any of his friends about the birth of Lieserl. In fact, there is no indication that he *ever* told them about her. Never once did he publicly speak of her or acknowledge that she even existed. No mention of her survives in any correspondence, except for a few letters between Einstein and Marić, and these were suppressed and hidden until 1986, when scholars and the editors of his papers were completely surprised to learn of Lieserl's existence.*

But in his letter to Marić right after Lieserl's birth, the baby brought out Einstein's wry side. "She's certainly able to cry already, but won't know how to laugh until much later," he said. "Therein lies a profound truth."

Fatherhood also focused him on the need to make some money while he waited to get the patent-office job. So the next day an ad appeared in the newspaper: "Private lessons in Mathematics and Physics… given most thoroughly by Albert Einstein, holder of the federal Polytechnic teacher's diploma… Trial lessons free."


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Lieserl's birth even caused Einstein to display a domestic, nesting instinct not previously apparent. He found a large room in Bern and drew for Marić a sketch of it, complete with diagrams showing the bed, six chairs, three cabinets, himself ("Johnnie"), and a couch marked "look at that!"[63] However, Marić was not going to be moving into it with him. They were not married, and an aspiring Swiss civil servant could not be seen cohabitating in such a way. Instead, after a few months,

Day to Day," *New York Evening Post*, Mar. 26, 1921.

67. Frank 1947, 219; Marianoff, 1; Fölsing, 428; Reiser, 193.

CHAPTER ELEVEN: EINSTEIN'S UNIVERSE

1. Overbye, 314; Einstein to Karl Schwarzschild, Jan. 9, 1916.
2. Einstein, "On a Stationary System with Spherical Symmetry Consisting of Many Gravitating Masses," *Annals of Mathematics*, 1939.
3. For a description of the history, math, and science of black holes, see Miller 2005; Thorne, 121–139.
4. Freeman Dyson in Robinson, 8–9.
5. Einstein to Karl Schwarzschild, Jan. 9, 1916.
6. CPAE vol. 8 brings together all of the correspondence between Einstein and de Sitter, with a good commentary on the dispute. Michel Janssen (uncredited author), "The Einstein–De Sitter–Weyl–Klein debate," CPAE 8a (German edition), p. 351.
7. Einstein to Willem de Sitter, Feb. 2, 1917.
8. Einstein to Paul Ehrenfest, Feb. 4, 1917.
9. Einstein, "Cosmological Considerations in the General Theory of Relativity," Feb. 8, 1917, CPAE 6: 43.
10. Einstein 1916, chapter 31.
11. Clark, 271.
12. For a delightful fictional tale along these lines (so to speak), see Edwin Abbott's *Flatland*, first published in 1880 and available in many paperback editions.
13. Edward W. Kold, "The Greatest Discovery Einstein Didn't Make," in Brockman, 205.
14. Lawrence Krauss and Michael Turner, "A Cosmic Conundrum," *Scientific American* (Sept. 2004): 71; Aczel 1999, 155; Overbye, 321. Einstein's famous blunder quote is from Gamow, 1970, 44.
15. Overbye, 327.
16. Einstein 1916, chapter 22.
17. There is a wonderful reprint now available in paperback of Eddington's classic book first published in 1920: Arthur Eddington, *Space, Time and Gravitation: An Outline of the General Relativity Theory* (Cambridge, En gland: Cambridge Science Classics, 1995). Page 141 describes the Principe expedition. See also an award-winning article: Matthew Stanley, "An Expedition to Heal the Wounds of War: 1919 Eclipse and Eddington as Quaker Adventurer," *Isis* 94 (2003):

28. Einstein, "My First Impressions of the U.S.A.," *Nieuwe Rotterdamsche Courant*, July 4, 1921, CPAE 7, appendix D; Einstein 1954, 3–7.
29. Einstein, "Einstein on His Theory," *The Times* of London, Nov. 28, 1919.
30. Einstein to Hedwig and Max Born, Jan. 27, 1920; Einstein to Arthur Eddington, Feb. 2, 1920. Einstein graciously told an embarrassed Eddington, "The tragicomical outcome of the medal affair [is] insignificant compared to the self-sacrificing and fruitful labors you and your friends devoted to the theory of relativity and its verification."
31. Frida Bucky, quoted in Brian 1996, 230.
32. Einstein, "The World as I See It" (1930), in Einstein 1954, 8. A different translation is in Einstein 1949a, 3.
33. This appraisal appears with slight variations in Infeld, 118; Infeld, "To Albert Einstein on His 75th Birthday," in Goldsmith et al., 25; and in the *Bulletin of the World Federation of Scientific Workers*, July 1954.
34. Editorial note by Max Born in Born 2005, 127.
35. Abraham Pais, "Einstein and the Quantum Theory," *Reviews of Modern Physics* (Oct. 1979). See also Pais, "Einstein, Newton and Success," in French, 35; Pais 1982, 39.
36. Einstein, "Why Socialism?," *Monthly Review*, May 1949, reprinted in Einstein 1954, 151.
37. Erik Erikson, "Psychoanalytic Reflections on Einstein's Centenary," in Holton and Elkana, 151.
38. This idea is from Barbara Wolff of the Einstein archives at Hebrew University.
39. Levenson, 149.
40. Einstein to Paul Ehrenfest, Jan. 17, 1922; Fölsing, 482.
41. Einstein to Eduard Einstein, June 25, 1923, Einstein family correspondence trust, unpublished, letter in possession of Bob Cohn, who provided me a copy. Cohn is a collector of Einstein material. The letters in his possession have been translated by Dr. Janifer Stackhouse. I am grateful for their help.
42. Michelmore, 79.
43. Einstein to Mileva Marić, May 12, 1924, AEA 75-629.
44. Einstein to Michele Besso, Jan. 5, 1924, AEA 7-346; Einstein to Hans Albert Einstein, Mar. 7, 1924.
45. Einstein to Heinrich Zangger, Mar. 1920; Fölsing, 474; Highfield and Carter, 192; Clark, 243.
46. Paul Johnson, *Modern Times* (New York: HarperCollins, 1991), 1–3. This

7. Einstein, "Anti-Semitism: Defense through Knowledge," after Apr. 3, 1920, CPAE 7: 35; Hubert Goenner, "The Anti-Einstein Campaign in Germany in 1920," in Beller et al., 107.
8. Elon, 277.
9. Hubert Goenner, "The Anti-Einstein Campaign in Germany in 1920," in Beller et al., 121.
10. *New York Times*, Aug. 29, 1920.
11. Frank 1947, 161; Clark, 318; Fölsing, 462; Brian 1996, 111.