Einstein's Quest for Truth

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Muhammad Ali was the most famous man in the world during the second half of the twentieth century; Albert Einstein was the world's most famous man of the first half of the century. Theorists of social degeneration may appear to have rich matter for speculation there, but in fact the hero worship of the physicist was not much different from that of the pugilist: it was typical yahoo adulation on both counts. As Charlie Chaplin, who became an Einstein pal and sidekick—the laws of celebrity cohesion are even queerer than those of molecular bonding—noted when Einstein asked him why the public made such a commotion over them, "People cheer me because they all understand me, and they cheer you because nobody understands you." The great passing show absorbed scientific genius of the highest order just as it does the ball-playing boys of summer and the ephemeral lovelies of bimbodom, and the onlookers had no idea what they were looking at; they just knew it was strange and wondrous.

Modern physics is indeed strange and wondrous and fiendishly difficult to describe and understand. The tensor mathematics that undergirds the general theory of relativity is so esoteric that Einstein himself had to seek the aid of an adept to conceive the geometry of spacetime and to work out the relevant equations. When a colleague remarked to Arthur Eddington, whose astronomical observations helped to certify general relativity, that there were reportedly only three men who understood Einstein's theory, Eddington answered, "Who's the other one?"

So one is more than grateful when several writers of exceptional talent and mental wattage undertake to explain Einstein's achievements in terms the layman can hope more or less to follow. Two new full-dress biographies that incorporate the latest scholarly information, Jürgen Neffe's *Einstein* and Walter Isaacson's *Einstein: His Life and Universe*, combine riveting accounts of Einstein's life with generally intelligible recapitulations of his theoretical labors.

Neffe is a German Ph.D. in biochemistry and the winner of Germany's most prestigious journalism award, while Isaacson is a former managing editor of *Time* and the biographer of Henry Kissinger and Benjamin Franklin; in their admirable lucidity about scientific matters and their eye for the telling anecdote or quotation, both writers are eminently suited to take on Einstein for the general reader.

Several other recent books on Einstein are more specialized and run to a higher degree of difficulty. *Einstein's Clocks, Poincaré's Maps: Empires of Time*, by Peter Galison, a Harvard physicist and historian of science, examines the technological advances in the coordination of synchronized clocks that set the stage for Einstein's redefinition of simultaneity in the special theory of relativity, and contrasts the career of the French mathematician, physicist,

Einstein: A Biography
by Jürgen Neffe (trans. Shelley Frisch)
FSG ~ 2007 ~ 461 pp.
$30 (cloth)

Einstein: His Life and Universe
by Walter Isaacson
Simon & Schuster ~ 2007 ~ 675 pp.
$32 (cloth)

Einstein's Clocks, Poincaré's Maps: Empires of Time
by Peter Galison
Norton ~ 2003 ~ 389 pp.
$14.95 (paper)

Einstein's Jury: The Race to Test Relativity
by Jeffrey Crelinsten
Princeton ~ 2006 ~ 397 pp.
$35 (cloth)

Uncertainty: Einstein, Heisenberg, Bohr, and the Struggle for the Soul of Science
by David Lindley
Doubleday ~ 2007 ~ 257 pp.
$26 (cloth)

Einstein and Oppenheimer: The Meaning of Genius
by Silvan S. Schweber
Harvard ~ 2008 ~ 432 pp.
$29.95 (cloth)

Einstein on Politics
(ed. David E. Rowe and Robert Schulmann)
Princeton ~ 2007 ~ 523 pp.
$29.95 (cloth)

philosopher, and technocrat Henri Poincaré, who embodied a hard-headed instrumental view of science, with that of Einstein, who pursued a quasi-theological quest for the fundamental order of the universe. *Uncertainty: Einstein, Heisenberg, Bohr and the Struggle for the Soul of Science*, by David Lindley, a Ph.D. in theoretical astrophysics, a sometime editor at *Nature*, and a science writer, details Einstein's theoretical dispute on basic principles with the champions of quantum mechanics; with a firmness that came to be widely considered mulish perversity, Einstein held to the end of his life that the bizarre theory of subatomic behavior reflects, not the true nature of matter, but experimental imprecision and thus inadequate knowledge. *Einstein's Jury: The Race to Test Relativity*, by Jeffrey Crelinsten, a science writer and head of a research firm specializing in science and technology, recounts the astronomical project to prove, or to disprove, general relativity; it is a fascinating study of profound difficulties overcome in the search for truth, not least of them the irrational rivalrousness that gets in the way of disinterested scientific purity—though as a worked-over Ph.D. dissertation the book does sometimes engage in stargazing detail that makes the ordinary reader's eyes roll back in their sockets. *Einstein and Oppenheimer: The Meaning of Genius*, by Silvan S. Schweber, an intellectual historian emeritus from Brandeis, relates its subjects' characters to the nature of the work they did—Einstein as a lone wolf who believed in the world-changing achievements of singular men such as Newton and himself, Oppenheimer as a full partner in the collaborative enterprise of post-quantum physics, which no one intelligence could hope to master on its own. And then there is *Einstein on Politics*, edited by David E. Rowe and Robert Schulmann, a 500-page compilation that shows what Einstein was thinking about when he wasn't thinking about time and space and matter. The volume's sheer heft suggests the energy Einstein devoted to his early militant pacifism, his revulsion against Nazism, his encouragement of a Zionism founded on the noblest moral principles, his advising President Roosevelt to start up an atomic bomb project, and his advocating a world government after Hiroshima and Nagasaki to make sure nuclear weapons were never used again.

In sum, this daunting but intoxicating pile of books presents the twentieth century's iconic genius as man and mind, and helps one begin to understand both. It offers a salutary introduction to the best known and least understood thinker of our time, or of the time recently past, which some—with apologies to Machiavelli, Bacon, and Descartes—may call the birth of modernity.

When Albert Einstein first showed his face to the world in 1879, his poor mother thought she had given birth to a freak: the newborn horrified her with his enormous misshapen cranium, built to house a formidable instrument. The instrument, however, did not seem so formidable in the early going: his parents actually consulted a doctor because the child was so slow learning to speak. Once he did learn, he had his own way of describing things; when his sister was born, he asked where her wheels were. Having eventually caught on to her humanity, he terrorized her, heaving a bowling ball at her head, and braining her with a hoe. Fortunately for all, the tantrums ceased, and the intellect began cranking. When Albert was four or five and sick in bed, his father brought him a compass. The boy felt tremors and chills at the marvelous apparatus that bespoke unseen powers in nature; it was an intimation of the world behind the world that he would devote his life to uncovering and explicating.

The Einstein mythology of course has it that the young Albert was a dunce in school, who even flunked math; in fact he was a whiz who was hungry for all the knowledge his mind could hold. There were, of course, things he would rather not have had to learn—such as what his Catholic schoolmates in Munich thought of Jews. One day his religion teacher brought a large nail to class, and informed the students that this was what the Jews had used to secure Jesus to the cross. Einstein was the only Jew in his class, and became thereupon the object of regular taunts and beatings. At nine he transferred to another school, which offered Jewish religious instruction, and for a few years he became a zealot, faithfully keeping the Sabbath, observing every dietary law, composing his own sacred songs. Science and mathematics provided another source of spiritual strength. His uncle Jakob Einstein, an engineer and Einstein's father's partner in an electric lighting company, presented the boy with Pythagoras' theorem to prove and introduced him to the "merry science" of algebra. A medical student who was a family friend brought the youth the twenty-one volumes of Aaron Bernstein's *People's Books on Natural Science;* Einstein loved the books, but their insistence on science as the sole human avenue to the truth about the universe soured him for good on orthodox religion.

Despite all his brilliance and curiosity, or perhaps because of them, Einstein grew increasingly bored with school. Teutonic regimentation was not for him, in more ways than one. When he was sixteen, he left Munich to join his parents in Italy, where they had gone after the family business had failed; determined never to return to Germany, he planned to study for admission to the Zurich Polytechnic—and, not incidentally, to avoid being drafted into the German army at seventeen. In the summer of 1895, he completed his first paper in theoretical physics, on the effects of a magnetic field on the ether, the ubiquitous but invisible medium in which light waves were believed to propagate. That year, too, he fell in love for the first time, with Marie Winteler, the daughter of the family he was boarding with in Aarau, Switzerland, while he went to prep school for a year. Marie's brother would end up marrying Einstein's sister, and Marie's sister would marry Einstein's best friend, Michele Besso. Marie herself would prove insufficiently extraordinary for Einstein, however, and he would look elsewhere for a wife.

At the Zurich Polytechnic, Einstein comported himself with his customary indifference to academic discipline. His primary physics professor, who disappointed the eager student by utterly ignoring James Clerk Maxwell's breakthroughs in electromagnetism, berated Einstein as the kind of person who can't be told anything. His mathematics professor called him a lazy dog. "I played hooky a lot and studied the masters of theoretical physics with a holy zeal at home," Einstein would say later in his defense. In his spare hours, he cultivated Bohemian friendships with like-minded truth-seekers, played Bach and Mozart on his beloved violin, and fell in love again, this time with a fellow physics student, Mileva Maric, a brooding Serbian three years older than he, with a congenitally dislocated hip that gave her a limp and a mug so unappetizing only genuine romance could see past it. Einstein's letters to her express his love for her through his love of physics: her shining mind captivates him, for they have scientific passion in common.

Tough times would ensue for the couple. Mileva failed to take her degree, and he was the only physics student in his 1900 graduating class not to get an academic job. University authorities would be unconscionably slow to recognize what they had in him: not until 1909, four years after he transformed physics, would he be tendered a junior professorship. In 1901, the doctoral dissertation he presented in the kinetic theory of gases was rejected as disrespectful to an esteemed predecessor whose work he controverted. Einstein was reduced to taking an underpaid tutoring job. The next year, Mileva gave birth in Serbia to a girl, named Lieserl, whose very existence remained a secret until 1986, when several letters in which the parents mention her were found; Einstein evidently never saw his child, who may have died or been given up for adoption. By this time he was angling for a job at the patent office in Bern, and to aspire to a position in the Swiss civil service required unimpeachable moral credentials; an acknowledged bastard infant would have been a wrench in the works.

As it happened, he got the job, and married Mileva once he had the income to support her. According to both Neffe and Isaacson, this supposedly menial position that a world uncomprehending of Einstein's genius forced him to settle for actually worked to his advantage. Ascending the career ladder at a university might well have stifled creativity rather than encouraged it; senior professors don't appreciate it when their junior colleagues overturn the accepted order of the universe. Work as a "patent boy" enhanced the critical faculties that enabled him to detect the flaws in a complex theoretical system, and developed sufficient confidence in his own judgment to withstand the pressure to conform to the prevailing wisdom.

The prevailing wisdom didn't stand a chance when Einstein turned the full powers of his mind upon it. In 1905 Einstein detonated, in Isaacson's description, "an *annus mirabilis* the like of which science had not seen since 1666, when Isaac Newton, holed up at his mother's home in rural Woolsthorpe to escape the plague that was devastating Cambridge, developed calculus, an analysis of the light spectrum, and the laws of gravity." Isaacson goes on to quote at length from a letter Einstein wrote to his friend Conrad Habicht in May 1905, describing what he had been thinking about the past three months:

> So what are you up to, you frozen whale, you smoked, dried, canned piece of soul…? Why have you still not sent me your dissertation? Don't you know that I am one of the 1 ½ fellows who would read it with interest and pleasure, you wretched man? I promise you four papers in return. The first deals with radiation and the energy properties of light and is very revolutionary, as you will see if you send me your work first. The second paper is a determination of the true sizes of atoms.… The third proves that bodies on the order of magnitude 1/1000 mm, suspended in liquids, must already perform an observable random motion that is produced by thermal motion. Such movement of suspended bodies has actually been observed by physiologists who call it Brownian molecular motion. 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.

His first, "very revolutionary" discovery took up where physicist Max Planck's research into blackbody radiation left off, held that light consists not only of waves but also of discrete particles (called quanta or photons), and laid the groundwork for the law of the photoelectric effect, in which light energy acts on metal to produce a stream of electrons, and for which he would be awarded the Nobel Prize in 1921. Neffe writes that Einstein's discovery of the quantum "has given rise to the high-tech world of microelectronics, cellular phones, digital photography, computers, chips, the Internet, superconductivity, nanotechnology, and modern chemistry." This discovery, which prepared the way for quantum physics, would distress Einstein himself to the end of his days. In old age he would write in consternation to his friend Michele Besso, "All these fifty years of pondering have not brought me any closer to answering the question, What are light quanta?"

The second paper, which would serve as his at-last-successful doctoral dissertation, determined the size of molecules in liquids. The third paper examined the way multitudinous bumps from liquid molecules caused the jitterbugging of microscopic particles suspended in the liquid. The theoretical physicist Max Born said these discoveries of Einstein's had cinched the argument for the existence of atoms and molecules: "At the time atoms and molecules were still far from being regarded as real. I think that these investigations of Einstein have done more than any other work to convince physicists of the reality of atoms and molecules."

Einstein promised a fourth paper on electrodynamics, space, and time, but there would actually be two papers on the special theory of relativity, the first demonstrating that the fundamental laws of physics are true for observers moving at a constant velocity relative to each other, the second deriving the world's most famous equation for the relationship between energy, mass, and the square of the speed of light. Special relativity revises the classical principle of relativity described by Galileo and adopted by Newton, which worked closely enough for the needs of classical mechanics; however, the velocity of light and of electrons, which the seventeenth century could not imagine, required a whole new explanation. According to Galilean relativity, when one thing moves in relation to another, both are effectively moving in relation to each other. As Neffe puts it, "If a train travels past a platform, the people waiting there see it in motion, whereas for the passengers in the train, the platform and the people waiting there are moving away from them. This statement, which may appear trivial at first, is of great moment. It means there is no privileged observer. Each party to the event has an equal right to claim that it is at rest and the other is moving relative to it." Galileo further saw that the speeds of objects moving relative to each other could be added, in what is known as the Galilean transformation. A train going fifty miles per hour in one direction and another going one hundred miles per hour in the opposite direction are going one hundred fifty miles per hour relative to each other.

In 1887, however, an experiment by the American physicists Albert

Michelson and Edward Morley demonstrated that the speed of light is *always* the same, at some 186,000 miles per second. This finding contradicted Galilean relativity: if you applied the Galilean transformation to two objects passing each other, each at 75 percent of the speed of light, then their relative speed should be 150 percent of the speed of light. Yet Michelson and Morley showed the constancy of the speed of light: a beam of light will come at you at the same speed whether its source is moving toward you or moving away from you, or whether you are moving toward or away from it.

Einstein faced this contradiction between classical relativity and the constant speed of light, and produced the insight that abolished absolute time and reconciled the apparent irreconcilables. As Walter Isaacson puts it, "two events that appear to be simultaneous to one observer will not appear to be simultaneous to another observer who is moving rapidly. And there is no way to declare that one of the observers is really correct. In other words, there is no way to declare that the two events are truly simultaneous." An elegant thought experiment makes the point. Imagine two flashlights mounted alongside railroad tracks to the right and left of a stationary observer on the platform; he sees them flash at the same time. But another observer, sitting on the train, moving toward one flashlight and away from the other, will see the very same flashes as one before the other.

The thought experiment continues. Now imagine a light beam in the moving train that bounds from the floor to a mirror on the ceiling and back down. From within the train the beam would appear to go straight up and down. From the platform, however, the beam would follow a zigzag path and appear to cover a greater distance. As the speed of light is constant, to travel this greater distance requires a longer time, so that time must *actually* pass more slowly in the moving system relative to the stationary one; this is known as "time dilation." Neffe further explains, "The faster the train goes, the more extended the zigzag appears from the outside, and the slower the clocks [on the train] run" as seen from the platform. When the train reaches the speed of light, "the light beam stops bouncing altogether—the clock in the train stands still as observed from the platform." Time dilation is accompanied by length contraction in the direction of travel. "To an outside observer, a square in a moving vehicle shrinks into an increasingly narrow rectangle as its speed increases without changing in height. At the speed of light, it becomes a line running straight up and down, as though it had lost a dimension." Thus Einstein overturned the Newtonian premise of an absolute time, of a single clock for the universe, and an absolute space, against which all motion is to be measured.

The only trouble with this sudden efflorescence of genius is that it failed to attract the attention Einstein had hoped for; he had thought some professorial eminence might take notice and immediately offer him a university post. The disheartening inattention, however, was relieved by the appreciative interest of none other than Max Planck, the foremost theoretical physicist in the world, and an editorial board member of *Annalen der Physik*, the illustrious journal that had published Einstein's path-breaking papers. Planck was soon lecturing on relativity at the University of Berlin. Generally, though, rampant mediocrity, both moral and intellectual, did not know what to make of Einstein's achievements—or knew only too well just what to make of them. Arnold Sommerfeld, who strangely enough would become a friend, discerned an insalubrious Jewish cast to Einstein's theorizing. To his esteemed colleague Hendrik Lorentz he wrote in 1907, "As remarkable as Einstein's papers are, it still seems to me that something almost unhealthy lies in this unconstruable and impossible to visualize dogma. An Englishman would hardly have given us this theory. It might be here too, as in the case of Cohn, the abstract conceptual character of the Semite expresses itself." And if it wasn't anti-Semitism, it was sheer academic dunderheadedness that obscured Einstein's light. In 1907 Einstein applied to the University of Bern for the quite shabby entry-level position of *Privatdozent*, and submitted as part of his application seventeen published papers, including those on special relativity and light quanta; the application customarily required an additional unpublished paper called a *Habilitation* thesis, which Einstein had not written, but which could be waived for applicants otherwise remarkable. The lumpen professoriate refused to waive the requirement; Einstein did not write the thesis, and was turned down for the job. A year later, after failing to make the short list for a high school teaching job, he swallowed his pride, wrote the *Habilitation*, and became a *Privatdozent*, though the pay was so dismal he had to stay on at the patent office as well.

At last, in 1909, the University of Zurich considered him for a junior professorship. The issue of Einstein's Jewishness came up—the hiring committee enumerated common and unpleasant "Israelite" traits, "such as intrusiveness, impudence, and a shopkeeper's mentality in the perception of their academic position"—but Einstein passed muster as a decent sort of Jew, and the University took him on. He was soon out the door, however, as the German branch of the University of Prague dangled a full professorship before him. But Prague did not suit him, and he left in short order as his alma mater, now known as the Swiss Federal Institute of Technology, beckoned him home to Zurich. Then in 1913 came the offer that left no doubt about his acceptance among the very best of the best: a professorship at the University of Berlin, directorship of a physics institute founded just for him, and inclusion in the Prussian Academy of Sciences, where at thirty-four he would be the youngest member.

There was an overriding reason why the Berlin offer appealed so much to him: he had fallen in love with his Berliner cousin Elsa Einstein. Mileva had borne him two sons, but her doom-laden temperament began to repel her husband, and he found warm comfort, if not exactly torrid passion, in the motherly attentions of Elsa. Mileva had an affair of her own, and in Berlin took the two boys and moved out. Einstein, who still loved his children, coaxed her back, then issued a directive of domestic tyranny that suggests a truly monstrous hatred for his wife: she must tend to his laundry and feeding and keep his office tidy, give up any intimacy, stop talking at his request, leave his bedroom or study when commanded, and treat him with respect in front of their children. At last Mileva could take no more, and left for Zurich with their sons. Einstein, who took pride in keeping his emotions under tight rein, accompanied them to the train station and wept uncontrollably all day.

Science was his perpetual refuge from personal turmoil, and as his marriage was dissolving the general theory of relativity was coming into being. He had really been thinking his way towards it since discovering the special theory of relativity in 1905, which had left two significant open questions. If nothing can travel faster than the speed of light, what is to be made of Newton's laws of gravity, which understand gravitational force between objects as instantaneous? And how can the special theory be generalized to include accelerated as well as uniform motion? Einstein conceived a thought experiment about a free-falling observer unaware of his own weight, and thereby devised the principle of equivalence, which states that the local effects of acceleration and of gravity are identical. That is, in Isaacson's words, "A person in a closed windowless chamber who feels his feet pressed to the floor will not be able to tell whether it's because the chamber is in outer space being accelerated upward or because it is at rest in a gravitational field."

Furthermore, according to the principle of equivalence, a gravitational field should bend a beam of light, just as accelerated motion does. "Imagine that the chamber is being accelerated upward. A laser beam comes in through a pinhole on one wall. By the time it reaches the opposite wall, it's a little closer to the floor, because the chamber has shot upward. And if you could plot its trajectory across the chamber, it would be curved because of the upward acceleration." In a 1911 paper Einstein contended that his proposition about light-bending could be demonstrated experimentally, and predicted the angle of deflection for a ray of light passing through the sun's gravitational field.

As light commonly appears to travel in straight lines, to speak of its following curved paths provoked far-reaching speculation about gravity's effect on the fabric of space. The mathematical arcana now called into play—the non-Euclidean geometry of geodesic lines on spherical surfaces—were beyond Einstein's reach, so he called on an old friend from the Polytechnic, Marcel Grossmann, to help him find a geometric system that accommodated his new questions about gravitational fields. Grossmann pointed him toward Riemann geometry—in Isaacson's words, "a way to describe a surface no matter how its geometry changed, even if it varied from spherical to flat to hyperbolic from one point to the next"—and the metric tensors used to gauge the distance between points in space, or for that matter in four-dimensional spacetime. That gravity directs matter in motion and that matter produces curved gravitational fields in spacetime were Einstein's complementary discoveries. "His head-snapping insight was that gravity could be defined as the curvature of spacetime, and thus it could be represented by a metric tensor," Isaacson writes. Spacetime "had its own dynamics that were determined by, and in turn helped to determine, the motion of objects within it—just as the fabric of a trampoline will curve and ripple as a bowling ball and some billiard balls roll across it, and in turn the dynamic curving and rippling of the trampoline fabric will determine the path of the rolling balls and cause the billiard balls to move toward the bowling ball." Three years of grinding out equations to fulfill the insight followed.

Einstein hoped to obtain some partial verification of his theorizing. On August 21, 1914 there was a total eclipse of the sun, most apparent in the Russian Crimea; an eclipse was necessary for starlight passing near the sun to be made visible, so that its bending could be calculated. The doughty young German astronomer Erwin Freundlich had been waiting three years for the chance to prove Einstein's predictions right, and he undertook a Crimean expedition. Unfortunately for Freundlich, World War I had just broken out, and he and his colleagues were taken prisoner by the Russians before they could observe the eclipse. This was fortunate for Einstein, as his predictions were wrong; Freundlich's capture would give Einstein the opportunity to correct them a year later, when he published his general relativity paper.

The conflagration of the Great War promptly incinerated most of what was decent and sensible in German intellectual life. In October 1914, ninety-three German thinkers, literary men, and scientists signed the "Appeal to the Cultural World," in which they endorsed the necessity of the war, naïvely repudiated the charges that the German army had committed atrocities against Belgian civilians, and upheld the sanctity of a national civilization that had produced Goethe, Beethoven, and Kant. Among the signatories were three of Einstein's friends: Max Planck, Fritz Haber, and Walther Nernst. War fever induced murderous conniptions in Haber and Nernst. Haber became the founding father of chemical warfare, personally overseeing the first vicious attack—it killed five thousand French and Belgian soldiers—with the chlorine gas he had invented. The fifty-year-old Nernst worked on his marching and saluting in the street with his wife egging him on, and eventually joined Haber's mass-asphyxiation team.

This outburst of mad violence, especially on the part of cultivated men whom he respected, appalled Einstein. He joined a doctor friend of Elsa's, Georg Nicolai, in writing a pacifist retort to the ninety-three, the "Manifesto to Europeans," which condemned the war as a violation of all that high culture represented. They could find only two other men willing to sign, however, and the counter-manifesto withered in a drawer. Still hopeful that Europe could be made to see reason, Einstein joined the New Fatherland League, which promoted peace in a hurry and a federated Europe that would make war obsolete. Brazen denunciations of Prussian militarism were anything but fashionable, yet Einstein openly declared his hopes for an Allied victory over an incorrigible Germany. Innate male sexual aggression, he opined in an essay published by the Goethe League, underlay the periodic riots of bloodletting that constituted so much of human history; only a world organization with the power to inhibit the rogue impulses of member states could hope to curb this rage to kill and be killed. When the war at last came to its end, he defended his vague and warm-hearted socialist inclinations against the totalitarian open razors of Bolshevism. "All true democrats must stand guard lest the old class tyranny of the Right be replaced by a new class tyranny of the Left," he declared in the face of a revolutionary student uprising in Berlin.

As the world was emerging from its manufactured hell, Einstein was at last getting out of his marriage to Mileva. Newfound freedom presented its own difficulties. According to a letter that Elsa's daughter Ilse wrote to a former lover, Einstein was more in love with Ilse than with Elsa. He wound up marrying the mother in 1919 and staying on decent terms with the daughter. Elsa was a rather doughy woman and a born *Hausfrau*, creating the contentment in which her husband could work at his best, always punctual with his favorite sausages and lentil soup, which she would leave him alone to eat. Einstein was something of a womanizer, and she mostly turned an obliging blind eye to his affairs, though she could get riled to action under exceptional provocation. Elsa was, in short, just the sort of wife Einstein wanted after the tumultuous years with Mileva. Physics was none of Elsa's concern, but as it was Einstein's obsession she happily enabled him to pursue it.

Another solar eclipse in 1919 brought a renewed opportunity to test general relativity. Two teams of British astronomers led by Arthur Eddington—one heading to Sobral in Brazilian Amazonia, the other to the island of Principe off Africa's Atlantic coast—took the pictures and made the calculations. The results were ambiguous, the numbers for one set of the Sobral pictures seeming far off, though with a large margin of error, another set from there running a bit high, and Eddington's own calculations from Principe coming out pretty much on the money. The Royal Society, Britain's scientific legion of honor, and the Royal Astronomical Society met specifically to hear the report on the observations. Frank Dyson, the Astronomer Royal, declared the findings with certitude: the measurements confirmed Einstein's theory beyond a doubt. Some of the members present, aware of Isaac Newton looking down at them from his portrait on the wall, demurred. But Sir J.J. Thomson, the discoverer of the electron, who presided over the Royal Society, announced, "The result is one of the greatest achievements of human thought." The philosopher Alfred North Whitehead, who described the atmosphere as that of a Greek drama, seconded Thomson: "a great adventure in thought had at length come safe to shore." As for Einstein, who was in Berlin at the time, when asked by a graduate student what he would have done had the astronomers found him wrong, he replied, "Then I would have been sorry for the dear Lord; the theory is correct."

However, the theory wasn't *entirely* correct. General relativity operated for a universe that was contracting or expanding; the astronomical observations of that time, however, which were limited to the Milky Way galaxy, showed a static universe. Einstein's field equations ruled out the possibility of stasis: gravity would draw all the matter together into an apocalyptic collision. Here Einstein's accustomed boldness folded under pressure. Rather than declare just how daringly innovative his theory was, he finagled a way to make general relativity jibe with the prevailing astronomical wisdom, introducing a repulsive force into his equations that he called the "cosmological constant" and that preserved the static universe. In the mid-1920s, the astronomer Edwin Hubble discovered not only that there are galaxies besides our own but that they are moving away from us, and Einstein had to admit to his "greatest blunder." (As it happens, current cosmologists have reintroduced the cosmological constant into their calculations to account for the so-called dark energy that seems to cause the universe's accelerating expansion.)

Although further measurements by the American astronomer William Wallace Campbell in Australia during a 1922 eclipse corroborated Einstein's theory, there remained serious doubters among serious scientists, as Jeffrey Crelinsten shows in *Einstein's Jury*. Heber Doust Curtis, head of the distinguished Lick Observatory in California, was defiantly convinced that general relativity was a sterling invention but not even a remote approximation to the truth. Campbell's findings, Curtis was sure, would eventually receive a better, and traditional, explanation: "I am firmly of the opinion…that we shall be able to explain this and the motion of the perihelion of Mercury by ordinary Newtonian mechanics. I find it impossible to believe that gravitation is not a force, but a property of space, that space and time are 'curved,' that the universe which appears to us as three-dimensional is really a 'four-dimensional manifold in space of six-fold curvature,' and all the rest of it." Curtis's dogged skepticism suggests the impasse between cutting-edge theory and the common-sense understanding of the physical world: the reality that science uncovers might be far stranger and more complex than appearances lead you to believe, and the world of appearances continues to exert its own strong claims to being real.

Einstein had his own exalted view of common sense, which of course had room for relativity. When told that new experimental refinements had shown the speed of light to be variable, thus disputing the basis of relativity, he replied, knowing this could not be right, "Subtle is the Lord, but malicious He is not"; the aphorism was subsequently carved in stone over a Princeton University fireplace. That is, nature may have its secrets, but it is meant for men to discover them, and God would not trifle with human intelligence for the sake of cruel sport. Quantum mechanics, however, made him reconsider his observation. As an old man he gestured to the carved quotation during a discussion of quantum theory and said, "Who knows, perhaps He is a little malicious." The theory of subatomic mechanics for which Einstein's discoveries about light had prepared the way frankly left him nonplussed. As David Lindley succinctly puts it in *Uncertainty*, "In classical physics, when anything happens, it happens for a reason, because prior events led up to it, set the conditions for it, made it inevitable. But in quantum mechanics, apparently, things just happen one way or another, and there is no saying why." Probability shoulders out causality in the quantum universe. Clarity, coherence, elegance: all the qualities Einstein demands from a master theory he finds lacking in quantum mechanics. Relativity shares the classical concern with order and certainty; quantum mechanics admits disorder and uncertainty, as though imprudently opening the front door of physics to a subatomic Manson family.

Quantum mechanics was flying high in the 1920s, at the hands of Niels Bohr, Werner Heisenberg, Paul Dirac, Wolfgang Pauli, Max Born. Honing the discoveries of Dirac and Pauli, Heisenberg in 1927 developed the infamous uncertainty principle: if you attempt to determine the position and the momentum of an electron, you will be able to find the one but not the other at any given time; indeed, the finer the measurement of one, the more hopeless will be the measurement of the other. Heisenberg then plunged onward into what some consider the groves of ethereal clairvoyance and others an ontological and epistemological wasteland: the electron *actually* has neither position nor momentum until one observes it. This is not a shortcoming of our methods of observation, the quantum theorists insist, but the way the world works at the subatomic level.

Einstein would have none of this. Although in a 1916 paper he had himself introduced probability and chance into a description of photon or quantized light emission, the implications of that discovery flummoxed him: that a light quantum could evidently choose to move, or a radioactive atom to decay, "of its own free will," as he put it, seemed absurd. Einstein invoked strict Newtonian causality as the antidote to this all-too-modern conceptual disarray. A virtually religious belief that the universe operates according to the rules of causality and that the mind of man shall discover those rules propelled his running argument with the quantum men. To his friend in contention Max Born, he wrote, "Quantum mechanics is certainly imposing. But an inner voice tells me that it is not yet the real thing. The theory says a lot, but it does not really bring us any closer to the secrets of the Old One. I, at any rate, am convinced that He does not play dice." Born admonished him not to tell God what to do, but Einstein remained adamant that his belief in a comparatively simple and straightforward universe gave him a privileged glimpse into divine workings. Einstein's continuing quarrel with quantum physics took on an air of futility, however, as the subatomic theory became so widely useful that questions about its premises evaporated. As Lindley writes, "It wasn't that hard, [even physicists baffled by the theory] found, to use quantum mechanics without indulging in philosophical worries about the nature of physical reality." Einstein himself could never quite let go of his philosophical worries: his noble understanding of physics as the search for truth would not allow him to be satisfied with the mere usefulness of a theory.

His persistent hope was to discover a unified field theory that would join quantum mechanics, gravity, electricity, and magnetism in a definitive explanation of the physical world. Most physicists saw his efforts in that direction to be quixotic, but periodically over decades Einstein would publish, to considerable popular acclaim, his latest stab at a theory of everything. By his bedside when he died in 1955 were a dozen scrawled pages of his latest attempts to explain it all. This heroic undertaking of his later life to master the universe by mind alone came to nothing.

But if his most important work had been completed by the time he was thirty-six, he still had a long life to live out, not only as scientist but as private and public man. His personal life was touched by great sadness. Elsa died in 1935; he would outlive her by twenty years. His younger son by Mileva, Eduard or "Tete," a young man of considerable literary and musical gifts, developed schizophrenia and was institutionalized in Switzerland in 1933; Einstein, who had fled Hitler's Germany for America, accepting a professorship at the Institute for Advanced Study in Princeton, would not see him again. Although one might say that Einstein took a fiercely principled stand in refusing ever to return to a defiled Europe, one might less generously conclude that he abandoned his disabled child.

The public career was a mixed lot as well. The astronomical proof of general relativity had made him a star, and there were those in Germany who objected to his shining so brightly. In 1920 a German nationalist named Paul Weyland took up the anti-relativity banner and founded the Study Group of German Scientists for the Preservation of a Pure Science. Rallies to do Einstein down were held across the country. Einstein attended one himself, and then replied to his opponents' charges in a newspaper article. Had he been a German nationalist rather than a Jew, he contended, there would be no such opposition to his work. Although some critics were surely troubled by Einstein's work for reasons unrelated to anti-Semitic bias—remember Heber Doust Curtis's misgivings, for instance—Einstein was certainly right about the situation in Germany. In 1921, the political neophyte Adolf Hitler took the opportunity to pontificate on matters he could not begin to understand: "Science, once our greatest pride, is today being taught by Hebrews." Even a distinguished physicist such as Philipp Lenard found so-called "Jewish science" infected by quasi-mystical fabrications in which the facts of nature were lost. Then in 1922 came the assassination of Walther Rathenau, Germany's Jewish foreign minister and a close friend of Einstein's. Only weeks before, Einstein had tried to convince Rathenau that his life was in danger and that he ought to resign from his ministerial post. Police warned Einstein that his prominence put a bull's eye on his own back. He left Berlin for a spell, but soon returned and promptly assumed a very visible role in a large pacifist rally.

Political activism played a significant part in Einstein's life; reading the voluminous output in *Einstein on Politics*, one sometimes wonders how he had time for his scientific work. His contempt for the German populace and polity and intelligentsia is evident from the Great War onward. After Rathenau's murder, he wrote with great boldness in a memorial essay: "I regretted that he became [Foreign] Minister. Given the attitude held by a great many of the educated class of Germany toward the Jews, it is my conviction that it would be most natural for Jews to keep a proud distance from public affairs. Yet I could not have imagined that hatred, blindness, and ingratitude could go so far. I would like to draw the attention of those, however, who have directed the moral education of the German people for the last fifty years, to the following: by their fruits shall ye know them."

As the native fruits swelled with poison, Einstein became ever more a Zionist, envisioning a Jewish "nationalism whose aim is not power but dignity and health," as he wrote in 1929 to Willy Hellpach, a sometime candidate for the presidency of Germany and a critic of Zionism: "I realized that salvation was only possible for the race if every Jew in the world should become attached to a living society to which he as an individual might rejoice to belong and which might enable him to bear the hatred and the humiliations that he has to put up with from the rest of the world."

Hatred and humiliations became too much to bear in Hitler's Germany; after the Reichstag arson in 1933, Einstein, who was in America at the time, resigned from the Prussian Academy, renounced his German citizenship, and published a statement declaring, "As long as I have any choice, I will only stay in a country where political liberty, tolerance, and equality of all citizens before the law prevail." (He would later become an American citizen, but always retained his Swiss citizenship as well.) In 1935, animated by the Nazi military threat, Einstein reversed his earlier militant pacifism and insisted "no reasonable human being would today favor the refusal to do military service, at least not in Europe, which is at present particularly beset with dangers." Confirmed pacifists must support the concerted action of decent states to foil the warlike designs of the indecent. In August 1939, having been informed by the Hungarian refugee physicists Leo Szilard and Eugene Wigner that the Germans may already be working on a nuclear bomb, Einstein famously wrote a letter to President Roosevelt urging that the U.S. government initiate a nuclear program of its own; it took months to see serious action, and Einstein was left out of atomic research during the war, but his letter was a prime impetus for the Manhattan Project.

After the war Einstein turned his powers to the abolition of nuclear weapons, to be achieved by a world government that would do away with war altogether. The only terms on which human life shall survive, he believed, require abandoning the life of men in nations, which has always seemed natural.

> So far as we, the physicists, are concerned, we are no politicians and it has never been our wish to meddle in politics. But we know a few things that the politicians do not know. And we feel the duty to speak up and to remind those responsible that there is no escape into easy comforts, there is no distance ahead for proceeding little by little and delaying the necessary changes into an indefinite future, there is no time left for petty bargaining. The situation calls for a courageous effort, for a radical change in our whole attitude, in the entire political concept.

Yet what do the physicists really know, one might ask, that the politicians do not? The specter of mass death is evident to everyone, and prudence as it has always been understood involves risk, but it is not suicide.

Einstein's uncompromising stand on nuclear disarmament did not sit well with the American security apparatus, to say the least. J. Edgar Hoover compiled a massive dossier on the physicist, in the hope of proving him a Soviet agent. That Einstein backed Henry Wallace in his failed 1948 presidential bid against Harry Truman tarred him as a stooge of the Kremlin; in fact he had a marked distaste for Soviet communism, though he did fault Truman, rather foolishly, for his part in making relations between the United States and the Soviet Union so perilous. In 1953, during the height of the Red Scare, he published an open letter in the *New York Times* exhorting a Brooklyn schoolteacher subpoenaed by a congressional investigative committee to remain silent: "What ought the minority of intellectuals to do against this evil? Frankly, I can see only the revolutionary way of non-cooperation in the sense of Gandhi's. Every intellectual who is called before one of the committees ought to refuse to testify, i.e., he must be prepared for jail and economic ruin, in short, for the sacrifice of his personal welfare in the interest of the cultural welfare of his country." To do otherwise, he concluded, was to live as a slave. One can only cringe at the rhetorical bluster, utterly oblivious to the fact that America was facing a potent enemy that kept tens of millions of slaves in the gulag archipelago. Einstein's genius suffered no greater injury than from his lifelong political crusading.

Yet his genius was of a very high order indeed. Peter Galison in *Einstein's Clocks, Poincaré's Maps* draws a sharp distinction between Einstein and a lesser hero of the intellect, Henri Poincaré, who in 1898 also perceived the flaws in the Newtonian measurement of time but thought them too minuscule to be of consequence. The theoretical anomaly did not trouble Poincaré enough to investigate further, whereas for Einstein it was the irritating grit from which he formed a conceptual pearl. Poincaré's world, Galison writes, was one

> where truth and the ultimate reality of things meant far less than the establishment of communicable, stable, durable relations—the kind of reliable relations that made action possible. As Poincaré put it, "science is only a classification and…a classification can not be true, merely convenient. But it is true that it is convenient, it is true that it is so not only for me, but for all men; it is true that it will remain convenient for our descendants; it is true finally that this cannot be by chance. In sum, the sole objective reality consists in the relations of things." A world of scientific rationality without metaphysical profundity: objective relations, not metaphysical objects.

Convenience would have struck Einstein as an unworthy standard for judging scientific excellence. He "did not think that theory had fulfilled its task by successfully and conveniently capturing true relations among phenomena," Galison writes. "He aimed for a depth between phenomena and the theory that underlay them. Like Poincaré, Einstein believed that laws must be simple, not for our convenience but because (as Einstein put it) 'nature *is* the realization of the simplest conceivable mathematical idea.'" The ancient Greeks' dream that unaided thought could penetrate to the marrow of reality remained alive in Einstein's theorizing. Science at its highest was a form of divination. Galison contrasts Poincaré's "relentless Third Republic secularism" with Einstein's "contemplative theology." To partake of God's fathomless mind, Einstein believed, was the physicist's holy communion; there was nothing more sacred to him than a true insight into the workings of Nature. As he wrote, the scientist's "religious feeling takes the form of a rapturous amazement at the harmony of natural law which reveals an intelligence of such superiority."

Einstein's passion for natural law, Walter Isaacson writes, carried him into a disheartening, even frightening, determinism that extended to all human action. "I do not at all believe in free will in the philosophical sense," he declared in the 1930 essay "What I Believe." If he meant by this no more than that we are all creatures and cannot make ourselves anything we want to be, there is little to quarrel with in that. But elsewhere he averred, "Everything is determined, the beginning as well as the end, by forces over which we have no control. It is determined for the insect as well as for the star. Human beings, vegetables, or cosmic dust, we all dance to a mysterious tune, intoned in the distance by an invisible player." His friend Max Born rightly saw the dire consequences for morality of Einstein's attitude, and looked not only to actual human behavior but also to indeterminacy at the quantum level as corrective to this hard fatalism. Einstein was willing to concede that human beings ought to live as if they enjoyed free will, for the sake of preserving civilization, and of course he could be downright eloquent in his profession of the ethical life: "The most important human endeavor is the striving for morality in our actions. Our inner balance and even our existence depend on it. Only morality in our actions can give beauty and dignity to life." He seemed finally to live a riven life, one of spiritual incoherence, denying freedom of choice yet preaching an exigent morality.

And what are the consequences of Einstein's thinking for *our* lives? The technological cornucopia is of course seemingly bottomless, but the theoretical underpinnings of this bounty remain a deep mystery not only to laymen but to many technicians themselves. Jeffrey Crelinsten says rightly that relativity "is still not part of our general culture": "Scientists in industry apply the equations of special relativity daily, and Einstein's general theory is guiding cosmologists in their search for a deeper understanding of the cosmos. Yet apart from the few specialists who work the equations, we do not need to understand the underlying concepts, nor do many of the experts."

This failure to understand the concepts extends beyond the realm of technology. The grotesque misprision of Einstein's theory, which has confounded relativity with relativism, has had mostly baneful consequences for intellectual and moral life. In the essay "English Prose Between 1918 and 1939," collected in *Two Cheers for Democracy*, E. M. Forster discusses the effect of Einstein on modern literature: "Can literary men understand Einstein? Of course they cannot—even less than they can understand Freud. But the idea of relativity has got into the air and has favoured certain tendencies in novels. Absolute good and evil, as in Dickens, are seldom presented. A character becomes good or evil in relation to some other character or to a situation which may itself change. You can't measure people up, because the yard-measure itself keeps altering its length." To be sure, one wouldn't want every novelist to be Dickens, yet the absence of clear good and evil in modern fiction bleeds all too readily into actual life. To lay all this in Einstein's lap is patently ridiculous, of course, but as Forster says, relativity has got into the air, and everyone thinks he understands its implications for the moral life even if he hasn't a clue about the science itself. Thus Forster applies Einstein's principle of length-contraction to the judgment of human character, in a high-flown sort of burbling. Had Einstein called his most famous works "invariance theories" as he had originally intended, the moronic chorus that chants "Everything's relative" would have to find other music. All manner of disturbing dreams and visions come from an ill-digested scientific theory. The cure for this sort of disturbance is clear: that literary men, and moral philosophers, and political men take some pains to try to understand Einstein's physics. The current crop of books congenial to the general reader is a good place to start.

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