The Patent Clerk from Mount Olympus

Einstein's annus mirabilis.

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1. Voyages

We are in the position of a little child entering a huge library filled with books in many different languages. The child knows someone must have written those books. It does not know how. It does not understand the languages in which they are written. The child dimly suspects a mysterious order in the arrangement of the books but doesn't know what it is. That, it seems to me, is the attitude of even the most intelligent human being toward God. We see a universe marvelously arranged and obeying certain laws, but only dimly understand these laws. Our limited minds cannot grasp the mysterious force that moves the constellations.

—Max Jammer, Einstein and Religion.

In 1768, Captain Cook and his crew headed off on their legendary voyage to Tahiti. In that same year a stream of photons from the Hyades star cluster embarked on a much longer journey, along the most literal of beelines to the earth. One and a half centuries later, in the middle of the morning of May 29, 1919, the photons crossed the boundaries of our solar system on their approach toward earth. Scheduled to hit the earth at mid-day, the photons would normally be invisible, overwhelmed by the brilliance of the sun. But May 29, 1919 was no ordinary day.

Shortly after lunch, the moon began to migrate across the face of the sun. The eerie mid-day darkness of an eclipse, with its not-quite-normal color scheme and Stephen King complexion began to move across the face of the earth. Mid-day night fell and the stars began poking through the opaque blue of the sky. The stream of photons that left the Hyades cluster in 1768 grazed the edge of the sun, passing close enough to the solar system's largest body to experience a more powerful gravitational tug than any of the other bodies in the solar system, including nearby Mercury.

The intense gravitational power of the sun altered the path of the stream of photons by just under two degrees; they careened off nothing, like the mysterious deflection of a Curt Schilling curve ball. The new path of the photons as they continued their trajectory toward the earth was changed ever so slightly.

One observer of this stellar event was British astronomer and Quaker Sir Arthur Eddington, who had traveled to the island of Principe, off the coast of West Africa, where the eclipse was full. Eddington and his team had been dispatched by England's Royal Society to measure the deflection of the stream of photons from the Hyades. The measurement was perhaps the most important single piece of scientific data ever acquired in a scientific investigation. If the deflection was as anticipated, a radical new theory of gravity, destined to topple Isaac Newton's venerable explanation, would be confirmed.

May 29 dawned cloudy, and Principe was visited by torrential downpours. Eddington's team stared fitfully at the heavens, wondering if something so banal as bad weather would interfere with the measurements historian Paul Johnson would later declare inaugurated the modern world. Even as the eclipse began the clouds continued to threaten but, at the last moment, as if God himself were authoring the revelation, the clouds broke, an eclipsed sun appeared and Eddington feverishly began to slide glass photographic plates in and out of his camera, recording the position of the Hyades.

When the eclipse and its Kodak Moment had passed, Eddington began to develop his photos and make measurements on them. The stars in the Hyades cluster appeared in a different location, their apparent home in the heavens displaced ever so slightly, precisely as predicted by the new theory. Eddington looked up from his plates at a vastly different world, one of only two people on the planet who, at that moment, fully appreciated what had just happened. Isaac Newton's theory of universal gravity, like the sun in Eddington's photos, had just been eclipsed.

2. Brave New World

Newton, forgive me, you found the only way which in your age was just barely possible for a man with the highest powers of *thought and creativity. The concepts which you created are guiding our thinking in physics even today.*

—Albert Einstein, in Albert Einstein: Philosopher Scientist, ed. P. A. Schlipp.

The other person who fully appreciated what had just happened was Albert Einstein, the respected but not yet iconic originator of the strange theory that predicted the deflection of the starlight. Einstein, so the story goes, slept peacefully while Eddington made his observations. In contrast, Max Planck, the editor of the *Annalen der Physik*, which would publish Eddington's result, remained wide awake, eagerly anticipating a cable from Principe. Einstein would later quip—tongue comfortably lodged in cheek—that Planck needed not have lost any sleep, for the theory being "tested" was so beautiful that it could not possibly fail to be confirmed by Eddington's measurements.

The confirmation of Albert Einstein's Theory of General Relativity in 1919 is one of those myth-making moments in history—like Galileo's trial before the Inquisition in 1633, or Huxley's confrontation with Wilberforce in 1860—when long burning fuses reach their destination and things explode.

Historian Paul Johnson begins his bestselling history of the 20th century, *Modern Times*, with the following words: "The modern world began on 29 May 1919 when photographs of a solar eclipse, taken on the island of Principe off West Africa and at Sobral in Brazil, confirmed the truth of a new theory of the universe."

There is, of course, far more to "Modern Times" than simply a new theory of gravity replacing Newton's old one. Einstein's new theory of gravity emerged at the same time that Freud's psychoanalysis was in its ascendancy, and Marxism was getting its first real-world applications. Einstein, Freud, and Marx were a synergistic trio with a common message: the world is not as it appears, and you need us to show you how things really are. Marx argued that surface economic relationships—between workers and bosses, for example—were deceptive. Management initiatives purporting to be about worker satisfaction were strategies to prevent workers from seeing how they were being exploited. Freud argued that human motivations were consistently misinterpreted; guilt, for example, was a trick played on individuals by society to get them to behave. And God was an illusion, human aspiration writ large.

Claims by Freud and Marx that the world of our experiences derived from a very different undercarriage could hardly have had a more robust analogue from the natural sciences than Einstein's Theory of Relativity. Eddington's measurements had established that the Hyades cluster was somewhere other than where it appeared. We can look over here for it and actually find it. But somehow it was, said Einstein, over there, in a different place. And, of course, those who had put their trust in the traditional Newtonian picture of the world turned out to be deceived. *Beware received wisdom* was the emerging refrain.

The London papers reported Eddington's discovery with two-inch headlines declaring "Lights all Askew in the Heavens." And the seer who had predicted this was a forty-year-old Jewish physicist who had just moved from academia to the center of Western culture, where he would take up residence as a brooding, detached, and haunting presence, a presence only marginally diminished by his death in 1955.

3. The Reluctant Guru

Creating a new theory is not like destroying an old barn and erecting a skyscraper in its place. It is rather like climbing a mountain, gaining new and wider views, discovering unexpected connections between our starting point and its rich environment. But the point from which we started out still exists and can be seen, although it appears smaller and forms a tiny part of our broad view gained by the mastery of the obstacles on our adventurous way up.

—Albert Einstein, Evolution of Physics.

The details of Einstein's life have been told many times, and every decade has seen its share of biographies taking a new look at Time magazine's "Man of the Century." Dennis Overbye's eminently readable *Einstein in Love: A Scientific Romance* is a coming-of-age account of the physicist's life in the first two decades of the century that he came to own. Einstein in love was not Einstein at his best, it turns out. Smitten as a young man with Mileva Maric, who bore him three children, one before they married, Einstein was never much of a father to any of them. Nor was he much of a husband to their mother, of whom he wrote in 1913: "I treat my wife as an employee whom one cannot fire. I have my own bedroom and avoid being with her." This letter was written to his cousin Elsa, whom he married in 1919 and soon came to regard as yet another domestic employee: "Talk of you or me, but never of 'us,' " he instructed her.

For better or worse, as has always been the case with celebrities, Einstein's failures at various "normal" activities, like being a husband and father, or even finding his way home at night, were considered nothing more than charming eccentricities, the collateral of great genius.

To call Einstein a "celebrity," however, is to squeeze his mystery into the pedestrian confines occupied by ephemera like Paris Hilton and Britney Spears. Einstein is a celebrity, to be sure, but he is also saint, martyr, prophet, and messiah. Michael Paterniti's *Driving Mr. Albert: A Trip Across America with Einstein's Brain*, is a light-hearted romp through the world of Einstein as Relic. By the time Einstein died, the prodigious genius lodged in his gray matter had assumed supernatural proportions, and the coroner who removed and mysteriously took ownership of the brain—the body was cremated—had been transformed into something of an Indiana Jones.

Einstein the man was never comfortable with the legend. He saw himself as little more than a gifted physicist, but—like a rock star invited to pronounce on the great questions facing civilization—he was besieged by uncomprehending admirers, who looked to him for wisdom on everything from international politics to religion. The role of guru was not one he took to comfortably and, in later life, he looked back nostalgically to his early years, when he was nothing more than a physics genius masquerading as a patent clerk.

4. Annus Mirabilis

If my theory of relativity is proven correct, Germany will claim me as a German and France will declare that I am a citizen of the world. Should my theory prove untrue, France will say that I am *a German and Germany will declare that I am a Jew.*

—Albert Einstein, Address, December 1929, at the Sorbonne. Quoted in the New York Times (February 16, 1930).

Albert Einstein entered the world of physics by stealth, in 1905. He was 26 years old, employed in a patent office in Berne, having been turned down for a couple of academic posts. It was honest work for a journeyman scholar with a physics degree. The work was interesting, not too demanding, and provided the young Albert with resources to support himself and time to think. And think he did.

In one astonishingly productive year, he wrote 23 review articles for various journals, summarizing areas of physics in the succinct and eloquent prose for which he would become known. But that was just by the way, for in the same year he produced five ground-breaking scientific papers, all of which were published in *Annalen der Physik*, the world's leading physics journal. The papers were peculiar. They were light on references, as if the author were somehow unaware of his quote-everyone-who-ever-said-anything-about-this-topic obligations. They were heavy on prose, seemingly treating the all-important mathematical equations as afterthoughts. And they were extraordinary—so extraordinary that the 1905 volume of the *Annalen der Physik* cannot be kept on a library shelf with its siblings. If you want to hold this sacred volume in your hands, you must find yourself a cooperative librarian who will take you to a small room and watch closely while you turn its hallowed pages.

The five papers, written in German, had rather unremarkable titles: "On a Heuristic Point of View Concerning the Production and Transformation of Light"; "A New Determination of Molecular Dimensions"; "On the Motion of Small Particles Suspended in Liquids at Rest Required by the Molecular-Kinetic Theory of Heat"; "On the Electrodynamics of Moving Bodies"; "Does the Inertia of a Body Depend on its Energy Content?"

The first paper explained the photoelectric effect, and is worth noting because it was this paper, rather than the more famous relativity papers, that would eventually earn Einstein the Nobel Prize. The behavior of light as it falls on various surfaces, causing electrons to come off, is quite mysterious. There are cases where a large amount of, say, *red* light is not enough to enable an electron to break free from the surface but a tiny amount of *blue* light would have electrons streaming away. What is happening here? Electrons are weakly bound to the atoms in the surface and need but a modest amount of energy to break free. Why was it not possible for this energy to come from red light? It was like trying to purchase a book from Mother Nature for $5 and discovering that even $100 worth of dimes was inadequate, while exactly $5 in quarters was fine.

Einstein resolved this paradox by postulating the existence of *photons*—discrete bundles of electromagnetic energy. Up to this point, everyone considered light and the rest of the electromagnetic spectrum to consist of waves: intense radiation was a big wave, weak radiation was a small wave. However, there was obviously something wrong with this picture when it came to electrons getting removed from surfaces by radiation.

Einstein's revolutionary paper suggested that the light falling on the surface consisted of discrete bundles of energy, called *quanta*. What if, for example, the quanta—bundles of energy—contained 10 units of energy and 20 were needed to free an electron? Was it possible to envision an electron absorbing a quanta of energy, getting almost free of the surface, and then falling back, only to absorb another quanta and fall back again? Perhaps there was something preventing electrons from absorbing two quanta at once.

In this scenario the electron is like a child who can jump no more than 12 inches into the air but would like to jump onto a box 18 inches high. There is no way to "add" the jumps together so, no matter how many times she jumps, she cannot get onto the box.

Einstein's explanation turned out to be very successful. Red light consists of photons of low energy, while blue light consists of photons with higher energy. The ability of incident radiation to free an electron is a function of the energy of the individual photons, not how many photons there are. This explanation, illuminating what is now known to every student of physics as the photoelectric effect, was a powerful argument for the reality of quanta, the first of the great revolutions in 20th-century physics.

Einstein explained the photoelectric effect and established the reality of light quanta with arguments any high school student could understand. The equations that go with the explanation are trivial, of the form a - b = c. The mental models could hardly have been simpler.

Picture an electron bound to an atom in the surface of a metal. The atom pulls on the electron and holds it in place. The electron needs 20 units of "jumping energy" to free itself from the atom. When photons with 10 units of energy fall on the electron it reaches for freedom but falls short. Ditto for 15 and 19 energy unit photons. But when a photon has 20 units of energy the electron can capture enough energy to break free. If it has more than 20 units, the electron emerges with some additional energy of its own. If you understand this paragraph you understand the photoelectric effect. Einstein won the Nobel Prize in 1921 for this explanation.

Einstein's second great paper, "A New Determination of Molecular Dimensions," was aimed at yet another revolutionary new concept—atoms. In 1905 the reality of atoms was still very much in question. Many scientists considered them useful fictions—hypothetical entities like magnetic field lines or centers of mass that helped one visualize phenomena but with no intrinsic reality of their own. The great Austrian physicist and philosopher Ernst Mach would go to his grave in 1916 denying that atoms were physically real. In this paper Einstein develops a technique, not only to establish the reality of atoms, but to estimate their size. He was awarded his doctorate in physics from the University of Zurich for this new theory.

His third paper, with the ever-so-catchy title, "On the Motion of Small Particles Suspended in Liquids at Rest Required by the Molecular-Kinetic Theory of Heat," was yet another novel argument for the reality of atoms. In 1827 a Scottish botanist named Robert Brown had observed, using an early microscope, that tiny particles of pollen suspended in a liquid jiggled back and forth for no apparent reason. This phenomena, known as

Brownian motion, was used by Einstein to make yet another argument for the reality of atoms. The tiny jiggling particles, he argued, were buffeted by invisible atoms. Purely hypothetical entities, of course, are not capable of buffeting. This paper has been cited more than any of Einstein's other papers.

These three papers by themselves would have placed their author firmly in the ranks of great scientists, despite having been written by a patent clerk in his spare time. But it was Einstein's two relativity papers that launched him onto Mount Olympus.

The first relativity paper, "On the Electrodynamics of Moving Bodies," introduced nothing less than a new theory of time. Using high school mathematics, the simplest of physical arguments, and absolutely no references to previous work, Einstein proved—not argued—that time runs at different rates depending on how fast you are moving. The implications are mind-boggling and lodge science fiction firmly within science: theoretically, a grandfather could get into a space ship, take a long journey at a very high speed, and return to find his grandchildren older than he is. While on the journey, time will pass normally for the grandfather. He will eat, sleep, exercise, and watch pre-recorded television shows in a routine that will be very familiar. A couple of years will pass before he returns. While he is gone, time will pass normally back on earth. His grandchildren will grow up, marry, have kids of their own, retire, become elderly, perhaps die of old age. Reality tv will pass into history and the iPod will be replaced with the next best thing. The grandfather will return to earth as Rip Van Winkle returned to his boyhood home in the Catskills, having mysteriously traveled into the future.

This radical new view of time undercuts our common-sense understanding of the world. But relativity is true, nevertheless. All the exotic phenomena predicted by it occur. We cannot, for practical reasons, send a grandfather into space for a high-speed trip, but we can—and have—put a clock on the space shuttle. And it returns, running behind the clocks that stayed on earth.

"Henceforth," wrote the great mathematician Hermann Minkowski, "space by itself and time by itself, are doomed to fade away into mere shadows, and only a kind of union of the two will preserve an independent reality." But we mortals do not live in "spacetime." We live in space—good old Isaac Newton space; and, as for time, time just passes. The phenomena of relativity are not a part of our everyday lives. We are all too prone to generalizing—often incorrectly—from an oversimplified set of limited experiences.

Einstein's second relativity paper, "Does the Inertia of a Body Depend on its Energy Content?," further elaborated his new theory and presented the single most famous formula in all of science: e = mc2, the source of the tremendous energies released in the atomic bombs. Initially Einstein believed that it would not be practical to convert matter into energy. But less than four decades later he was persuaded to write his famous letter to President Roosevelt recommending that the United States begin work on the atomic bomb.

These five papers, and the more than two dozen additional lesser publications that appeared in Einstein's miracle year, were like a marching band announcing the arrival of a new celebrity. Slowly, gradually, and with minimal fanfare at first, Einstein the physicist began to take his place in the scientific community.

5. Myth-Making

But the years of anxious searching in the dark, with their intense longing, their alternations of confidence and exhaustion, and the final emergence into the light—only those who have experienced it can understand that.

—Albert Einstein, quoted in Journey into Gravity and Spacetime, by John Archibald Wheeler.

Einstein's 1905 papers were remarkable in two ways. In the first, and most obvious sense, they extended the boundaries of our knowledge. But the relativity papers, as they gradually were digested, fundamentally changed the way physicists thought about the world and how best to understand it. The central idea was symmetry. Einstein had this way of looking at the world and seeing relationships and patterns that others had missed, or failed to appreciate. Within spacetime, there exists a symmetry between space and time; similarly, the energy paper derived a symmetry between energy and matter. Symmetries simplify the world by turning two, or more, things into one.

Symmetry was the central inspiration for Einstein's single greatest achievement, the theory of General Relativity, on which he began work in 1907. (The relativity of 1905 is known as "special" relativity because it cannot be applied to objects that are accelerating. It deals only with the special case of objects moving at constant speeds.)

General Relativity began with what Einstein would later call "the happiest thought of my life," namely a deep symmetry between acceleration and gravity. A man falling freely—plummeting from a plane, for example—cannot feel his own weight; it is as if gravity has been shut off. But a man in a gravity-free environment—in a box in outer space, say—would feel his weight if the box were accelerating, as if a new gravity had been turned on. (This is how artificial gravity is created in space stations.)

Einstein labored in virtual isolation for 11 years to develop the mathematical structure of the theory. It was an achievement that still stands as perhaps the most remarkable creation of any single human mind, captivating all who master it.

In the wake of Eddington's stunning confirmation of General Relativity, interest in the theory began to grow. Mathematical physicists mastered its esoteric foundations and began to look for interesting solutions to its challenging equations. One such solution suggested that the universe might be expanding, a possibility rejected by Einstein that had him incorporating a fudge factor into the theory to do away with the offending possibility. In 1929, however, Edwin Hubble discovered that the universe was indeed expanding, and Einstein ruefully removed the fudge factor two years later, calling it the "greatest blunder of my career." Within a decade, the Belgian priest-astrophysicist Georges LeMaitre and the Russian émigré George Gamow were speculating that an expanding universe could have originated in what one detractor was disparaging as a "Big Bang." The Big Bang was confirmed in 1965 when two scientists at Bell Labs detected and measured the radiation emitted by the associated "explosion." Since then, its fortunes have steadily improved until now General Relativity and the Big Bang are two of the most well established ideas in physics, firmly rooted in a myriad of careful observations. Very recent measurements have offered even further support.

6. Looking Down from Olympus

If I would be a young man again and had to decide how to make my living, I would not try to become a scientist or scholar or teacher. I would rather choose to be a plumber or a peddler in the hope to find that modest degree of independence still available under present circumstances.

—Albert Einstein, quoted in The Reporter magazine (November 18, 1954).

Einstein, like the theory of General Relativity he had so heroically created, increased in stature as the 20th century unfolded, his power and cultural relevance growing steadily. A brief but abortive attempt in the 1920s to dismiss Einstein's physics as too "Jewish" clarified for the great physicist the value of intellectual freedom, a cause for which he fought his entire life. In the 1930s Einstein was instrumental in bringing scores of Jewish physicists from Europe to America, greatly advancing science in the New World; in the 1940s his seminal letter to Roosevelt would help launch the Manhattan Project, the success of which led him to lament, "If only I had known, I should have become a watchmaker." Queries to a young Jean Piaget on how children understand time launched Piaget on the work that eventually made him famous. In 1952, the sad-eyed guru was offered the presidency of the recently created state of Israel, declining with the claim he was "deeply touched by the offer but not suited for the position." "Politics," he liked to say, "is more difficult than physics." On the eve of his death in 1955, Einstein co-authored a political document with Bertrand Russell. The Russell-Einstein Manifesto, as it came to be known, was released in London on July 9, 1955 and argued for peace through disarmament, encouraging governments "to find peaceful means for the settlement of all matters of dispute between them." In a way that seems strangely appropriate, the great physicist remained naïve and optimistic to his death.

In the history of the legend that was and is Albert Einstein, his physical passing in 1955 seems almost irrelevant, like moving to a new address or getting married. He took up residence, first in

Western culture and then globally, in a way that makes him seem eternally present. Physicists today who struggle to reconcile quantum theory with general relativity do so knowing that Einstein worked on this problem for half a century. Breakthroughs from repeated applications of symmetry continue to affirm Einstein's fundamental orientation toward the underlying beauty and simplicity of the world. Calendars are still printed every year with Einstein's wise countenance looking out from above proverbially wise sayings: "The most incomprehensible thing about the universe is its comprehensibility," or "Everything should be made as simple as possible, but not simpler."

It is hard to imagine, exactly 100 years after his *annus mirabilis*, that there could be another Einstein. Surely there are a finite number of one-man revolutions available in science, and perhaps there are no more to be had. But then, 100 years ago, it was hard to imagine another Newton.

The Newtons and Einsteins of the world are always larger than life, nurtured in part by our perennial need for heros. Perhaps, when we go too long without one, it is that much easier to find, in the groundbreaking work of yet another patent clerk, the mythology of genius.