# Einstein and Newton:

# TWO LEGACIES

Albert Einstein was born in Ulm, Germany, the son of a factory owner, on March 14, 1879. Centennial celebrations are planned around the world. Einstein's most revolutionary work, contained in a handful of articles, was published before he was 40; in his last decades, however, he shunned the quantum mechanics he had helped to develop. Why? Part of the answer can be gleaned from a 1927 essay he wrote for the *Manchester Guardian* on the bicentennial of Isaac Newton's death. We reprint it here, annotated and slightly abridged by the editors, following an introduction by the Smithsonian Institution's Paul Forman.

*by Paul Forman*

Albert Einstein composed tributes to many individuals but to only three men he had never met—Johannes Kepler (d. 1630), who formulated the laws of planetary motion; Isaac Newton (d. 1727), who derived those laws from general dynamic principles and a law of universal gravitation; and James Clerk Maxwell (d. 1879), who, by a mathematical formulation of Michael Faraday's concept of a physical state pervading all matter and space (a "field"), obtained the laws of electromagnetism. For Einstein, these three men defined the enterprise he adopted as his own life's work: the construction of a *complete* description of physical reality using the concepts of space, time, force, material point (matter), and continuous field.

Of these three men, it was Newton whom Einstein regarded as the father of theoretical physics. For it was Newton who invented differential calculus and thus laid the foundations of a mechanics providing continuous, pictorial, causal descriptions of physical processes. A profound natural philosopher, he brought undreamed of order and interconnection into Nature through his hypothesis of universal gravitation. With a single

mathematical law, he accounted for the tides, the motion of objects on earth, and the paths of bodies in the heavens. And yet—and this especially excited Einstein's admiration—Newton was not so blinded by the brilliance of his achievement that he overlooked the logical and metaphysical weaknesses of his own mechanical axioms and physical hypotheses.

Still, Einstein, intent upon seeing in Newton the origins of his own scientific goals and tools, attributed to his hero much that does not fit the historical person. In his 1927 essay, he misrepresents Newton most seriously by attributing to him his own, deterministic belief that the entire future evolution of the universe could be calculated given its configuration and motion at any given moment. So rigorous an exclusion of God from any further influence upon the world He had created was, to Newton's mind, too close to atheism.

### Spraining the Brain

Nor did Einstein appreciate how extremely different Newton's personality and values were from his own. Newton largely neglected the mathematical physics for which he was uniquely suited, devoting himself instead to intellectually less demanding investigations, such as Biblical chronology. In 1695, at the age of 53, Newton obtained appointment as Master of the Mint and abandoned his scholarly life in Cambridge for the bustle of London. Einstein, by contrast, never shirked the extraordinarily difficult assignment he had given himself. Nor did he bolster himself with romantic illusions about the nature of that task: "He who knows the pleasures of intellectual work does not go chasing after it," he often remarked. But an unceasing "spraining of the brain," he would add, was the fate of "a man of my type."

In their relations with people, too, Einstein and Newton could scarcely have been less alike. The Briton was celibate, secretive, vindictive, variously fawning or haughty, tolerant only of sycophants—in short, a cold and unattractive personality. Einstein, on the other hand, at least in his mature years, displayed the greatest warmth, gentleness, openness to criti-

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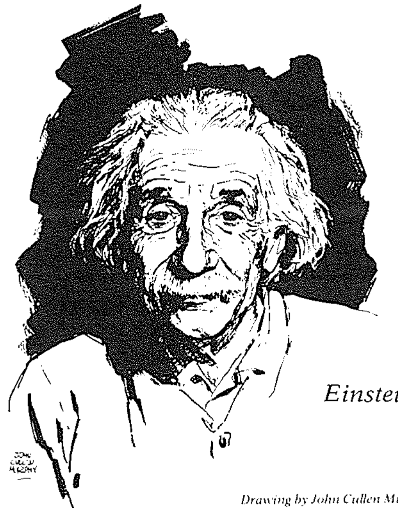


*Einstein at age 70.*

Drawing by John Cullen Murphy.

cism, disregard for social rank and convention, and the deepest concern for humanity. Only with his fellow physicists was Einstein's tone a bit impatient, ironic, mocking. Only from them did he *expect* something, and almost invariably they disappointed him. With his work, they seldom could help; their own seemed largely directed by academic fashion and opportunism.

As a theoretical physicist, Einstein was almost entirely self-taught. His formal higher education was limited to a four-year course at the Swiss Federal Polytechnic in Zurich, where he was trained as a high school teacher of mathematics and physics. A mediocre student, he neglected his course work (with first-rate scientists) in order to pursue his private study of the classics of theoretical physics, including the works of Gustav Kirchhoff, Hermann Helmholtz, and Heinrich Hertz.

Following graduation in 1900, Einstein lived and worked for nine intensely creative and productive years in a nonacademic environment; most of this time was spent as a patent examiner at the Swiss patent office in Bern. Here the young "Technical Expert, 3rd class" conceived the special theory of relativity (from which he deduced the equivalence of mass and energy, $E=mc^2$); a general statistical mechanics (from which he deduced the laws governing the fluctuations in the motion of a particle suspended in a fluid, and thus made possible the experimental determination of the size of a molecule); and the idea that light really consists of particles, whose behavior is wave-like only on the average (thus explaining the circumstances

under which electrons are released from metals by light, and several other puzzling phenomena).

Remarkably, Einstein's first papers on all three subjects appeared not only in a single year—his twenty-seventh, 1905—but also in a single volume of the German journal, *Annalen der Physik*. (Compare Newton, who, in a single fruitful year—his twenty-fourth, 1666—discovered that "white" light is actually a rainbow of colors, invented differential and integral calculus, and worked out the basic laws of mechanics as well as the law of universal gravitation.)

In view of the novelty and ultimate importance of Einstein's ideas, in particular those three which he exposed almost simultaneously in 1905, it would be easy, and it certainly is common, to describe Einstein as a revolutionary in science. Yet, considering the case more closely, a revolutionary guise seems improbable for Einstein, who in these early years was isolated socially and intellectually from his fellow physicists. In fact, while his academic colleagues were behaving like self-conscious revolutionaries—striving to replace the old, mechanistic world view with one founded upon electromagnetism and the newly discovered electron—Einstein sustained himself with the notion that he was within the high tradition of theoretical physics, extending and perfecting the mechanical picture deriving ultimately from Newton. Certainly that was the intent behind his special theory of relativity, which, by obtaining the same results as were derived from the electromagnetic world view, but without any assumptions about the nature of the forces or substances involved, pulled the rug out from under the electromagnetic program.

Philosophically, Einstein was much influenced in these years by Ernst Mach (1836–1916) and Henri Poincaré (1854–1912), who persuasively expressed certain views which were widespread among late 19th- and early 20th-century physicists. Mach and Poincaré emphasized, on the one hand, that only concepts and constructs capable of being defined in terms of sensory experiences—i.e., in terms of possible experiments—were to be admitted into science. On the other hand, they believed, the actual choice of concepts, especially fundamental concepts, was to a large degree arbitrary, a matter of convention. But while his fellow physicists persisted in this view, which they eventually regarded as strikingly confirmed by Einstein's own work, Einstein himself gradually moved "backward" philosophically to the *realist* view that scientific constructs—the conservation of energy, say, or the concept of the atom—approximate entities and connections that really exist.

In one crucial respect, Einstein never deviated from that "outmoded" realist metaphysics, namely, in his adherence to causality. In the years before the First World War, Einstein's contemporaries declared the notion of cause-and-effect to have no place in physics, which, they alleged, dealt only with functional relations. Yet in these years, Einstein framed profound questions and hypotheses based on the idea of causality, believing firmly that the world is *necessarily* thus and not otherwise.

### God Doesn't Play Dice

"What is the reason," he was forever asking, "that Nature behaves in this or that way?" And if no sufficient reason was to be found, he said, then Nature's laws must be other than we have supposed. To carry out these logical investigations, Einstein adopted, primarily from Newton, the so-called thought experiment—an experiment conducted only in the mind, using idealized instruments (such as absolutely rigid rods and perfectly accurate clocks)—and made it his characteristic tool of conceptual analysis.

In 1909, Einstein received his first academic appointment; four years later, he was offered the most prestigious and advantageous position in the world of science, the research professorship in the Prussian Academy of Sciences, which he held until the Nazis came to power in 1933. It was, however, with very mixed feelings that, in the spring of 1914, Einstein moved from Zurich to Berlin, to the capital of the country whose citizenship he had deliberately renounced as a youth of 16 and whose social-political system he still disliked. Within a few months, the break-up of his marriage and the outbreak of the First World War would further aggravate his sense of personal isolation. Einstein threw himself into his work and brought the general theory of relativity to completion. The end of the war gave Germany a (short-lived) democratic republic. It also marked the beginning of Einstein's world renown—a result of the confirmation, by British scientists observing the total eclipse of the sun in 1919, of Einstein's prediction that starlight passing close to the sun is deflected by its gravitational field.

Meanwhile, with the end of World War I, there swept over Germany a new romanticism—a "life philosophy" whose most popular prophets were Oswald Spengler, Ludwig Klages, Hermann Keyserling, and Rudolf Steiner. In their view, theoretical physics was the deplorable epitome of Western culture's logical, abstract, unintuitive, and, above all, causal mode of apprehending the world. Surprisingly, many theoretical physicists in

*Engraving of Isaac Newton by Sir Godfrey Kneller.*

German-speaking Central Europe proved susceptible to this anti-scientific spirit.

The concept of causality at issue in the 1920s, the concept many physicists then wished to banish from science, was not that old-fashioned, metaphysical notion of cause-and-effect which they (excepting Einstein!) had eliminated years before. Rather it was the essential, indeed indispensible, principle of functional relationship, of unambiguous determination of physical events. Causality in this heretofore accepted sense meant lawfulness: A system arranged in a definite way would evolve in a definite way. It meant that experiments can be replicated; that there are fixed rules; that God, in Einstein's celebrated phrase, "doesn't play dice."

As noted, Einstein's opponents, the anticausalist physicists were impelled to a radical departure from the traditional goal of science, not primarily by problems or theories within physics itself but by pressure from the general intellectual environment. Justification of the anticausalist position from within physical theory became possible only in 1925–26 with the development of quantum mechanics. Early in the following year—as Einstein was composing the essay on Newton reprinted here—Werner Heisenberg derived his "uncertainty principle," which denies the possibility of predicting in all detail the results of any experiment.

In this "violent dispute over the significance of the law of causality," as physicist Max Planck described it, it was, by and large, the politically and culturally more "progressive" in-

dividuals who followed the fashion of the times, while more conservative figures insisted upon the traditional goals of their discipline. Thus, ironically, Einstein's allies were not his closest personal friends. They included not only Max Planck, whom he respected, but also Wilhelm Wien, whose personality and political views he found distasteful. Indeed, the subject and theme of the opening paragraph of Einstein's essay on Newton are virtually identical with those of several of Wien's popular essays and addresses of the preceding year or two.

### In Defense of Reason

Einstein's essay on Newton, then, is only secondarily a tribute to the scientist; it is primarily a reaffirmation of allegiance to the goal of a causal description of Nature. It is the admonition of an avowed causalist to his contemporaries—layman and physicist alike. Thirteen times in less than 3,000 words we read "cause," "causality," or "causation." Fifteen years later, in 1942, when Einstein again wrote on Newton—on the occasion of the tricentenary of his birth—neither "causality" nor any of its variants were cited even once. What had changed? Not Einstein's understanding of the historical Newton—anyway, not significantly—but rather the world in which Einstein lived.

By the end of 1942, Einstein had been in the United States for nine years. In November 1940, as a recently naturalized citizen, he had cast his vote for a third term for Roosevelt. He welcomed America's belated entry into World War II and contributed both his prestige and his scientific knowledge to the war effort. "Causality" seemed a terribly abstract notion compared to the more immediate and comprehensive value, "reason," which was at that hour gravely menaced (as indeed it had been during the entire previous decade) by totalitarian dogma. Thus it was "reason," not "causality" that Einstein chose to defend in his second tribute to Newton.

Perhaps more important, Einstein's essay of 1927 belongs, essentially, to that early, acute phase of the causality crisis before the establishment of the quantum mechanics—a phase of ideological competition characterized by manifestos against causality and exhortations in its favor. In the following years, the Heisenberg-Schrödinger noncausal mechanics proved extraordinarily successful in accounting for physical processes at the atomic level and in withstanding Einstein's most determined efforts, over several years, to find gaps in its logical structure. By 1935, the debate between Einstein and his fellow physicists had shifted to a metaphysical plane. *They* maintained

that a theory which accounts for the results of all experiments—as quantum mechanics could—is complete. But Einstein contended that a theory which gives no account of the real world, but only of our imperfect (probabilistic) knowledge of that world, is incomplete.

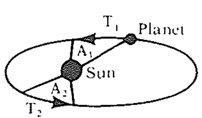
Partly for this reason, the world's most renowned scientist, during the last 20 years of his life, felt almost completely isolated in his scientific work and goals. The situation began to change, however, shortly before Einstein's death in 1955. Today, the subjects of Einstein's own scientific efforts—the general theory of relativity and the unification of the various physical forces (gravitation, electromagnetism, and so on) in a single field theory—have gradually become two of the most important foci of attention in physics.

More to the point of Einstein's 1927 essay, physicists since the early 1950s have been less and less joyful about the indeterminism of our most fundamental theory, more and more ready to declare this feature of quantum mechanics unsatisfactory.

# ON NEWTON (1927)

*by Albert Einstein*

It is just two hundred years ago that Newton closed his eyes. We feel impelled at such a moment to remember this brilliant genius, who determined the course of Western thought, research, and practice like no one else before or since. Destiny placed him at a turning point in the history of the human intellect: Before Newton, there existed no self-contained system of physical causality that was somehow capable of representing any of the deeper features of the empirical world.




If $T_1 = T_2$, $A_1 = A_2$

Newton's object was to answer the question: Is there any simple rule by which one can calculate the movements of the heavenly bodies in our planetary system completely, when the state of motion of all these bodies at one moment is known? Kepler's empirical laws of planetary movement, deduced from Tycho