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TIME BANDITS

What were Einstein and Gödel talking about?

By Jim Holt
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Einstein said he went to his office at the Institute for Advanced Study "just to have the privilege of walking home with Kurt Gödel." Photograph from Getty Images

In 1933, with his great scientific discoveries behind him, Albert Einstein came to America. He spent the last twenty-two years of his life in Princeton, New Jersey, where he had been recruited as the star member of the Institute for Advanced Study. Einstein was reasonably content with his new milieu, taking its pretensions in stride. "Princeton is a wonderful piece of earth, and at the same time an exceedingly amusing ceremonial backwater of tiny spindle-shanked with a leisurely walk from his house, at 115 Mercer Street, to his office at the institute. He was by then one of the most famous and, with his distinctive appearance—the whirl of pillow-combed hair, the baggy pants held up by suspenders—most recognizable people in the world.

A decade after arriving in Princeton, Einstein acquired a walking companion, a much younger man who, next to the rumpled Einstein, cut a dapper figure in a white linen suit and matching fedora. The two would talk animatedly in German on their morning amble to the institute and again, later in the day, on their way homeward. The man in the suit may not have been recognized by many townspeople, but Einstein addressed him as a peer, someone who, like him, had single-handedly launched a conceptual revolution. If Einstein had upended our everyday notions about the physical world with his theory of relativity, the younger man, Kurt Gödel, had had a similarly subversive effect on our understanding of the abstract world of mathematics.

Gödel, who has often been called the greatest logician since Aristotle, was a strange and ultimately tragic man. Whereas Einstein was gregarious and full of laughter, Gödel was solemn, solitary, and pessimistic. Einstein, a passionate amateur violinist, loved Beethoven and Mozart. Gödel's taste ran in another direction: his favorite movie was Walt Disney's "Snow White and the Seven Dwarfs," and when his wife put a pink flamingo in their front yard he pronounced it *furchtbar herzig*—"awfully charming." Einstein freely indulged his appetite for heavy German cooking; Gödel subsisted on a valetudinarian's diet of butter, baby food, and laxatives. Although Einstein's private life was not without its complications, outwardly he was jolly and at home in the world. Gödel, by contrast, had a tendency toward paranoia. He believed in ghosts; he had a morbid dread of being poisoned by refrigerator gases; he refused to go out when certain distinguished mathematicians were in town, apparently out of concern that they might try to kill him. "Every chaos is a wrong appearance," he insisted—the paranoiac's first axiom.

Although other members of the institute found the gloomy logician baffling and unapproachable, Einstein told people that he went to his office "just to have the privilege of walking home with Kurt Gödel." Part of the reason, it seems, was that Gödel was undaunted by Einstein's reputation and did not hesitate to challenge his ideas. As another member of the institute, the physicist Freeman Dyson, observed, "Gödel was . . . the only one of our colleagues who walked and talked on equal terms with Einstein." But if Einstein and Gödel seemed to exist on a higher plane than the rest of humanity, it was also true that they had become, in Einstein's words, "museum pieces." Einstein never accepted the quantum theory of Niels Bohr and Werner Heisenberg. Gödel believed that mathematical abstractions were every bit as real as tables and chairs, a view that philosophers had come to regard as laughably naïve. Both Gödel and Einstein insisted that the world is independent of our minds, yet rationally organized and open to human understanding. United by a shared sense of intellectual isolation, they found solace in their companionship. "They didn't want to speak to anybody else," another member of the institute said. "They only wanted to speak to each other."

People wondered what they spoke about. Politics was presumably one theme. (Einstein, who supported Adlai Stevenson, was exasperated when Gödel chose to vote for Dwight Eisenhower in 1952.) Physics was no doubt another. Gödel was well versed in the subject; he shared Einstein's mistrust of the quantum theory, but he was also skeptical of the older physicist's ambition to supersede it with a "unified field theory" that would encompass all known forces in a deterministic framework. Both were attracted to problems that were, in Einstein's words, of "genuine importance," problems pertaining to the most basic elements of reality. Gödel was especially preoccupied by the nature of time, which, he told a friend, was *the* philosophical question. How could such a "mysterious and seemingly self-contradictory" thing, he wondered, "form the basis of the world's and our own existence"? That was a matter in which Einstein had shown some expertise.

A century ago, in 1905, Einstein proved that time, as it had been understood by scientist and layman alike, was a fiction. And this was scarcely his only achievement that year, which John S. Rigden skillfully chronicles, month by month, in "Einstein 1905: The Standard of Greatness" (Harvard; $21.95). As it began, Einstein, twenty-five years old, was employed as an inspector in a patent office in Bern, Switzerland. Having earlier failed to get his doctorate in physics, he had temporarily given up on the idea of an academic career, telling a friend that "the whole comedy has become boring." He had recently read a book by Henri Poincaré, a French mathematician of enormous reputation, which identified three fundamental unsolved problems in science. The first concerned the "photoelectric effect": how did ultraviolet light knock electrons off the surface of a piece of metal? The second concerned "Brownian motion": why did pollen particles suspended in water move about in a random zigzag pattern? The third concerned the "luminiferous ether" that was supposed to fill all of space and serve as the medium through which light waves moved, the way sound waves move through air, or ocean waves through water: why had experiments failed to detect the earth's motion through this ether?

Each of these problems had the potential to reveal what Einstein held to be the underlying simplicity of nature. Working alone, apart from the scientific community, the unknown junior clerk rapidly managed to dispatch all three. His solutions were presented in four papers, written in the months of March, April, May, and June of 1905. In his March paper, on the photoelectric effect, he deduced that light came in discrete particles, which were later dubbed "photons." In his April and May papers, he established once and for all the reality of atoms, giving a theoretical estimate of their size and showing how their bumping around caused Brownian motion. In his June paper, on the ether problem, he unveiled his theory of relativity. Then, as a sort of encore, he published a three-page note in September containing the most famous equation of all time: $E = mc2$.

All of these papers had a touch of magic about them, and upset deeply held convictions in the physics community. Yet, for scope and audacity, Einstein's June paper stood out. In thirty succinct pages, he completely rewrote the laws of physics, beginning with two stark principles. First, the laws of physics are absolute: the same laws must be valid for all observers. Second, the speed of light is absolute; it, too, is the same for all observers. The second principle, though less obvious, had the same sort of logic to recommend it. Since light is an electromagnetic wave (this had been known since the nineteenth century), its speed is fixed by the laws of electromagnetism; those laws ought to be the same for all observers; and therefore everyone should see light moving at the same speed, regardless of the frame of reference. Still, it was bold of Einstein to embrace the light principle, for its consequences seemed downright absurd.

Suppose—to make things vivid—that the speed of light is a hundred miles an hour. Now suppose I am standing by the side of the road and I see a light beam pass by at this speed. Then I see you chasing after it in a car at sixty miles an hour. To me, it appears that the light beam is outpacing you by forty miles an hour. But you, from inside your car, must see the beam escaping you at a hundred miles an hour, just as you would if you were standing still: that is what the light principle demands. What if you gun your engine and speed up to ninety-nine miles an hour? Now I see the beam of light outpacing you by just one mile an hour. Yet to you, inside the car, the beam is still racing ahead at a hundred miles an hour, despite your increased speed. How can this be? Speed, of course, equals distance divided by time. Evidently, the faster you go in your car, the shorter your ruler must become and the slower your clock must tick relative to mine; that is the only way we can continue to agree on the speed of light. (If I were to pull out a pair of binoculars and look at your speeding car, I would actually see its length contracted and you moving in slow motion inside.) So Einstein set about recasting the laws of physics accordingly. To make these laws absolute, he made distance and time relative.

It was the sacrifice of absolute time that was most stunning. Isaac Newton believed that time was regulated by a sort of cosmic grandfather clock. "Absolute, true, mathematical time, of itself, and from its own nature, flows equably without relation to anything external," he declared at the beginning of his "Principia." Einstein, however, realized that our idea of time is something we abstract from our experience with rhythmic phenomena: heartbeats, planetary rotations and revolutions, the ticking of clocks. Time judgments always come down to judgments of simultaneity. "If, for instance, I say, 'That train arrives here at 7 o'clock,' I mean something like this: 'The pointing of the small hand of my watch to 7 and the arrival of the train are simultaneous events,' " Einstein wrote in the June paper. If the events in question are at some distance from one another, judgments of simultaneity can be made only by sending light signals back and forth. Working from his two basic principles, Einstein proved that whether an observer deems two events to be happening "at the same time" depends on his state of motion. In other words, there is no universal *now*. With different observers slicing up the timescape into "past," "present," and "future" in different ways, it seems to follow that all moments coexist with equal reality.

Einstein's conclusions were the product of pure thought, proceeding from the most austere assumptions about nature. In the century since he derived them, they have been precisely confirmed by experiment after experiment. Yet his June, 1905, paper on relativity was rejected when he submitted it as a dissertation. (He then submitted his April paper, on the size of atoms, which he thought would be less likely to startle the examiners; they accepted it only after he added one sentence to meet the length threshold.) When Einstein was awarded the 1921 Nobel Prize in Physics, it was for his work on the photoelectric effect. The Swedish Academy forbade him to make any mention of relativity in his acceptance speech. As it happened, Einstein was unable to attend the ceremony in Stockholm. He gave his Nobel lecture in Gothenburg, with King Gustav V seated in the front row. The King wanted to learn about relativity, and Einstein obliged him.

In 1906, the year after Einstein's annus mirabilis, Kurt Gödel was born in the city of Brno (now in the Czech Republic). As Rebecca Goldstein recounts in her enthralling intellectual biography "Incompleteness: The Proof and Paradox of Kurt Gödel" (Atlas/Norton; $22.95), Kurt was both an inquisitive child—his parents and brother gave him the nickname *der Herr Warum*, "Mr. Why?"—and a nervous one. At the age of five, he seems to have suffered a mild anxiety neurosis. At eight, he had a terrifying bout of rheumatic fever, which left him with the lifelong conviction that his heart had been fatally damaged.

Gödel entered the University of Vienna in 1924. He had intended to study physics, but he was soon seduced by the beauties of mathematics, and especially by the notion that abstractions like numbers and circles had a perfect, timeless existence independent of the human mind. This doctrine, which is called Platonism, because it descends from Plato's theory of ideas, has always been popular among mathematicians. In the philosophical world of nineteen-twenties Vienna, however, it was considered distinctly old-fashioned. Among the many intellectual movements that flourished in the city's rich café culture, one of the most prominent was the Vienna Circle, a group of thinkers united in their belief that philosophy must be cleansed of metaphysics and made over in the image of science. Under the influence of Ludwig Wittgenstein, their reluctant guru, the members of the Vienna Circle regarded mathematics as a game played with symbols, a more intricate version of chess. What made a proposition like "2 + 2 = 4" true, they held, was not that it correctly described some abstract world of numbers but that it could be derived in a logical system according to certain rules.

Gödel was introduced into the Vienna Circle by one of his professors, but he kept quiet about his Platonist views. Being both rigorous and averse to controversy, he did not like to argue his convictions unless he had an airtight way of demonstrating that they were valid. But how could one demonstrate that mathematics could not be reduced to the artifices of logic? Gödel's strategy—one of "heart-stopping beauty," as Goldstein justly observes—was to use logic against itself. Beginning with a logical system for mathematics, one presumed to be free of contradictions, he invented an ingenious scheme that allowed the formulas in it to engage in a sort of double speak. A formula that said something about numbers could also, in this scheme, be interpreted as saying something about other formulas and how they were logically related to one another. In fact, as Gödel showed, a numerical formula could even be made to say something about itself. (Goldstein compares this to a play in which the characters are also actors in a play within the play; if the playwright is sufficiently clever, the lines the actors speak in the play within the play can be interpreted as having a "real life" meaning in the play proper.) Having painstakingly built this apparatus of mathematical self-reference, Gödel came up with an astonishing twist: he produced a formula that, while ostensibly saying something about numbers, also says, "I am not provable." At first, this looks like a paradox, recalling as it does the proverbial Cretan who announces, "All Cretans are liars." But Gödel's self-referential formula comments on its provability, not on its truthfulness. Could it be lying? No, because if it were, that would mean it could be proved, which would make it true. So, in asserting that it cannot be proved, it has to be telling the truth. But the truth of this proposition can be seen only from outside the logical system. Inside the system, it is neither provable nor disprovable. The system, then, is incomplete. The conclusion—that no logical system can capture all the truths of mathematics—is known as the first incompleteness theorem. Gödel also proved that no logical system for mathematics could, by its own devices, be shown to be free from inconsistency, a result known as the second incompleteness theorem.

Wittgenstein once averred that "there can *never* be surprises in logic." But Gödel's incompleteness theorems did come as a surprise. In fact, when the fledgling logician presented them at a conference in the German city of Königsberg in 1930, almost no one was able to make any sense of them. What could it mean to say that a mathematical proposition was true if there was no possibility of proving it? The very idea seemed absurd. Even the once great logician Bertrand Russell was baffled; he seems to have been under the misapprehension that Gödel had detected an inconsistency in mathematics. "Are we to think that 2 + 2 is not 4, but 4.001?" Russell asked decades later in dismay, adding that he was "glad [he] was no longer working at mathematical logic." As the significance of Gödel's theorems began to sink in, words like "debacle," "catastrophe," and "nightmare" were bandied about. It had been an article of faith that, armed with logic, mathematicians could in principle resolve any conundrum at all—that in mathematics, as it had been famously declared, there was no *ignorabimus*. Gödel's theorems seemed to have shattered this ideal of complete knowledge.

That was not the way Gödel saw it. He believed he had shown that mathematics has a robust reality that transcends any system of logic. But logic, he was convinced, is not the only route to knowledge of this reality; we also have something like an extrasensory perception of it, which he called "mathematical intuition." It is this faculty of intuition that allows us to see, for example, that the formula saying "I am not provable" must be true, even though it defies proof within the system where it lives. Some thinkers (like the physicist Roger Penrose) have taken this theme further, maintaining that Gödel's incompleteness theorems have profound implications for the nature of the human mind. Our mental powers, it is argued, must outstrip those of any computer, since a computer is just a logical system running on hardware, and our minds can arrive at truths that are beyond the reach of a logical system.

Gödel was twenty-four when he proved his incompleteness theorems (a bit younger than Einstein was when he created relativity theory). At the time, much to the disapproval of his strict Lutheran parents, he was courting an older Catholic divorcée by the name of Adele, who, to top things off, was employed as a dancer in a Viennese night club called Der Nachtfalter (the Moth). The political situation in Austria was becoming ever more chaotic with Hitler's rise to power in Germany, although Gödel seems scarcely to have noticed. In 1936, the Vienna Circle dissolved, after its founder was assassinated by a deranged student. Two years later came the Anschluss. The perilousness of the times was finally borne in upon Gödel when a band of Nazi youths roughed him up and knocked off his glasses, before retreating under the umbrella blows of Adele. He resolved to leave for Princeton, where he had been offered a position by the Institute for Advanced Study. But, the war having broken out, he judged it too risky to cross the Atlantic. So the now married couple took the long way around, traversing Russia, the Pacific, and the United States, and finally arriving in Princeton in early 1940. At the institute, Gödel was given an office almost directly above Einstein's. For the rest of his life he rarely left Princeton, which he came to find "ten times more congenial" than his once beloved Vienna.

"There it was, inconceivably, *K. Goedel*, listed just like any other name in the bright orange Princeton community phonebook," writes Goldstein, who came to Princeton University as a graduate student of philosophy in the early nineteen-seventies. (It's the setting of her novel "The Mind-Body Problem.") "It was like opening up the local phonebook and finding *B. Spinoza* or *I. Newton*." Although Gödel was still little known in the world at large, he had a godlike status among the cognoscenti. "I once found the philosopher Richard Rorty standing in a bit of a daze in Davidson's food market," Goldstein writes. "He told me in hushed tones that he'd just seen Gödel in the frozen food aisle."

So naïve and otherworldly was the great logician that Einstein felt obliged to help look after the practical aspects of his life. One much retailed story concerns Gödel's decision after the war to become an American citizen. The character witnesses at his hearing were to be Einstein and Oskar Morgenstern, one of the founders of game theory. Gödel took the matter of citizenship with great solemnity, preparing for the exam by making a close study of the United States Constitution. On the eve of the hearing, he called Morgenstern in an agitated state, saying he had found an "inconsistency" in the Constitution, one that could allow a dictatorship to arise. Morgenstern was amused, but he realized that Gödel was serious and urged him not to mention it to the judge, fearing that it would jeopardize Gödel's citizenship bid. On the short drive to Trenton the next day, with Morgenstern serving as chauffeur, Einstein tried to distract Gödel with jokes. When they arrived at the courthouse, the judge was impressed by Gödel's eminent witnesses, and he invited the trio into his chambers. After some small talk, he said to Gödel, "Up to now you have held German citizenship."

No, Gödel corrected, Austrian.

"In any case, it was under an evil dictatorship," the judge continued. "Fortunately that's not possible in America."

"On the contrary, I can prove it is possible!" Gödel exclaimed, and he began describing the constitutional loophole he had descried. But the judge told the examinee that "he needn't go into that," and Einstein and Morgenstern succeeded in quieting him down. A few months later, Gödel took his oath of citizenship.

Around the same time that Gödel was studying the Constitution, he was also taking a close look at Einstein's relativity theory. The key principle of relativity is that the laws of physics should be the same for all observers. When Einstein first formulated the principle in his revolutionary 1905 paper, he restricted "all observers" to those who were moving uniformly relative to one another—that is, in a straight line and at a constant speed. But he soon realized that this restriction was arbitrary. If the laws of physics were to provide a truly objective description of nature, they ought to be valid for observers moving in any way relative to one another—spinning, accelerating, spiralling, whatever. It was thus that Einstein made the transition from his "special" theory of relativity of 1905 to his "general" theory, whose equations he worked out over the next decade and published in 1916. What made those equations so powerful was that they explained gravity, the force that governs the over-all shape of the cosmos.

Decades later, Gödel, walking with Einstein, had the privilege of picking up the subtleties of relativity theory from the master himself. Einstein had shown that the flow of time depended on motion and gravity, and that the division of events into "past" and "future" was relative. Gödel took a more radical view: he believed that time, as it was intuitively understood, did not exist *at all.* As usual, he was not content with a mere verbal argument.

Philosophers ranging from Parmenides, in ancient times, to Immanuel Kant, in the eighteenth century, and on to J. M. E. McTaggart, at the beginning of the twentieth century, had produced such arguments, inconclusively. Gödel wanted a proof that had the rigor and certainty of mathematics. And he saw just what he wanted lurking within relativity theory. He presented his argument to Einstein for his seventieth birthday, in 1949, along with an etching. (Gödel's wife had knitted Einstein a sweater, but she decided not to send it.)

What Gödel found was the possibility of a hitherto unimaginable kind of universe. The equations of general relativity can be solved in a variety of ways. Each solution is, in effect, a model of how the universe might be. Einstein, who believed on philosophical grounds that the universe was eternal and unchanging, had tinkered with his equations so that they would yield such a model—a move he later called "my greatest blunder." Another physicist (a Jesuit priest, as it happens) found a solution corresponding to an expanding universe born at some moment in the finite past. Since this solution, which has come to be known as the Big Bang model, was consistent with what astronomers observed, it seemed to be the one that described the actual cosmos. But Gödel came up with a third kind of solution to Einstein's equations, one in which the universe was not expanding but rotating. (The centrifugal force arising from the rotation was what kept everything from collapsing under the force of gravity.) An observer in this universe would see all the galaxies slowly spinning around him; he would know it was the universe doing the spinning, and not himself, because he would feel no dizziness. What makes this rotating universe truly weird, Gödel showed, is the way its geometry mixes up space and time. By completing a sufficiently long round trip in a rocket ship, a resident of Gödel's universe could travel back to any point in his own past.

Einstein was not entirely pleased with the news that his equations permitted something as Alice in Wonderland-like as spatial paths that looped backward in time; in fact, he confessed to being "disturbed" by Gödel's universe. Other physicists marvelled that time travel, previously the stuff of science fiction, was apparently consistent with the laws of physics. (Then they started worrying about what would happen if you went back to a time before you were born and killed your own grandfather.) Gödel himself drew a different moral. If time travel is possible, he submitted, then time itself is impossible. A past that can be revisited has not really passed. And the fact that the actual universe is expanding, rather than rotating, is irrelevant. Time, like God, is either necessary or nothing; if it disappears in one possible universe, it is undermined in every possible universe, including our own.

Gödel's conclusion went almost entirely unnoticed at the time, but it has since found a passionate champion in Palle Yourgrau, a professor of philosophy at Brandeis. In "A World Without Time: The Forgotten Legacy of Gödel and Einstein" (Perseus; $24), Yourgrau does his best to redress his fellow-philosophers' neglect of the case that Gödel made against time. The "deafening silence," he submits, can be blamed on the philosophical prejudices of the era. Behind all the esoteric mathematics, Gödel's reasoning looked suspiciously metaphysical. To this day, Yourgrau complains, Gödel is treated with condescension by philosophers, who regard him, in the words of one, as "a logician par excellence but a philosophical fool." After ably tracing Gödel's life, his logical achievements, and his friendship with Einstein, Yourgrau elaborately defends his importance as a philosopher of time. "In a deep sense," he concludes, "we all do live in Gödel's universe."

Gödel's strange cosmological gift was received by Einstein at a bleak time in his life. His quest for a unified theory of physics was proving fruitless, and his opposition to quantum theory alienated him from the mainstream of physics. Family life provided little consolation. His two marriages had been failures; a daughter born out of wedlock seems to have disappeared from history; of his two sons one was schizophrenic, the other estranged. Einstein's circle of friends had shrunk to Gödel and a few others. One of them was Queen Elisabeth of Belgium, to whom he confided, in March, 1955, that "the exaggerated esteem in which my lifework is held makes me very ill at ease. I feel compelled to think of myself as an involuntary swindler." He died a month later, at the age of seventy-six. When Gödel and another colleague went to his office at the institute to deal with his papers, they found the blackboard covered with dead-end equations.

After Einstein's death, Gödel became ever more withdrawn. He preferred to conduct all conversations by telephone, even if his interlocutor was a few feet distant. When he especially wanted to avoid someone, he would schedule a rendezvous at a precise time and place, and then make sure he was somewhere far away. The honors the world wished to bestow upon him made him chary. He did show up to collect an honorary doctorate in 1953 from Harvard, where his incompleteness theorems were hailed as the most important mathematical discovery of the previous hundred years; but he later complained of being "thrust quite undeservedly into the most highly bellicose company" of John Foster Dulles, a co-honoree. When he was awarded the National Medal of Science, in 1975, he refused to go to Washington to meet Gerald Ford at the White House, despite the offer of a chauffeur for him and his wife. He had hallucinatory episodes and talked darkly of certain forces at work in the world "directly submerging the good." Fearing that there was a plot to poison him, he persistently refused to eat. Finally, looking like (in the words of a friend) "a living corpse," he was taken to the Princeton Hospital. There, two weeks later, on January 14, 1978, he succumbed to self-starvation. According to his death certificate, the cause of death was "malnutrition and inanition" brought on by "personality disturbance."

A certain futility marked the last years of both Gödel and Einstein. What may have been most futile, however, was their willed belief in the unreality of time. The temptation was understandable. If time is merely in our minds, perhaps we can hope to escape it into a timeless eternity. Then we could say, like William Blake, "I see the Past, Present and Future, existing all at once / Before me." In Gödel's case, Rebecca Goldstein speculates, it may have been his childhood terror of a fatally damaged heart that attracted him to the idea of a timeless universe. Toward the end of his life, he told one confidant that he had long awaited an epiphany that would enable him to see the world in a new light, but that it never came. Einstein, too, was unable to make a clean break with time. "To those of us who believe in physics," he wrote to the widow of a friend who had recently died, "this separation between past, present, and future is only an illusion, if a stubborn one." When his own turn came, a couple of weeks later, he said, "It is time to go." ♦

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