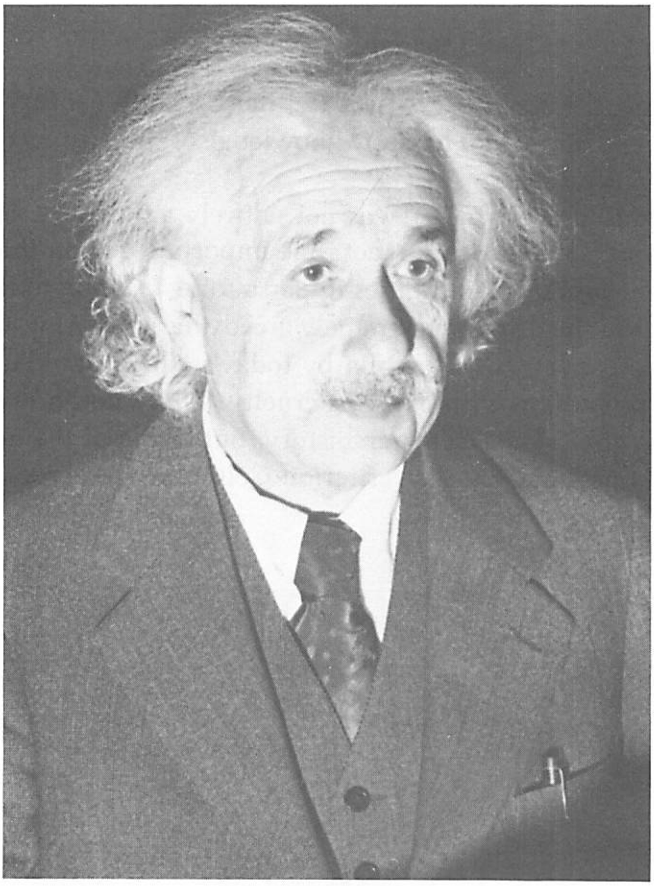


10 ALBERT EINSTEIN

1879-1955

Albert Einstein, the greatest scientist of the twentieth century and one of the supreme intellects of all time, is best known for his theory of relativity. There are actually two theories involved: the special theory of relativity, formulated in 1905, and the general theory of relativity, formulated in 1915, which might better be called Einstein's law of gravitation. Both theories are highly complicated, and no attempt will be made to explain them here; however, a few comments on special relativity are in order.

A familiar maxim has it that "everything is relative." Einstein's theory, however, is not a repetition of this philosophical platitude, but rather a precise mathematical statement of the way in which scientific measurements are relative. It is obvious that subjective perceptions of time and space depend on the observer. Before Einstein, however, most people had always believed that behind these subjective impressions were real distances and an absolute time, which accurate instruments could measure objectively. Einstein's theory revolutionized scientific thought by denying the existence of any absolute time. The following example may illustrate just how radically his theory revised our ideas of time and space.

Imagine a spaceship, spaceship *X*, moving away from Earth at a speed of 100,000 kilometers per second. The speed is measured by observers on both the spaceship and on Earth, and their measurements agree. Meanwhile, another spaceship, spaceship *Y*, is moving in exactly the same direction as spaceship *X*, but at a much greater speed. If observers on Earth measure the speed of spaceship *Y*, they find that it is moving away from the Earth at a speed of 180,000 kilometers per second. Observers on spaceship *Y* will reach the same conclusion.

Now, as both spaceships are moving in the same direction, it would seem that the difference in their speeds is 80,000 kilometers per second, and that the faster ship must be moving away from the slower ship at this rate.

However, Einstein's theory predicts that when observations are taken from the two spaceships, observers on both ships will agree that the distance between them is increasing at the rate of 100,000 kilometers per second, not 80,000 kilometers per second.

Now, on the face of it such a result is ridiculous, and the reader may suspect that some trick of wording is involved, or that some significant details of the problem have not been mentioned. Not at all. The result has nothing to do with the details of construction of the spaceships or with the forces used to propel them. Nor is it due to any errors of observation, nor to any defects in the measuring instruments. No trick is involved. According to Einstein, the foregoing result (which can readily be computed from his formula for the composition of velocities) is a consequence only of the basic nature of time and space.

Now, all of this may seem awfully theoretical, and indeed for years many persons dismissed the theory of relativity as a sort of "ivory tower" hypothesis, which had no practical significance. No one, of course, has made that mistake since 1945, when atomic bombs were dropped on Hiroshima and Nagasaki. One of the conclusions of Einstein's theory of relativity is that matter and energy are in a certain sense equivalent, and the relation between them is given by the formula $E = Mc^2$ in which E represents energy, M equals mass, and c represents the speed of light. Now since c, which is equal to 186,000 miles per second, is a very large number, c^2 (that is, c times c) is a simply enormous number. It follows that even the partial conversion of a small amount of matter will release tremendous quantities of energy.

One cannot, of course, build an atomic bomb or a nuclear power plant simply from the formula $E = Mc^2$. It must be borne in mind, too, that many other persons played important roles in the development of atomic energy; however, the importance of Einstein's contribution is indisputable. Furthermore, it was Einstein's letter to President Roosevelt, in 1939, pointing out the possibility of developing atomic weapons and stressing the importance of the United States developing such weapons before the Germans did, which helped launch the Manhattan Project, and which led to the development of the first atomic bomb.

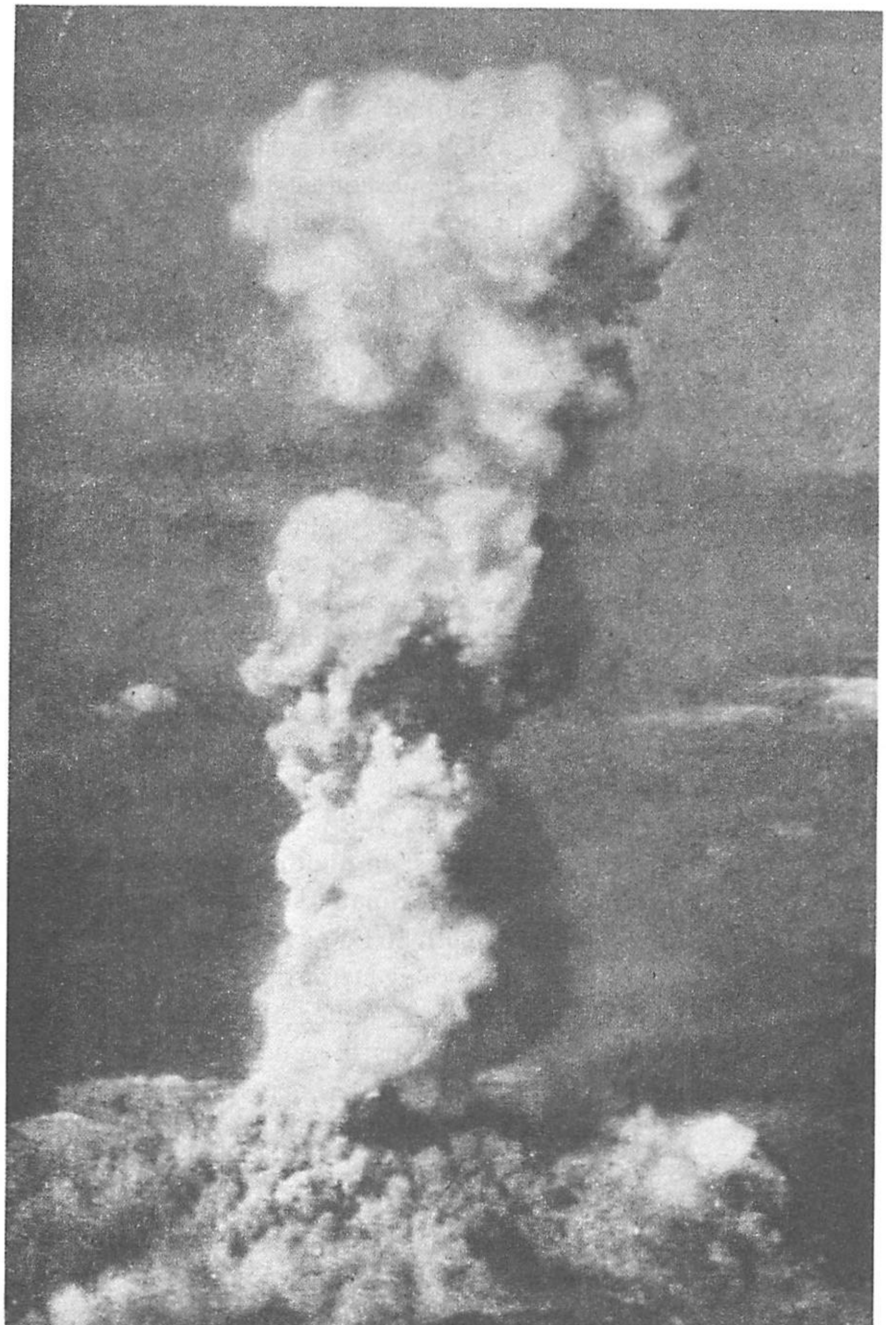
Special relativity aroused heated controversy, but on one point everyone was agreed; it was the most mind-boggling scientific theory that would ever be invented. But everyone was wrong, for Einstein's general theory of relativity takes as a starting point the premise that gravitational effects are not due to physical forces in the normal sense of the word, but rather result from a curvature of space itself—a truly astonishing idea!

How can one measure a curvature of space itself? What does it even *mean* to say that space is curved? Einstein had not only advanced such a theory, but he had put his theory in a clear mathematical form, from which explicit predictions could be made and his hypothesis tested. Subsequent observations—the most celebrated of which are those made during total eclipses of the sun—have repeatedly confirmed the correctness of Einstein's equations.

The general theory of relativity stands apart in several ways from all other scientific laws. In the first place, Einstein derived his theory not on the basis of careful experiments, but rather on grounds of symmetry and mathematical elegance—on rationalistic grounds, as the Greek philosophers and the medieval scholastics had attempted to do. (In so doing, he ran counter to the basically empirical outlook of modern science.) But whereas the Greeks, in their search for beauty and symmetry, had never managed to find a mechanical theory that could survive the crucial test of experiment, Einstein's theory has so far successfully withstood every test. One result of Einstein's approach is that the general theory of relativity is generally acknowledged to be the most beautiful, elegant, powerful, and intellectually satisfying of all scientific theories.

General relativity stands apart in another way also. Most other scientific laws are only approximately valid. They hold in many circumstances, but not in all. So far as we know, however, there are no exceptions at all to the general theory of relativity. There is no known circumstance, either theoretical or experimental, in which the predictions of general relativity are only approximately valid. Future experiments may mar the theory's perfect record; but so far the general theory of relativity remains the closest approach to ultimate truth that any scientist has yet devised.

Though Einstein is best known for his theories of relativity, his other scientific achievements would have won him renown as a scientist in any case. In fact, Einstein was awarded the Nobel Prize in physics primarily for his paper explaining the photoelectric effect, an important phenomenon that had previously puzzled physicists. In that paper, he postulated the existence of



The atomic bomb explodes at Hiroshima, August 6, 1945.

photons, or particles of light. Since it had been long established through interference experiments that light consisted of electromagnetic waves, and since it was considered "obvious" that waves and particles were antithetical concepts, Einstein's hypothesis represented a radical and paradoxical break with classical theory. Not only did his photoelectric law turn out to have important practical applications, but his hypothesis of the photon had a major influence on the development of quantum theory, and is today an integral part of that theory.

In evaluating Einstein's importance, a comparison with Isaac Newton is revealing. Newton's theories were basically easy to understand, and his genius lay in being the first to develop them. Einstein's theories of relativity, on the other hand, are extremely difficult to understand, even when they are carefully explained. How much more difficult, therefore, to devise them originally! While some of Newton's ideas were in strong contradiction to the prevailing scientific ideas of his time, his theory never appeared to lack self-consistency. The theory of relativity, on the other hand, abounds with paradoxes. It was part of Einstein's genius that at the beginning, when his ideas were still the untested hypothesis of an unknown teenager, he did not let these apparent contradictions cause him to discard his theories. Rather, he carefully thought them through until he could show that these contradictions were apparent only, and that in each case there was a subtle but correct way of resolving the paradox.

Today, we think of Einstein's theory as being basically more "correct" than Newton's. Why, then, is Einstein lower on this list? Primarily because it was Newton's theories that laid the groundwork for modern science and technology. Most of modern technology would be the same today had only Newton's work been done, and not Einstein's.

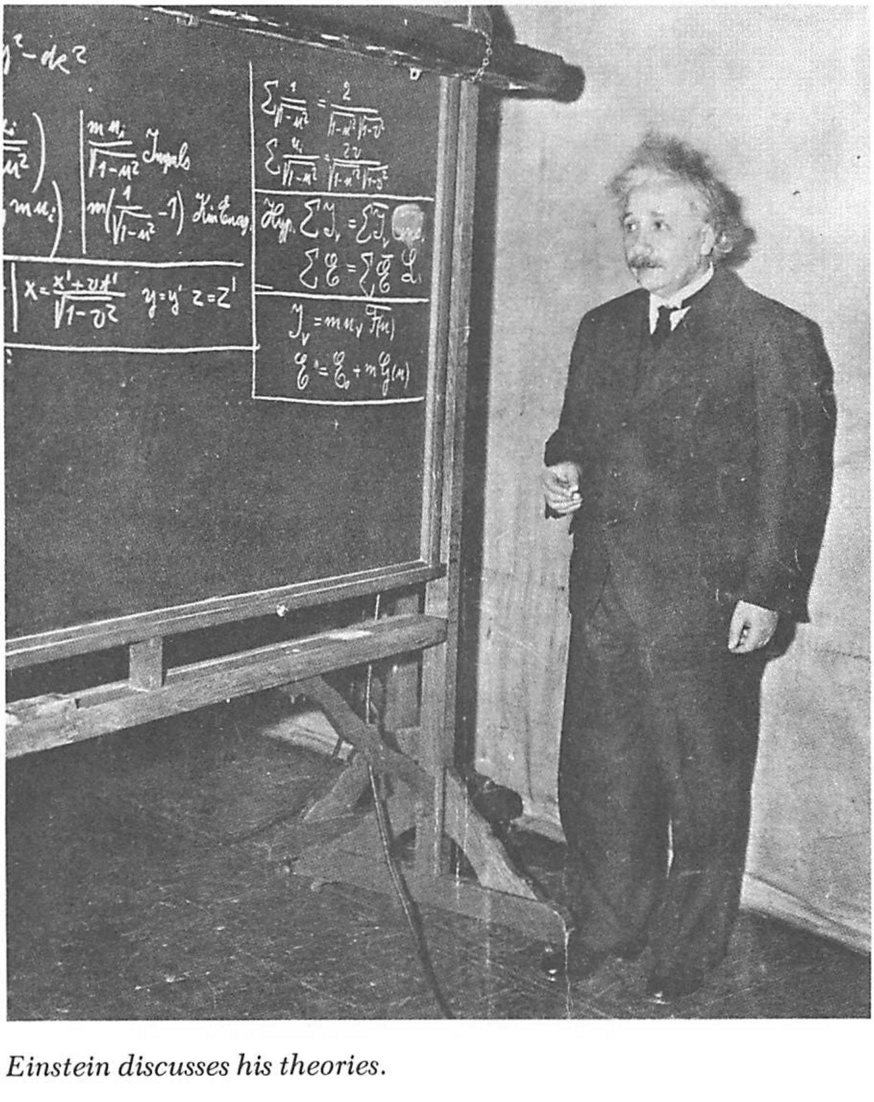
There is another factor which affects Einstein's place on this list. In most cases, many men have contributed to the development of an important idea, as was obviously the case in the history of socialism, or in the development of the theory of electricity and magnetism. Though Einstein does not deserve 100 percent of the credit for the invention of the theory of relativity, he certainly deserves most of it. It seems fair to say that, to a larger degree than is the case for any other ideas of comparable importance, the theories of relativity are primarily the creation of a single, outstanding genius.

Einstein was born in 1879, in the city of Ulm, Germany. He attended high school in Switzerland, and became a Swiss citizen in the year 1900. He received his Ph.D. in 1905 from the University of Zurich, but was unable to find an academic position at that time. However, that same year, he published his papers on special relativity, on the photoelectric effect, and on the theory of Brownian motion. Within a few years, these papers, particularly the one on relativity, established his reputation as one of the most brilliant and original scientists in the world. His theories were highly controversial; no modern scientist except Darwin has ever engendered as much controversy as Einstein. In spite of this, in 1913 he was appointed a professor at the University of Berlin, at the same time becoming director of the Kaiser Wilheim Institute of Physics and a member of the Prussian Academy of Science. These posts left him free to devote his full time to research, if he so chose.

The German government had little reason to regret offering Einstein this unusually generous package, for just two years later he succeeded in formulating the general theory of relativity, and in 1921 he was awarded the Nobel Prize. For the last half of his life, Einstein was world-famous, in all probability the most famous scientist that ever lived.

Since Einstein was Jewish, his situation in Germany became precarious when Hitler rose to power. In 1933, he moved to Princeton, New Jersey, to work at the Institute for Advanced Study, and in 1940 he became a United States citizen. Einstein's first marriage ended in divorce; his second was apparently happy. He had two children, both boys. He died in 1955, in Princeton.

Einstein was always interested in the human world about him, and frequently expressed his views on political matters. He was a consistent opponent of political tyranny, an ardent pacifist, and a firm supporter of Zionism. In matters of dress and social conventions, he was a marked individualist. He had a fine sense of humor, a becoming modesty, and some talent as a violinist. The inscription on Newton's tomb might be applied even more appropriately to Einstein: "Let mortals rejoice that so great an ornament to the human race has existed!"



Einstein discusses his theories.