**Further Reading**

Bauer, H. “Paul Ehrlich’s Influence on Chemistry and Biochemistry.” *Annals of the New York Academy of Sciences* 59 (1954): 150-167. This detailed biography concentrates on the ways in which the field of medicine has advanced as a result of Ehrlich’s contributions.


Marquardt, Martha. *Paul Ehrlich*. New York: Henry Schuman, 1951. Personal recollections of Ehrlich by his secretary. Biographical details are balanced by interesting anecdotes that provide insights into the personality of this eccentric scientist.


See also: Sir Macfarlane Burnet; Gerhard Domagk; Willem Einthoven; Sir Alexander Fleming; Baron Florey; Peyton Rous; Jonas Salk; Theobald Smith; Selman Abraham Waksman; George Hoyt Whipple.

**Related articles** in *Great Events from History: The Twentieth Century*:


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**Albert Einstein**

German-born American physicist

Einstein was the principal founder of modern theoretical physics, and his theory of relativity fundamentally changed the understanding of the physical world. His stature as a scientist, together with his strong humanitarian stance on major political and social issues, including nuclear energy and weaponry, made him one of the outstanding thinkers of the twentieth century.

**Born:** March 14, 1879; Ulm, Germany

**Died:** April 18, 1955; Princeton, New Jersey

**Areas of achievement:** Physics, astronomy, mathematics, peace advocacy

**Early Life**

Albert Einstein (IN-stin) was born in Ulm, Germany, to moderately prosperous Jewish parents. His early childhood did nothing to suggest future greatness; he was late learning to speak, and his parents feared that he might be backward. He was apparently fascinated at the age of five by the mysterious workings of a pocket compass, and at the age of twelve he became enthralled by a book on Euclidean geometry. In his childhood, he also learned to play the violin and so acquired a love of music that was to last throughout his life.

In 1888, Einstein was sent to the Luitpold gymnasium in Munich, but he disliked the regimented and authoritarian atmosphere of the school. Even at this young age he seems to have exhibited the independence of mind, the ability to question basic assumptions and to trust in his own intuition, which were to lead him to his brilliant achievements. He left the gymnasium in 1895, without gaining a diploma. His father tried to send him to a technical school in Zurich, but he failed the entrance examination, in spite of high scores on mathematics and physics. The following year he was more successful, and in 1900, he received the diploma that qualified him to teach. To his disappointment, however, he failed to obtain a teaching position at the school.

In 1901, Einstein became a Swiss citizen. (He had renounced his German citizenship in 1896.) In 1902, after temporary positions at schools in Winterthur and Schaffhausen, he secured a post as a technical expert in the Swiss patent office in Berne, where he was to remain for seven years. In the following year, he married Mileva Maric, a friend from his student days in Zurich, and in 1904 the first of their two sons was born.

Einstein’s first scientific paper had been published in 1901, and he had also submitted a Ph.D. thesis to the Uni-
University of Zurich. While he was working quietly in the patent office, however, isolated from the mainstream of contemporary physics, there was little to suggest the achievements of 1905, which were to shake the scientific world to its core.

Life’s Work
In 1905, Einstein published three major papers, any one of which would have established his place in the history of science. The first, which was to bring him the Nobel Prize in Physics in 1921, explained the photoelectric effect and formed the basis for much of quantum mechanics. It also led to the development of television. The second concerned statistical mechanics and explained the phenomenon known as Brownian motion, the erratic movement of pollen grains when immersed in water. Einstein’s calculations gave convincing evidence for the existence of atoms.

It was the third paper, however, containing the special theory of relativity, that was to revolutionize understandings of the nature of the physical world. The theory stated that the speed of light is the same for all observers, and is not dependent on the speed of the source of the light, or of the observer, and that the laws of nature (both the Newtonian laws of mechanics and Maxwell’s equations for the electromagnetic field) remain the same for all uniformly moving systems. This theory meant that the concept of absolute space and time had to be abandoned because it did not remain valid for speeds approaching those of light. Events that happen at the same time for one observer do not do so for another observer moving at high speed in respect of the first. Einstein also demonstrated that a moving clock would appear to run slow compared with an identical clock at rest with respect to the observer, and a measuring rod would vary in length according to the velocity of the frame of reference in which it was measured.

In another paper published in 1905, Einstein stated, by the famous equation \( E = mc^2 \), that mass and energy are equivalent. Each can be transferred into the other because mass is a form of concentrated energy. This equation suggested to others the possibility of the development of immensely powerful explosives.

Such was Einstein’s achievement at the age of twenty-six. There had not been a year like it since Newton published his Principia in 1687. The scientific world quickly recognized him as a creative genius, and in 1909 he took up his first academic position, as associate professor of theoretical physics at the University of Zurich. After two more positions, one in Prague and the other in Zurich, he became a member of the Prussian Academy of Sciences and moved to Berlin in 1914.

In the meantime, Einstein had been working to extend the special theory of relativity to include new laws of gravitation, and the general theory of relativity was published in 1916. It was one of the greatest intellectual productions ever achieved by one person, and its picture of the universe as a four-dimensional space-time continuum lies at the foundation of all modern views of the universe. The theory stated that large masses produce a gravitational field around them, which results in the curvature of space-time. This gravitational field acts on objects and on light rays; starlight, for example, is deflected when passing through the gravitational field of the sun.

In 1919, the general theory received experimental confirmation from a team of British astronomers. Suddenly, the world awoke to the implications of Einstein’s work, and he found himself internationally celebrated as the greatest scientist of the day. During the early 1920’s, he traveled extensively in Europe, the Far East, and the Americas, hailed everywhere as genius, sage, and hero. With his untidy shock of hair—formerly black, now graying—rising from a high forehead, his deep brown eyes, and small mustache, he made a striking figure. It
was not only his superior intellect that aroused public recognition and respect but also his simple good nature, nobility, and kindliness. However, Einstein, always modest, was genuinely astonished at the attention he received.

It was during his travels in the 1920’s that the other great concerns of Einstein’s life came to the fore. A man of deep humanitarian instincts, he did not isolate himself from the turbulent political events around him. During World War I, he had spoken out against militarism and nationalism. Now, as a famous person, he once more took up the cause of pacifism, expressing his opinion openly, caring nothing for popularity. Einstein’s other lasting concern was the promotion of Zionism, and his tour of the United States in 1921 was undertaken in part to raise funds for Hebrew University. These activities made him a target for fierce abuse from the Nazis, and even outside Germany, his radical political views made him a controversial figure.

When Hitler came to power in 1933, Einstein was on his third visit to the United States, and he resolved not to return to Germany. After brief stays in Belgium and England, he left Europe for the last time, to become a professor at the Institute for Advanced Study at Princeton. He continued to lend his support to the cause of justice and freedom, helping Jewish refugees whenever he could, and he modified his former pacifism in the face of the threat of Nazi domination. In 1939, he was persuaded to write a letter to President Franklin D. Roosevelt, alerting him to the military potential of atomic energy. (Einstein played no part, however, in the research that led to the development of the atomic bomb, which merely verified the truth of his famous equation.) After the war, he remained tirelessly devoted to the cause of world peace, and proposed a world government in which all countries were to agree to forfeit part of their national sovereignty.

His later scientific career took two main directions. First, he was so deeply convinced of nature’s fundamental simplicity that he labored unsuccessfully for thirty years in an attempt to construct a unified field theory. Second, he could not accept one of the fundamental results of quantum theory, that the interaction of subatomic particles could be predicted only in terms of probabilities. “God does not play dice with the world,” he remarked. Many of his colleagues thought him stubborn, but nevertheless he remained a revered figure; his reputation as a genius who also possessed wisdom and saintliness never left him, neither in life nor in death.

**Significance**

Einstein’s scientific achievements place him alongside such figures as Copernicus, Galileo, and Newton, as one who vastly enlarged the scope of human knowledge about the physical universe. In this respect he is a universal figure and belongs to no country. It is perhaps appropriate, however, that Einstein, a German Jew to whom destiny had decreed a nomadic existence, eventually found a permanent home in the United States. His links with his adopted country—he became a U.S. citizen in 1941—are profound. He was the most illustrious of the hundreds of intellectuals who fled from Europe be-

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**Einstein on the Scientific Impulse**

*In an article published in Scientific American in 1950—more than three decades after he first presented his general theory of relativity—Albert Einstein philosophized on the human impulse toward theoretical science.*

What, then, impels us to devise theory after theory? Why do we devise theories at all? The answer to the latter question is simply: Because we enjoy “comprehending,” i.e., reducing phenomena by the process of logic to something already known or (apparently) evident. New theories are first of all necessary when we encounter new facts which cannot be explained by existing theories. But this motivation for setting up new theories is, so to speak, trivial, imposed from without. There is another, more subtle motive of no less importance. This is the striving toward unification and simplification of the premises of the theory as a whole.

There exists a passion for comprehension, just as there exists a passion for music. That passion is rather common in children, but gets lost in most people later on. Without this passion, there would be neither mathematics nor natural science. Time and again the passion for understanding has led to the illusion that man is able to comprehend the objective world rationally, by pure thought, without any empirical foundations—in short, by metaphysics. I believe that every true theorist is a kind of tamed metaphysicist, no matter how pure a “positivist” he may fancy himself. The metaphysicist believes that the logically simple is also the real. The tamed metaphysicist believes that not all that is logically simple is embodied in experienced reality, but that the totality of all sensory experience can be “comprehended” on the basis of a conceptual system built on premises of great simplicity. The skeptic will say that this is a “miracle creed.” Admittedly so, but it is a miracle creed which has been borne out to an amazing extent by the development of science.
fore World War II, and his presence at the newly formed Institute for Advanced Study, which marked a new period of development for American research and education, played a key role in attracting other eminent scholars.

Einstein had always viewed the United States as a bulwark of democracy and individual freedom, and in the debates that divided the country in the postwar decade—particularly debates on the Cold War and the use of nuclear energy—his was a consistent voice for sanity and decency in human affairs. He spoke out for freedom of thought and speech in the McCarthy era, when he feared that the United States was betraying its own ideals, and he continued to urge scientists to consider the social responsibilities of their work in the atomic age. In his final year, he and a group of leading scientists signed a statement, known as the Russell-Einstein Manifesto, warning about the terrible consequences of nuclear war. This led to the Pugwash Conference on science and world affairs in 1957, in which for the first time scientists from East and West met to discuss nuclear arms. A series of influential conferences followed, and the Pugwash movement has continued its activities ever since.

—Bryan Aubrey

FURTHER READING


Clark, Ronald W. Einstein: The Life and Times. New York: World, 1971. Lengthy, authoritative, and readable. Gives a balanced treatment of Einstein’s life, although the author tends to see Einstein as an idealist who was out of his depth when he entered practical politics.


Robinson, Andrew, et al. Einstein: A Hundred Years of Relativity. New York: Harry N. Abrams, 2005. One of the better books released to commemorate the one-hundredth anniversary of Einstein’s scientific paper outlining the theory of relativity. This volume includes essays by prominent physicists, including Stephen Hawking and Freeman Dyson, who discuss Einstein’s theories and influence. It also features photographs of Einstein bequeathed by him to Hebrew University in Jerusalem.

Sayen, Jamie. Einstein in America: The Scientist’s Conscience in the Age of Hitler and Hiroshima. New York: Crown, 1985. A well-researched, detailed account of Einstein’s nonscientific activities from 1933 to 1955. Gives political and historical background on issues such as Palestine, the Cold War, and McCarthyism.


SEE ALSO: Leo Baek; Niels Bohr; Percy Williams Bridgman; Louis de Broglie; Enrico Fermi; Werner Heisenberg; Gustav Hertz; Georges Lemaître; Hendrik Antoon Lorentz; Max Planck; Johannes Stark; Hideki Yukawa.

RELATED ARTICLES in Great Events from History: The Twentieth Century:

1901-1940: March, 1905: Einstein Describes the Photoelectric Effect; Fall, 1905: Einstein States


Willem Einthoven
Dutch physiologist

Accomplished in several areas of physiology, physics, and medicine, Einthoven elaborated techniques for measuring minute electrical currents in the human heart. His string galvanometer—best known in its later form as an electrocardiogram, or EKG—became the basis for modern electrocardiography and made possible great advances in combating heart disease. He was awarded the Nobel Prize in Physiology or Medicine in 1924.

Born: May 21, 1860; Semarang, Java, Dutch East Indies
Died: September 28, 1927; Leiden, the Netherlands

Areas of achievement: Physiology, medicine, physics

Early Life

There are few published details concerning the early life of Willem Einthoven (VIHL-ehm INT-hoh-vehn). He was born in Semarang, Java, the Dutch East Indies (now the Republic of Indonesia), the son of a Jewish doctor who served there as the municipal physician. When Willem was six, his father died, and four years later his mother, Louise de Vogel, left Semarang with her six children to settle among relatives in the homeland city of Utrecht, the Netherlands, where Willem received most of his early education.

On his graduation from high school in 1879, Einthoven immediately registered as a medical student at the University of Utrecht. Trim, athletic and an active sportsman, he made a wrist that he had broken in a fall the occasion for his initial medical publication. Produced in 1882, it was a study on rotations of the hand and forearm (pronation and supination) and articulation of the elbow.

A superb medical student, Einthoven was also blessed with unusually capable teachers whom he remembered fondly throughout life. Although he worked closely with the physicist Buys Ballot and with the anatomist Willem Koster, his most intensive study and experimentation came under the tutelage of Dutch ophthalmologist Hermann Snellen, whom he assisted in the medical school clinic as well as in Snellen’s private practice, and under the distinguished physiologist-ophthalmologist Franciscus Cornelius Donders. Between 1858 and 1864, Donders had variously discovered major causes of farsightedness and of astigmatism, and it was under Donders’s direction that Einthoven received his Ph.D. in medicine—cum laude—in 1885, his dissertation having been written on stereoscopy (the study of three-dimensional sight) through color differentiation.

With medical school behind him, Einthoven married his cousin, Frédérique Jeanne Louise de Vogel (with whom he eventually had three children), and prepared to settle vigorously at the age of twenty-five into his new professorship in physiology and histology at the University of Leiden—a post he occupied until his death.

Life’s Work

Einthoven’s research and writing, viewed over the full span of his career, were catholic in their breadth. His dissertation aside, he variously published results of his investigations on the physiology of the bronchial musculature, on the physiology of the eye, on the physiology of the nasal passages and the larynx, as well as on the physics of the capillary electrometer and the law of nerve energies. Thus, although his professional training had been in medicine, he revealed himself to be as much the physicist as the doctor or physician. Moreover, because he understood the history both of physiology and of physics, he clearly perceived their areas of interrelation and acted on those perceptions.