

must be chosen locally is crucial; his realization that rapid transitions lead to defects also applies to condensed-matter physics. One can replace relativistic causality with reasoning based on scaling of a system's "reflexes" that deteriorate near the critical point ("critical slowing down") or, equivalently, rely on the existence of a sonic horizon (an analogue of the causal horizon) to predict the size of the domains that break symmetry and, hence, estimate the density of defects. (See Tom's feature article, *PHYSICS TODAY*, September 2007, page 47.) The past few years have seen increasingly precise quantitative confirmations of Tom's ideas in systems that range from solid state, such as multiferroics, to Bose-Einstein condensates.

Tom's legacy is evident in the scope of his work—from the origin of fundamental forces via cosmology and particle physics to condensed matter. His contributions were recognized by numerous prizes, including the first *Nature*/NESTA lifetime achievement award for mentoring, in 2005; the American Physical Society's 2010 J. J. Sakurai Prize (shared with the other discoverers of the Higgs boson); the Royal Medal of the Royal Society in 2012; a knighthood, bestowed on him in 2014; and, posthumously, the Isaac Newton Medal of the Institute of Physics.

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Ahmed Hassan Zewail

On a summer day in 2008, during one of my stays at Caltech, I watched how Ahmed Hassan Zewail, the sole recipient of the 1999 Nobel Prize in Chemistry, welcomed an enthusiastic physics master's student from New York who wanted to meet him. I was amazed to witness Ahmed explain his research to the young man; Ahmed had the excitement, fascination, and joy of a PhD student getting his first results. That attitude embodies Ahmed's personality: a man who despite reaching the acme of prestige and international recognition kept a passion and rigor for science and contin-

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Ahmed Hassan Zewail

ued to be tremendously generous and display an intelligence of the heart in his relations with others.

Ahmed was born on 26 February 1946 in Damanhur, Egypt, and died on 2 August 2016 in Pasadena, California, from multiple myeloma. He obtained his bachelor's and master's degrees in chemistry from Alexandria University in 1967 and 1969, respectively. He then attended the University of Pennsylvania for his PhD; his thesis, on optical and magnetic resonance spectra in molecular crystals, was supervised by Robin Hochstrasser. After obtaining his doctorate in 1974, Ahmed spent two years as a postdoc in Charles Harris's group at the University of California, Berkeley, where he used, for the first time, the recently developed picosecond lasers. That experience proved crucial for his future career; in 1976 he became an assistant professor at Caltech and started picosecond laser studies of molecular systems.

From a series of experiments that he called "mind opening," Ahmed developed new concepts about molecular coherence. Those were the stepping-stones to the birth of a new field of research: femtochemistry. When the first femtosecond lasers appeared in the mid 1980s, Ahmed was well aware of the powerful tool they presented. He quickly achieved a series of breakthroughs by visualizing in real time the nuclear motion of simple molecular systems.

Ahmed then studied atomic edifices of ever-greater complexity—large molecules, clusters, proteins, and solutions.

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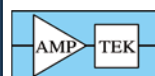


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He intuitively selected the ideal system that would best demonstrate a given phenomenon or effect. His discoveries, which he conveyed with contagious enthusiasm, opened new avenues for research in biology, condensed-matter physics, and materials science. Ahmed ushered in a genuine transformation in science, which the Nobel Committee recognized in 1999—barely 12 years after his first groundbreaking experiments.

While the femtochemistry revolution was unfolding in the early 1990s, Ahmed already had the next step in mind. He was aware that optical-domain spectroscopy—in the UV, visible, and IR—does not deliver molecular structure and that the ideal approach would be to combine the atomic-scale temporal resolution of femtoseconds with the atomic-scale spatial resolution of x-ray or electron-based structural methods. His choice of electron-based approaches was daring and visionary; most of the community of ultrafast scientists, including me, adopted ultrashort pulses of x rays.

Ahmed's big challenge was to generate sufficiently short electron pulses that would not be destroyed by space-charge effects. He overcame that difficulty, and

just as he did in the case of femtochemistry, he achieved milestones first by studying simple molecular systems and then gradually increasing their complexity. By the early 2000s, he conducted the first ultrafast electron diffraction and crystallography studies of systems such as water and molecular adsorbates on surfaces and fatty-acid bilayers.

Ahmed's next big breakthrough would be to implement real-time and real-space electron microscopy, which he dubbed four-dimensional electron microscopy. The approach embodies, in my and others' opinion, a true transformation in the field of structural dynamics. That work was Ahmed's masterpiece, as it allowed him to unravel a large class of dynamical phenomena in biology, materials science, and nanoscience.

What is remarkable about Ahmed's achievements is the number of new, electron-based methods he initiated. They include ultrafast electron energy-loss spectroscopy, photon-induced near-field electron microscopy, ultrafast electron nanodiffraction, Kikuchi diffraction, and scanning ultrafast electron microscopy. At his Nobel lecture in 1999, Ahmed jokingly thanked the Nobel Committee for

not mentioning in the prize citation his work on ultrafast electron diffraction. It is the deep conviction of many that he would have received a second Nobel for his extraordinary breakthroughs in electron-based science.

In recognition of his scientific accomplishments, which included more than 600 articles and a dozen books, Ahmed received over a hundred prizes, awards, and honorary degrees. Many of his former students and postdocs—his "science family," as he called them—are leaders in their fields throughout the world.

Even before receiving the Nobel Prize, Ahmed traveled around the globe as an ambassador of science. He later served as the first US science envoy to the Middle East in 2009–11, a member of President Obama's Council of Advisors on Science and Technology in 2009–13, and a member of UN secretary general Ban Ki-moon's Scientific Advisory Board in 2013.

Ahmed had another facet to his personality: his commitment to the "have-nots," as he would say. He gave special attention to the Arab world and particularly to Egypt, his birthplace. He believed that supporting and encouraging science in the developing world was of central importance to helping its people. Toward that effort, he donated some of his Nobel Prize money for scholarships in Egypt.

During Egypt's tumultuous events of 2010–13, Ahmed made it clear that he had no interest in becoming a politician. For him, pursuing excellence in science was the best way to help his homeland. After spending years dealing with bureaucratic and political hurdles, Ahmed achieved his long-term dream of building a world-class Egyptian university, the Zewail City of Science and Technology, which was inaugurated in 2011 in Giza.

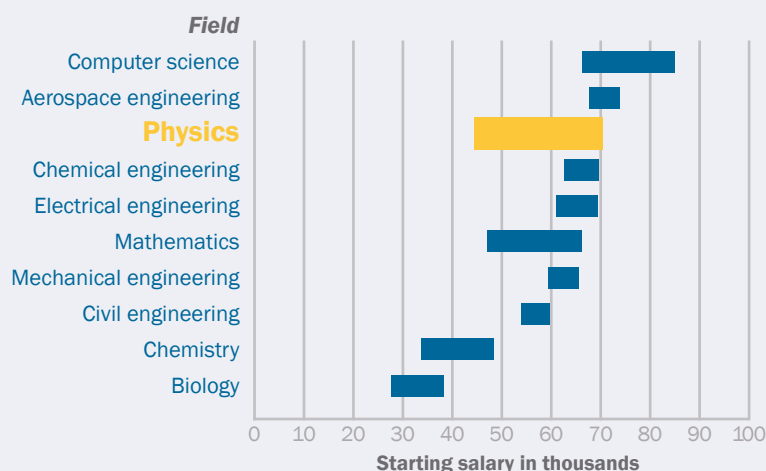
On one of the last occasions I met Ahmed, over a year ago, we spent an afternoon smoking cigars—a ritual every time we got together—and chatting about science, politics, and life in general. Although he was in declining physical health, I was profoundly impressed by his sparkling and uplifting spirit, his enthusiasm, his sense of humor, and his insightful thinking about scientific problems. In science and in the world at large, Ahmed Zewail's legacy is far-reaching and will last for generations.

Majed Chergui

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