Ahmed Hassan Zewail (1946–2016)

Egyptian-American Nobel Laureate, Ahmed Hassan Zewail known as the 'father of femtochemistry' died in USA on 2 August 2016. He leaves behind many science breakthroughs and an enduring legacy. A military funeral was held for Zewail on 7 August 2016 in Cairo, Egypt. It was attended by senior academics, military generals, members of the judiciary, family, friends and high-ranking Egyptian officials. Those attending included President Abdel Fattah el-Sisi, Prime Minister Sherif Ismail, along with former Presidents and Prime Ministers respectively.

Zewail was born on 26 February 1946, in Damanhour in the delta of the river Nile, Egypt. He grew up in Alexandria. He obtained B Sc (1967) and M Sc (1969) in chemistry from Alexandria University, Alexandria, Egypt. He then moved to the United States, where he completed his Ph D (1974) from the University of Pennsylvania, Philadelphia, under the supervision of Robin M. Hochstrasser, well-known for his pioneering work in molecular spectroscopy. For his postdoctoral research, Zewail joined the group of Charles Bonner Harris at the University of California, Berkeley, USA. Zewail and Harris worked on the theoretical and experimental aspects of the spectroscopy of pairs of molecules[1,2]. At Berkeley, Zewail and collaborators extended the concept of coherence to multidimensional systems. He joined California Institute of Technology (Caltech), Pasadena as a faculty member in 1976. At Caltech, he introduced the idea of shaped pulses to examine molecular processes using molecular coherence[3]. The works on molecular coherence eventually led to the birth of femtochemistry. This work earned Zewail the tenured position at Caltech within two years. He became a naturalized citizen of the USA on 5 March 1982. He became the first Linus Pauling Chair in Chemical Physics (1990). At the time of his death, Zewail held multiple positions: the Linus Pauling Professor of Chemistry, professor of physics, and director of the Physical Biology Center for Ultrafast Science and Technology at the California Institute of Technology.

Over the centuries chemists have studied chemical reactions in terms of the starting ingredients and the final products and occasionally by examining the transitory products. In this way of study, it is not possible to observe the actual dynamics, as the process of chemical bonding is very swift. It was then thought that the chemical reactions occurred at the time scales of molecular vibrations. A vibration of an atom in a molecule takes about 10–100 femtoseconds (10^{-15} sec). The study of chemical reactions required femtosecond lasers, which became available in the 1980s. Zewail made brilliant use of the new lasers by using them as strobe lights. He used two laser pulses for studying the chemical reactions. The stronger pulse was used to initiate the chemical reaction and the weaker pulse was used to probe

this chemical reaction. The measurements were conducted with varying time interval between the two laser pulses. This enabled the reconstruction of the different stages of the chemical reactions. Thus, one could visualize the motion of atoms in a molecular system in 'real time'. Zewail demonstrated his technique for a variety of chemical reactions from simple to very complex. The technique pioneered by Zewail is now a very widely used procedure in chemistry, biology, condensed matter physics and materials science. Using the real time information about the molecular processes, it is now possible to manipulate chemical and biological reactions. The technique has wide applications impacting the development of faster electronics[4,5]. The technique developed by Zewial is likened to Galileo's use of his telescope, which revolutionized modern astronomy. Zewail received the 1999 Chemistry Nobel Prize unshared[6]. The citation said, 'for his studies of the transition states of chemical reactions using femtosecond spectroscopy'. He is the first and only Arab to win the Nobel Prize in science. On that occasion he said, 'If you can understand the landscape of a chemical change or a biological change, you might be able to alter the landscape'.

In 2008, Zewail once again impressed the scientific community, when he and his team developed 'four dimensional electron microscopy'. The traditional electron microscopy is able to resolve structures on the atomic scale in three spatial dimension (3D). By incorporating the fourth dimension (namely time) to electron microscopy, it is possible to obtain resolutions that are 10–100 times better than those of conventional electron microscopes[7]. With this technology, it is possible to capture and recreate the movement and dynamics of fleeting changes in the structure and shape of matter, in real-time, and real-space. In recent years, Zewail conducted a wide range of studies using 4D electron microscopy, electron diffraction and related methods[8]. The femtochemistry is based on laser-light. The 4D electron microscopy is based on electrons and opened new avenues in biology, chemistry, materials science and nanoscience. This would have been Zewail's path to another Nobel Prize for his outstanding achievements using electron-based techniques[9].

For his numerous achievements (over 600 scientific papers and 16 books), Zewail received more than a hundred prizes. His many awards include the 1989 King Faisal International Prize for Science (in the subcategory physics), which he shared with Theodor Wolfgang Hänsch from Germany[10]. In 1999, Egypt bestowed upon him the highest state honour, the Grand Collar of the Nile. Egypt issued postage stamps in his hounour. His Indian honours include: Honorary Doctorate by Jadavpur University, Kolkata (2001); Sir C. V. Raman Award, Indian Institute of Science Education and Research, Kolkata (2002);

Honorary Fellow, Chemical Society of India (elected 2001); Member, Indian Academy of Sciences (elected 2001); Foreign Fellow, Indian National Science Academy (elected 2002). Zewail delivered the 'Rajiv Gandhi Science Lecture' on 17 October 2002 in Bangalore. In this lecture he acknowledged the scientific tradition and achievements of India[11].

After receiving the Nobel Prize, Zewail also devoted time to improving scientific research in Egypt[12]. He will be remembered for his public service through tireless contribution to the science and education sphere as well as for his scientific feats. In 1999, Zewail initiated the major project known as the Zewail City for Science and Technology in Giza, Egypt (http://www.zewailcity.edu.eg/). The Egyptian Cabinet has proclaimed the project as 'National Project for Scientific Renaissance'[13]. He was one of the speakers at the Opening Ceremony of the 2015 International Year of Light and Light-based Technologies[14,15]. He held high profile political appointments including: United States First Science Envoy to the Middle East (2009–2011), President Obama's Council of Advisors on Science and Technology (2009–2013) and UN Secretary General Ban Ki-moon's Scientific Advisory Board (2013–). Several prizes, schools and even localities have been named in honour of Zewail[16].

The 'Science Family' as Zewail liked to call it, consisted of his students and postdoctoral researchers, is distributed in prestigious positions across the world. He had more than three hundred collaborators from over thirty countries[16]. He is survived by his Syrian-American wife, a doctor, Dema Faham; his two daughters, Maha and Amani; and two sons, Nabeel and Hani.

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16. For a comprehensive biography, list of awards and honours and 'Science Family', visit http://www.zewail.caltech.edu/

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