Professor George William Gray CBE, FRS, FRSE

4 September 1926 – 12 May 2013

George Gray was an outstanding and pre-eminent organic chemist who became the world's leading authority on liquid crystal materials for use in displays. He invented the first stable liquid crystal materials that enabled the LCD technology used in televisions, laptop and tablet computers, mobile phones, iPods, digital clocks and watches and many other items of electronic equipment. He was also inspiring, enthusiastic and a true gentleman, blessed with Scottish charisma, a great sense of humour and considerable modesty.

Born in Denny, Scotland, to John and Jessie Gray in 1926, George picked up an enthusiasm for chemistry and molecules from his father, who owned a pharmacy in the town. This led him to study chemistry at Glasgow University, graduating with a BSc and, at the behest of Brynmor Jones, moving to University College Hull - then part of the University of London - in 1946 to resurrect their chemistry laboratories after the war. Under the tutelage of Brynmor Jones, George became fascinated by materials called liquid crystals, which were neither crystals, nor liquids, but a new, so called "mesomorphic", phase of matter. Their existence had been known since 1888, but there was almost no detailed academic knowledge about the molecular structure and properties of such materials. He was invited to stay on at Hull, as an Assistant Lecturer, and to commence research on liquid crystals for his PhD, which he received from the University of London in 1953 for a thesis entitled "Mesomorphism of Aromatic Carboxylic Acids". That same year, George married Marjorie Canavan and they remained together and raised their 3 daughters in Hull. Having achieved his PhD, George progressed, through Senior Lecturer and Reader at Hull, to become Professor of Organic Chemistry in 1978 and then GF Grant Professor of Chemistry in 1984.

George spent the 10 years after his PhD, understanding the forms of various liquid crystal molecules, what phases they exhibited and what sorts of properties they possessed. This seminal research allowed him to formulate criteria for the design and synthesis of materials with desired properties. This body of understanding was published in his book, "Molecular Structure and the Properties of Liquid Crystals" in 1962. Research on liquid crystals was then regarded as something of a backwater and he found it difficult to obtain funding for his work from the then SERC, the natural source of funding for research in chemistry. Faced with such diffidence, George sought and obtained funding from the Medical Research Council and from Reckitt and Colman to study the liquid crystal nature of the cell walls in bacteria, focusing on lipopolysaccharides in Pseudomonas Seruginosa. This also allowed him the freedom to synthesise and research the derivatisation of biphenyl and terphenyl moieties. His success at this led to him submitting a proposal to SERC, which was rejected with the advice that he should employ the services of a competent organic chemist. Since he was then a Senior Lecturer in Organic Chemistry, this was not well received, nor was it forgotten. It illustrated, however, that the members of the relevant board did not understand the rather arcane and academic science of liquid crystals. Things were about to change, however.

George's opportunity to see his academic knowledge applied came in the late 1960s, as a result of a challenge, from (the now notorious) John Stonehouse, who was the Minister of Technology, to find an alternative to the shadow mask colour TV tube, since the UK was paying royalties to use this that exceeded the development costs of Concorde. This challenge was taken up by Cyril Hilsum, an Individual Merit top scientist at the Royal Radar Establishment (RRE, subsequently RSRE, DERA and then Qinetiq) in Malvern, who convened a working party to explore whether the discovery by US researchers that a thin layer of impure liquid crystal could be used to make a crude optoelectronic display, might offer some hope for meeting this challenge. At their initial meeting, George sufficiently distinguished himself and his knowledge to be awarded an MOD contract to explore this possibility further. Concurrently, in 1971, researchers in Switzerland had discovered and published a new display mechanism, the Twisted Nematic effect. This was a pure field-effect and did not require the presence of impurities, and George focused on finding new materials for this.

A typical twisted nematic display consists of a thin layer (~ 5 microns in thickness) of a nematic liquid crystal, sealed between glass plates that have shaped layers of a transparent conductor and rubbed alignment films on their inner surfaces. The alignment layers caused the rod-like liquid crystal molecules to twist smoothly through 90^o within the layer. When placed between crossed Polaroid sheets, which normally appear black, the cell effectively untwists the sheets to allow light to pass through and give a bright OFF state. Applying a low frequency alternating voltage to selected electrodes locally creates an electric field that reorients the molecules and disrupts this twisted state, so that these activated ON areas show the black appearance of the crossed polaroids. Removing the voltage allows the surface alignment layers to reimpose the twisted OFF state. Such a display can be used with a reflector, or a backlight, behind it. The display contrast can be inverted if the Polaroid sheets are made parallel and further elements, such as tiny colour filters and Thin Film Transistors (TFTs) can be incorporated to produce complex, colour LCDs. The turn ON time depends on the strength of the applied voltage, but the turn OFF time depends principally on the layer thickness and the viscosity of the liquid crystal and may be around 10 milliseconds, or longer.

The liquid crystal materials known then had to be heated to 70^{o}C or more, usually decomposed in a few minutes and were rather viscous, which made their response sluggish. Invariably they comprised two benzene rings joined by a double, or triple, bond linkage that was easily broken by photolysis or hydrolysis. George's defining achievement was to use his deep knowledge and long experience of liquid crystals to eliminate this linkage entirely and to synthesise a number of biphenyl molecules, with a cyano group at one end, two directly coupled benzene rings in the middle and an alkyl chain of a defined length at the other. Three of these cyanobiphenyl compounds were liquid crystalline over a narrow interval at around room temperature and these were revealed to the world forty years ago in a scientific publication on 22 March 1973. Working in collaboration with scientists at the RRE, led by Peter Raynes, further compounds were synthesised and evaluated. These cyanobiphenyl compounds had a low viscosity, proved extremely stable (as George had predicted) and, formulated as eutectic mixtures, they could remain liquid crystalline from -10^{o}C to +60^{o}C. These were patented and subsequently licensed by the MOD, through the aegis of Cyril Hilsum, since the university baulked at the costs and risks involved. They were then published in the peer reviewed scientific literature.

This turned the field of research on LCDs into an expanding international activity, with adequate supplies of the materials being available, under licence, from Merck Ltd (then BDH Ltd), due to the foresight of Ben Sturgeon, their Research Director. Many companies exploited George's materials in their LCDs, the most successful being large Japanese corporations. In the UK, George, BDH, RRE and potential manufacturers participated in a consortium set up by Cyril Hilsum to advance LCD research and a number of further breakthroughs were made, all based on using materials from George and his group at Hull. Later on, George adapted his knowledge to synthesise and evaluate a variety of quite different liquid crystal materials, including new, ultrafast, ferroelectric liquid crystals and materials for large flat-panel TV screens. It can fairly be said that George's principal invention of the cyanobiphenyls enabled a multi-billion pound industry that spawned a very wide range of products now in everyday use by the young and the not so young, around the world. It is estimated that 750 million LCD products, with an estimated value of £56 billion, were manufactured worldwide during the last year. There are now many more LCDs in existence around the world than there are people! Part of George's legacy is to have enabled such a phenomenal benefit to humanity. Others may have manufactured the products, but George was the individual that created the key materials that made it possible.

George received considerable recognition for his contributions to LCD technology. Together with his principal collaborators, he won the Queen's Award to Industry for Technological Achievement in 1979 and the Rank Prize for Optoelectronics in 1980. He was elected a Fellow of the Royal Society in 1983 and a Fellow of the Royal Society of Edinburgh in 1989. He was appointed a CBE in 1991 and received honorary degrees from Hull and many other universities. He was also a Member of the Royal Irish Academy. Beyond this, he personally won the Clifford Paterson Lecture and Prize from the Royal Society in 1985 and the 1987 Royal Society Leverhulme Medal. In 2005, the Royal Society of Chemistry awarded Hull University a Historical Chemical Landmark to commemorate more than 50 years of liquid crystal research based on George's work. He also gained significant international personal recognition and was awarded the prestigious Karl Ferdinand Braun Prize in 1996 by the Society for Information Display, having received the even more prestigious Kyoto Prize for Advanced Technology in 1995. After the presentation of this, George and Marjorie travelled to Tokyo to meet with the Japanese Emperor in the Imperial Palace.

In recognition of his achievements, Hull Trains named their first British Rail Class 222 'Pioneer' high-speed train *Professor George Gray* and the British Liquid Crystal Society honoured him by creating their George W Gray Medal, awarded for contributions to liquid crystal research and technology.

George retired from the University of Hull in 1990 and was succeeded by John Goodby, his former research student, whom he had previously managed to attract back to Hull, from his work at Bell Research Laboratories in the USA, based on an industrial funding package. George became both an Honorary Professor at Hull and a Visiting Professor at Southampton University. He also moved to Poole and became Advanced Materials Consultant at Merck Ltd. In September 2006, George and Marjorie celebrated George's 80th birthday with many of their closest friends and colleagues at the Royal Society in London. Although dedicated to the advancement of research into liquid crystals he admitted to a love of gardening and an enthusiasm for philately. After further quiet and happy years at Poole, George died on 12 May 2013, just two weeks after the death of his beloved Marjorie. They are survived by their daughters Caroline and Veronica. Their third daughter, Elizabeth, predeceased them.

Ian Shanks

George W Gray, BSc(Glas), PhD(Lond), HonDSc(Hull, Nott, Soton, E Ang, Aberd, Exe, CChem, FRSC, HonMRIA, FRS, FRSE. Born 4 September 1926. Elected FRSE 1989. Died 12 May 2013