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OBITUARY

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Paul C. Lauterbur, the father of magnetic resonance imaging, died of kidney disease on 27 March 2007. He had been ailing for several years.

Lauterbur was born in Sidney, Ohio, USA, on 6 May 1929. His father's ancestry had come from Luxembourg, his mother's from the Baden-Baden region in Germany. His father was an engineer; both parents were attached to the countryside and Paul grew up on their farm outside Sidney.

After high school he attended Case Institute of Technology in Cleveland, Ohio. He received a Bachelor of Science degree in chemistry from Case in 1951 and then accepted a position at the Mellon Institute in Pittsburgh. In 1955, he returned to Mellon after serving in the US Army. While in the army, he helped set up an NMR laboratory and began research on NMR spectroscopy. Still at Mellon, he worked on his PhD at the University of Pittsburgh, receiving the degree in 1962.

His work on ^{29}SI and ^{13}C NMR spectroscopy was an important contribution to the understanding of electronic structures of molecules. Particularly his research on ^{13}C NMR was seminal and has heavily influenced NMR spectroscopy.

In 1963, Lauterbur moved to the State University of New York (SUNY) at Stony Brook's Department of Chemistry and continued his NMR studies.

The 1970s and 1980s were the decisive years in Lauterbur's scientific life. While at Mellon, Lauterbur had helped to set up NMR Specialties, a small company in western Pennsylvania, and, as a result, was on its Board of Directors in 1971. Because the company was about to go bankrupt, Lauterbur agreed to take over its presidency. In an article about his scientific life, Lauterbur recalls the spring and summer of 1971 as follows:

> "... Classes were over, I faced a summer without a grant or summer salary, and my superconducting system might never be finished if I didn't do something."

> "There is a book to be written about that summer... The possibility of observing interactions of water

with living tissues has attracted occasional investigators over the years. Perhaps the most indefatigable of these was Odeblad who was fascinated by the opportunities for characterizing the properties of human cells and secretions, and by the technical problems of observing NMR signals from small biological samples."

"... All of this information about the tissues was apparently there, however, within the living organism." [1]

And elsewhere:

"... normal tissues differed markedly among themselves in NMR relaxation times, and I wondered whether there might be some way to noninvasively map out such quantities within the body. The principle upon which a technique might be based, the encoding of spatial coordinates by known magnetic field shapes, occurred to me the same evening. Over the next several days, a general method for decoding the information, so as to generate a true image from the combination of many NMR signals in different magnetic field gradients, became clear." [2]

On 2 September 1971, he wrote down in a notebook the original idea on how to create a series of projections and then mathematically reconstruct a two-dimensional (2D) image—and had it countersigned by a witness. After working out the feasibility of his approach he began experiments at SUNY at Stony Brook. For one of these he used a pair of capillary tubes filled with water in a bigger tube with heavy water. The results were fuzzy but there were recognizable pairs of images of the cross-sections of the tubes, images that changed as a result of the effect of different RF power levels and T1 relaxation times of the different liquids. He presented his results at the Annual Meeting of the American Physical Society in January 1973; shortly afterwards he published a paper in *Nature*. The paper explicitly mentions the principle in use for MR imaging today:

"The variations in water contents and proton relaxation times among biological tissues should permit the generation, with field gradients large compared to internal inhomogeneities, of useful zeugmatographic images from rather sharp water resonances of organisms, selectively picturing the various soft structures and tissues." The word zeugmatography was a construction by Lauterbur from the Greek word zeugma for yoke because of the linking of chemical and spatial information.

In the paper he also pointed out:

"A possible application of considerable interest at this time would be to the in vivo study of malignant tumours ..." [3]

After his initial publication, Lauterbur gave numerous talks in universities and industry, but aroused little interest in the latter. He also was unable to get a patent for his invention because the administration of SUNY at Stony Brook thought that there was no potential market for this kind of imaging. In contrast to others in the field, Lauterbur never seemed to have pursued financial interests from his NMR research.

For those who worked with him at that time, his playing ping pong with them at the weekly meetings are memorable. He easily could drop an idea or rough outline: "Try it!" There were many successful experiments and studies.

During the next 10 years, Lauterbur, his students and collaborators were extremely productive and innovative in both basic imaging research and pinpointing many applications that only in the late 1980s were taken up again by others and clinically applied. Between the first publication on MR imaging in 1973 and 1985, Lauterbur published or coauthored some 80 papers.

For example, he and his collaborators conducted studies of chemical shift imaging of proton signals, proposals for microscopic imaging beyond 0.1-mm spatial resolution, tumor imaging, studies of infarcted myocardium and edematous lungs. They proposed the introduction of paramagnetic contrast agents, three-dimensional projection reconstruction, and surface-coil imaging.

In the early 1980s, Lauterbur constructed a whole-body 3D MR imaging system in which the first 3D images of the brain and EKG-synchronized images of the beating heart were acquired. Off-resonance (magnetization transfer) imaging and in-vivo fluorine ventilation imaging of the lungs were also performed.

Although he was a Professor of Experimental Radiology at Stony Brook, his main position was Professor of Organic Chemistry; over the years, there were very few medical doctors in his small research group.

By his marriage to Rose Mary Caputo in 1962 he had two children, Daniel and Sharon. After the divorce from his first wife, in 1984 he married Joan Dawson, an American physiologist, working at that time at University College, London, and they moved to Urbana, Illinois, in 1985, with a new baby daughter, Elise. He joined the faculty of the University of Illinois at Urbana-Champaign, where he became Director of the Biomedical Magnetic Resonance Laboratory. Unfortunately, the new position at the University of Illinois did not fulfill its promises. The problems were never solved, and Lauterbur finally moved out of research in magnetic resonance, attacking perhaps the biggest of biological questions: the origin of life.

Lauterbur was bestowed numerous prizes and awards including the Lasker Award, the US National Medal of Science, the European Magnetic Resonance Award, and the Gold Medal of the European Congress of Radiology—and finally received the Nobel Prize in Physiology or Medicine in 2003 for his discoveries concerning magnetic resonance imaging, jointly with Sir Peter Mansfield.

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