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MILESTONE 8

New resonance

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If, during the 1920s and 1930s, the atomic nucleus had seemed of interest to few besides the (mostly) gentleman scientists studying it, by the end of the Second World War its wider importance was abundantly clear. The coming of the nuclear age was an appropriate cue for the two papers that cleared the way for arguably the most widespread practical application of nuclear spin today: nuclear magnetic resonance (NMR) spectroscopy.

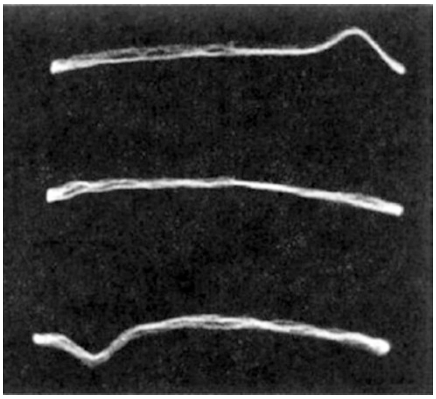
The 1946 work of Edward Mills Purcell at the Massachusetts Institute of Technology and Felix Bloch at Stanford University gave new relevance to one object of intense gentlemanly interest before the war; the Zeeman splitting of nuclear spin states in a magnetic field (Milestone 1). The degree of splitting at a particular magnetic field strength depends on the gyromagnetic ratio of the nucleus. In NMR, a second, transverse field at the characteristic (typically radio) spin-transition frequency produces an absorption resonance — a powerful way to identify the nuclei present in a sample.

Purcell *et al.* brought protons (^{1}H) in solid paraffin to resonance; Bloch *et al.* did the same in liquid water. The coincident timing was no accident: the development of radar technologies during the war, for which several of the researchers involved had won their spurs, had made sources of radiofrequency radiation freely available for the first time.

The effect itself was not entirely new. In 1938, Isidor Rabi had used it to measure magnetic moments of both atomic species in a lithium chloride molecular beam, receiving the 1944 Nobel Prize in Physics for that advance. Even earlier, the Dutch physicist Cornelis J. Gorter had looked for the resonance of ^{7}Li in lithium fluoride and ^{1}H in alum, using a calorimetric method. Hampered by experimental vagaries and limited resources, he published a negative result. (In later years, on receiving a prize for his contributions to low-temperature physics, Gorter would muse on his strange ability to miss out on groundbreaking discoveries in this and other instances.)

The innovations offered by Bloch and Purcell's approaches were the transition to real liquid and solid systems, and, in Bloch's case, the use of an induction coil to pick up and sharpen the resonance signal. These opened the way for the use of NMR in all manner of contexts, including in living tissue — where it became the lynchpin of magnetic resonance imaging (Milestone 14).

In 1944, although shielded in the relative obscurity of Kazan in the steppes of Tatarstan, the Soviet physicist Yevgeny Zavoisky published the first measurements of an analogous effect involving electron spins. Electron paramagnetic resonance depends on an atom possessing an unpaired electron, thereby limiting the range of its application, but making it useful for the detection and identification of free radicals. Zavoisky might also have been the first to see an NMR signal, but he did not follow it up, at least not with publications. Had the vicissitudes of the age been less, and the dissemination of scientific information easier, his claim might have been better heard in the West. As it was, the 1952 Nobel Prize in Physics went to Bloch and Purcell.



First NMR signals from water. Image reprinted with permission from Bloch, F., Hansen, W. W. and Packard, M. *Phys. Rev.* **70**, 474–485 (1946) [http://prola.aps.org/abstract/PR/v70/i7-8/p474_1]; courtesy of the American Physical Society.

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