

Lemieux R U, Kullnig R K, Bernstein H J & Schneider W G. Configurational effects on the proton magnetic resonance spectra of six-membered ring compounds. *J. Amer. Chem. Soc.* **80**:6098-105, 1958.
[University of Ottawa and the National Research Council of Canada, Canada]

The proton magnetic resonance spectra of six-membered ring compounds indicate that the signals for protons in the axial orientation occur at higher field than those for equatorial hydrogens, and this result was borne out with few exceptions for 16 acetylated sugars. No exception was encountered, however, to the result that in fixed conformations the spin-spin coupling constant between neighboring hydrogens in the axial orientation is about two to three times larger than for neighboring hydrogens in other orientations. [The *SCI*[®] indicates that this paper has been cited over 655 times since 1961.]

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"My colleagues and I were duly impressed to find our 1958 paper in the most cited list.¹ That the paper eventually became a *Citation Classic*² is not surprising—the findings were practical. It had become evident that nuclear magnetic resonance (nmr) spectroscopy provided a convenient and effective tool for both structural and conformational studies of widespread application to organic chemistry. These findings represent what must be a classical case of experiencing the right problem with the right people at the right time.

"With the upsurge of conformational analysis, my attention became focused on a puzzling aspect of carbohydrate chemistry. Following the principles established by Barton,² the thermodynamically more stable anomer for certain sugar derivatives would have the 1-substituent in the unfavorable axial orientation and this was the apparent anomaly. However, the non-bonded interactions that existed between the various polar substituents about the pyranose ring of these polyfunctional molecules could not be assessed.

"It was in Ottawa that I first learned of the

existence of high-resolution nmr spectroscopy and the excitement it brought to chemists. Furthermore, and fortunately for me, leaders in the field were at the National Research Council Laboratories.

"By 1955, it was already established that high-resolution nmr allowed the differentiation not only of chemically different hydrogen atoms, but also, in a few cases, of chemically similar hydrogen atoms in different environments. I wondered whether or not this new tool would differentiate chemically similar hydrogens on saturated structures that differed in their orientations about a six-membered ring such as the pyranose ring of sugars. Bill Schneider and Harold Bernstein³ immediately became interested in this idea.

"Just at that time, Rudy Kullnig joined my group. He showed unusual mathematical talent and background training in physics for one registered for research in organic chemistry and volunteered to become engaged.

"High-resolution nmr was really still in its infancy in 1955. This was before the super voltage stabilizers were introduced and, at first, even the spinning of the sample had not been introduced. The achievement and maintenance of a suitably homogeneous magnetic field seemed more an answer to a prayer than good management.

"We found the desired structure-chemical shift relationships and also had the added bonus of finding a relationship between the magnitude of the spin-spin coupling constant and the torsion angle defined by vicinal hydrogens. Evidently, nmr would provide a quantum leap in matters related to the determination of configurational relationships and conformational equilibria—matters of special importance to the burgeoning field of conformational analysis. My own special joy was to achieve direct experimental evidence for the conformations of sugars and their derivatives and, thereby, an experimental base for assessing what I later termed the 'anomeric effect'. I shall always feel indebted to Bernstein and Schneider for their enthusiastic involvement. Both their instrument and their deep practical and theoretical understanding of the nmr experiment were vital to the project. Kullnig did the hard work."

1. Garfield E. Highly cited articles 38. Physics and chemistry papers published in the 1950s.

Current Contents (23):5-9. 6 June 1977. (Reprinted in: Garfield E. *Essays of an information scientist* Philadelphia: ISI Press, 1980 Vol 3 p 125.-9.)

2. Barton D H R. The conformation of the steroid nucleus. *Expenientia* 6:316-20, 1950.

3. Pople J A, Schneider W G & Bernstein H J. *High resolution nuclear magnetic resonance* New York. McGrawHill, 1959. 501 p.