The Russell Varian Lecture and Prize

The Russell Varian prize honors the memory of the pioneer behind the first commercial Nuclear Magnetic Resonance spectrometers and co-founder of Varian Associates. The prize is awarded to a researcher based on a single innovative contribution (a *single* paper, patent, lecture, or piece of hardware) that has proven of high and broad impact on state-of-the-art NMR technology. The prize is designed to recognize the initial contribution that laid the foundations for a specific technology of great importance in state-of-the-art NMR. The award ceremony will take place at the EUROMAR 2015 meeting in Prague, Czech Republic, 5th – 11th July, 2015, with the winner delivering the Russell Varian Lecture.

Rules for the Russell Varian Prize

- Only single pieces of work are considered (a paper, a lecture, a patent, etc).
- In the case of multiple authorship, the prize is awarded to the author with the largest creative and innovative share of the contribution. In the exceptional case of truly equal shares in the contribution, the Prize may be split between two authors.
- No individual may receive the prize more than once.
- Prizewinners become members of the Advisory Board for the Russell Varian Prize that evaluates future nominations and makes recommendations to the Prize Committee.

Call for Nominations

Nominations must be forwarded by email to the Secretary of the Prize Committee, Gareth Morris, at g.a.morris@manchester.ac.uk. The deadline for nominations is February 16th, 2015. Nominations should be laid out in the format of a publishable laudatio proposal (cf. earlier laudatios below) thatin the case of multiple authorship must include an explanation of why the nominee is the most innovative author behind the paper. Attention is further drawn to the fact that the Russell Varian prize rewards the earliest seed paper of an important technology, rather than later more comprehensive and highly cited papers.

Prize Committee

Jean Jeener (Chairman), Krish Krishnamurthy, Vladimir Sklenář (EUROMAR 2015 representative), Gareth A. Morris (Secretary), Lucio Frydman, and Ole W. Sørensen.

Advisory Board for the Russell Varian Prize

Weston Anderson, Ad Bax, Nicolaas Bloembergen, Ray Freeman, Erwin Hahn, Martin Karplus, Alex Pines, Alfred G. Redfield.

Former Russell Varian Prize Laureates

Jean Jeener, Professor Emeritus, Université Libre de Bruxelles, Belgium (**2002**):

- *Technology*: **Multidimensional Fourier NMR spectroscopy and imaging**
- *Awarded Contribution*: The lecture given at the Ampere Summer School in Basko Polje, Yugoslavia, September, 1971, where Jean Jeener introduced two-dimensional Fourier NMR spectroscopy by what is today known as the COSY experiment.

Erwin Hahn, Professor Emeritus, University of California, Berkeley, USA (**2004**):

- *Technology*: **Basics of modern time-domain NMR spectrometers, spin-echo phenomena and experiments, diffusion measurements, and J couplings**

- *Awarded Contribution*: Bull. Am. Phys. Soc. 24, No. 7, 13 (1949), reprinted in Phys. Rev. 77, 746 (1950).

Nicolaas Bloembergen, Professor of optical sciences, University of Arizona, Tucson, Arizona, USA, and Gerhard Gade University Professor Emeritus, Division of Applied Science and Physics Department, Harvard University, Cambridge, Massachusetts USA (**2005**):

- *Technology*: **NMR relaxation for experimental study of molecular motion**
- *Awarded Contribution:* Nuclear Magnetic Relaxation, by N. Bloembergen, E. M. Purcell, and R. V. Pound, Nature, 160, 475-476, (1947).

John S. Waugh, Professor emeritus, Massachusetts Institute of Technology, Cambridge, Massachusetts, USA (**2006**):

- *Technology:* **Average Hamiltonian Theory**
- *Awarded Contribution*: J.S. Waugh, C.H. Wang, L.M. Huber, and R.L. Vold, “Multiple-Pulse NMR Experiments”, J. Chem. Phys. 48, 662-670 (1968). This paper announces further results that appeared a few weeks later in J. S. Waugh, L. M. Huber, and U. Haeberlen, "Approach to High-Resolution NMR in Solids", Phys. Rev. Lett. 20, 180-182 (1968).

Alfred G. Redfield, Professor Emeritus of Physics, Biochemistry, and Rosenstiel Basic Medical Sciences Research Center, Brandeis University, Waltham, Massachusetts, USA (**2007**):

- *Technology:* **Relaxation Theory**
- *Awarded Contribution*: A.G. Redfield, “On the Theory of Relaxation Processes”, IBM Journal of Research and Development 1, 19-31 (1957). Recent references to this fundamental paper are often given implicitly by quoting the revised version published by Redfield in Adv. Magn. Reson. 1, 1-32 (1965).

Alexander Pines, Glenn T. Seaborg Professor of Chemistry, UC Berkeley, and Senior Scientist, Lawrence Berkeley National Laboratory, Berkeley, USA (**2008**):

- *Technology:* **Cross-polarization method for NMR in solids**
- *Awarded Contribution*: A. Pines, M. G. Gibby, and J. S. Waugh, “Proton-Enhanced Nuclear Induction Spectroscopy. A Method for High Resolution NMR of Dilute Spins in Solids”, J. Chem. Phys. 56, 1776-1777 (1972).

Albert W. Overhauser, Stuart Distinguished Professor of Physics, Purdue University, West Lafayette, IN, USA (**2009**):

- *Technology:* **Nuclear Overhauser Effect**
- *Awarded Contribution*: The talk given by Albert Overhauser at the American Physical Society meeting on May 1, 1953, of which an abstract appeared as Albert W. Overhauser, Polarization of Nuclei in Metals, Phys. Rev. 91, 476 (1953), and full detail as Albert W. Overhauser, Polarization of Nuclei in Metals, Phys. Rev. 92, 411-415 (1953).

Martin Karplus, Professor Emeritus, Department of Chemistry and Chemical Biology, Harvard University, Cambridge, Massachusetts; and Laboratoire de Chimie Biophysique, ISIS, Université Louis Pasteur, Strasbourg, France (**2010**):

- *Technology:* **Karplus Equation**
- *Awarded contribution:* M. Karplus, “Contact Electron-Spin Coupling of Nuclear Magnetic Moments“, J. Chem. Phys. 30, 11-15 (1959).

Gareth Alun Morris, Professor of Physical Chemistry, School of Chemistry, The University of Manchester, UK (**2011**):

- *Technology:* **INEPT pulse sequence**
- *Awarded contribution:* G. A. Morris and R. Freeman: “Enhancement of nuclear magnetic resonance signals by polarization transfer”, J. Am. Chem. Soc. 101, 760-762 (1979).

Raymond Freeman, John Humphrey Plummer Professor of Magnetic Resonance (Emeritus), Department of Chemistry, University of Cambridge, UK and **Weston A. Anderson**, Senior Principal Scientist and Varian Fellow Emeritus (**2012**):

- *Technology:* **Double Resonance**
- *Awarded contribution:* R. Freeman and W.A. Anderson: “Use of Weak Perturbing Radio-Frequency Fields in Nuclear Magnetic Double Resonance”, J. Chem. Phys. 37, 2053-2074 (1962).

Lucio Frydman, Professor and Kimmel Fellow, Weizmann Institute, Israel (**2013**):

- *Technology:* **Ultrafast NMR**
- *Awarded contribution:* L. Frydman, T. Scherf , and A. Lupulescu, "The acquisition of multidimensional NMR spectra within a single scan", Proc. Natl. Acad. Sci. USA, 99, 15858-15862 (2002).

Adriaan Bax, NIH Distinguished Investigator, National Institutes of Health, Bethesda, MD, USA (**2014**):

- *Technology:* **Homonuclear Broadband Decoupled Absorption Spectra**
- *Awarded contribution:* A. Bax, A.F. Mehlkopf and J. Smidt, “Homonuclear Broadband Decoupled Absorption Spectra”, J. Magn. Reson. 35, 167-169 (1979).

Laudatio 2002

Awarded Contribution:

The lecture given at the Ampere Summer School in Basko Polje, Yugoslavia, September, 1971, where Jean Jeener introduced two-dimensional Fourier NMR spectroscopy by what is today known as the COSY experiment. The unpublished lecture notes were later published in "NMR and More in Honour of Anatole Abragam", Eds. M. Goldman and M. Porneuf, Les editions de physique, Avenue du Hoggar, Zone Industrielle de Courtaboeuf, BP 112, F-91944 Les Ulis cedex A, France (1994).

The Prize Winner:

Jean Jeener, Professor Emeritus, Université Libre de Bruxelles, Belgium

The Technology:

The awarded contribution introduced two-dimensional NMR spectroscopy and has shown an unprecedented impact on the development of state-of-the-art NMR spectroscopy. In principle, any multiple-dimensional NMR experiment introduced so far relies on the method proposed by Jean Jeener. Countless examples can be found in both liquid-state and solid-state NMR, as well as in NMR imaging applications in medicine, biology and material science.

Laudatio 2004

Awarded Contribution:

E. L. Hahn, Spin Echoes, Bull. Am. Phys. Soc. 24, No. 7, 13 (1949), reprinted in Phys. Rev. 77, 746 (1950). (This is the abstract for a ten minutes presentation to be given at the Chicago meeting of the American Physical Society on November 25, 1949.)

The Prize Winner:

Erwin L. Hahn, Professor Emeritus, University of California, Berkeley, USA

The Technology:

The awarded contribution contains several original ideas and results that have had a strong impact on modern NMR technology, notably

- (a) the two pulse spin echo that still is the method of choice for e.g. refocusing chemical shift dephasings in pulse sequences, not to mention widespread applications in MRI;

- (b) the interpretation of spin echoes, where time (rather than frequency) is used as the essential variable beyond the initial stage of Bloch's theory of CW spectroscopy and of relaxation measurements: this spin dynamics method was immediately essential for the development of spin echo applications, and it is still today the theoretical approach used for most NMR techniques;

- (c) the experimental demonstration that the observation of NMR pulse responses is a viable technology that can provide higher sensitivity than CW spectroscopy.

The awarded contribution clearly was the foundation for the more extensive description of spin echoes in E. L. Hahn, Spin Echoes, Phys. Rev. 80, 580-594 (1950), that was submitted six months after the lecture at the Chicago meeting, where further high-impact ideas related to spin echoes were presented:

- (d) the study of molecular diffusion and bulk motion by observation of their effects on the spin echoes: with minor modifications, this is still the method of choice for accurate measurements of molecular diffusion coefficients in liquids and for flow measurements in general;

- (e) the study of "secondary" spin echoes after three pulses, another step towards multiple-pulse techniques;

- (f) the observation of a modulation of the peak spin echo amplitudes in some homonuclear spin systems and the conclusion that the modulation cannot be explained by differences in chemical shifts, hence that it indicates a new spin-spin coupling not averaged out by molecular motion. This proved later to be J couplings. It also showed that multiple-pulse spectroscopy provides important qualitative information that was not directly available by CW techniques;

- (g) the description and use of a coherent pulse spectrometer including a CW reference oscillator at the NMR frequency, hence control of the phase of the pulses and observation of the phase of the spin responses: the basic elements of modern pulse spectrometers are presented here for the first time.

Laudatio 2005

Awarded Contribution:

Nuclear Magnetic Relaxation, by N. Bloembergen, E. M. Purcell, and R. V. Pound, Nature, 160, 475-476, (1947).

This paper contains all the essential ideas and results that were later described in greater detail in Bloembergen's PhD thesis (Leiden, 1948) and in the "BPP" paper, N. Bloembergen, E. M. Purcell, and R. V. Pound, Relaxation Effects in Nuclear Magnetic Resonance Absorption, Phys. Rev. 73, 679-712 (1948). A preliminary report was given by Bloembergen as a Contributed Paper at the APS meeting in New York in late January 1947 (N. Bloembergen, R. V. Pound, and E. M. Purcell, The Width of the Nuclear Magnetic Resonance Absorption in Gases, Liquids, and Solids, Phys. Rev. 71, 466 (1947)).

The Prize Winner:

Nicolaas Bloembergen, Professor of optical sciences, University of Arizona, Tucson, Arizona, USA, and Gerhard Gade University Professor Emeritus, Division of Applied Science and Physics Department, Harvard University, Cambridge, Massachusetts USA

The Technology:

The awarded paper proposed a semi-quantitative prediction for Bloch's relaxation times T_1 and T_2, based on an appropriate adaptation of transition probability theory (as originally presented by Weisskopf and Wigner) combined with the assumption that relaxation is dominated by the effects of molecular Brownian motion on a "fluctuating local field" acting on each spin. The paper introduced the notion of "motional narrowing" and established NMR as an essential tool for the experimental study of molecular motion, a situation that still persists today.

Laudatio 2006

Awarded Contribution:

J.S. Waugh, C.H. Wang, L.M. Huber, and R.L. Vold, “Multiple-Pulse NMR Experiments”, J. Chem. Phys. 48, 662-670 (1968). This paper announces further results that appeared a few weeks later in J. S. Waugh, L. M. Huber, and U. Haeberlen, "Approach to High-Resolution NMR in Solids", Phys. Rev. Lett. 20, 180-182 (1968).

The Prize Winner:

John S. Waugh, Professor emeritus, Massachusetts Institute of Technology, Cambridge, Massachusetts, USA

The Technology:

The awarded paper is the seed for multi-pulse line-narrowing, coherent averaging, and Average Hamiltonian Theory (AHT) in solid-state NMR spectroscopy. The version of AHT proposed in the awarded contribution unlocked the whole field of multiple pulse line narrowing in solid-state NMR by providing an efficient systematic tool for the analysis, design, and optimization of such schemes. Almost immediately, the first application of the new idea by Waugh was the WAHUHA sequence for homonuclear line narrowing in solids, which started the successful development of high-resolution NMR in solids for chemical and structural applications (beyond the preliminary results of broader and often unresolved lines obtained with MAS alone). AHT is the method of choice to understand or design many solid-state pulse sequences like homo- and heteronuclear decoupling experiments, often in combination with magic-angle spinning, dipolar recoupling experiments, and advanced experiments for quadrupolar nuclei. In liquid-state NMR, AHT was essential for the breakthrough of designing the first coherent multi-pulse decoupling schemes and TOCSY-type elements.

Laudatio 2007

Awarded Contribution:

A.G. Redfield, "On the Theory of Relaxation Processes", IBM Journal of Research and Development 1, 19-31 (1957). Recent references to this fundamental paper are often given implicitly by quoting the revised version published by Redfield in Adv. Magn. Reson. 1, 1-32 (1965).

The Prize Winner:

Alfred G. Redfield, Professor Emeritus of Physics, Biochemistry, and Rosenstiel Basic Medical Sciences Research Center, Brandeis University, Waltham, Massachusetts, USA

The Technology:

The awarded paper casts the semi-quantitative predictions of BPP (Bloembergen, Purcell, and Pound, Phys. Rev. 73, 679 (1948)) in the form that became that of modern spin dynamics. Assuming only that the "thermal bath" executes a stationary random motion and that the spin system is weakly coupled to the "bath", Redfield derives a kinetic equation of motion for the complete spin density operator, taking into account all spin and spin-spin interactions "exactly", without resort to transition probability arguments. The paper demonstrates a general scheme, applicable to any NMR situation: solids, liquids or gasses, many spins coupled in a molecule, classical or quantum mechanical description of the thermal bath, or persistent irradiation during the experiment. The paper also provides the first example of the usefulness of the "Liouville space" or "superoperator" scheme for the discussion of NMR problems involving relaxation in a non-trivial way. After more than 50 years, the early work of Redfield is still a basic reference in the field of relaxation.

Laudatio 2008

Awarded Contribution:

A. Pines, M. G. Gibby, and J. S. Waugh, "Proton-Enhanced Nuclear Induction Spectroscopy. A Method for High Resolution NMR of Dilute Spins in Solids", J. Chem. Phys. 56, 1776-1777 (1972). The technique announced in this short note is explained in detail in A. Pines, M. G. Gibby, and J. S. Waugh, "Proton-Enhanced NMR of Dilute Spins in Solids", J. Chem. Phys. 59, 569-590 (1973). Alex Pines played the leading role in the published work.

The Prize Winner:

Alexander Pines, Glenn T. Seaborg Professor of Chemistry, UC Berkeley, and Senior Scientist, Lawrence Berkeley National Laboratory, Berkeley USA

The Technology:

The proposal of a new method for sensitive, high-resolution observation of rare spins (e.g. ^{13}C in natural abundance) in solids, in the presence of abundant spins (e.g.

protons). Relaxation is first used to polarize the abundant spins, part of this polarization is then transferred to the rare spins by cross-polarization "in the rotating frame", and the free induction response of the rare spins is finally observed under CW irradiation of the abundant spins. This simple method, often called just "cross polarization", helped launch the modern era of solid-state NMR in chemistry, materials, and biology, and inspired a wealth of useful variations, many of which are still among the popular tools of practical solid state NMR.

Laudatio 2009

Awarded Contribution:

The talk given by Albert Overhauser at the American Physical Society meeting on May 1, 1953, of which an abstract appeared as Albert W. Overhauser, Polarization of Nuclei in Metals, Phys. Rev. 91, 476 (1953), and full detail as Albert W. Overhauser, Polarization of Nuclei in Metals, Phys. Rev. 92, 411-415 (1953).

Prize Winner:

Albert W. Overhauser, Stuart Distinguished Professor of Physics, Purdue University, West Lafayette, IN, USA

The Technology:

This contribution is the seed of two important techniques in modern NMR: the Nuclear Overhauser Effect (NOE) and Dynamic Nuclear Polarization (DNP).

NOE describes the mutual influence of the polarizations of two spin species by spin-lattice relaxation. Originally, the spins were those of the nuclei of a metal and those of its conduction electrons. Soon after Overhauser's prediction, the effect was demonstrated by C. P. Slichter on metallic lithium, and was shown by Ionel Solomon to also exist between different nuclei in ordinary liquids. The NOE has played a key role in liquid state NMR over several decades, notably in establishing the overall structure of biological macromolecules in solution

DNP describes the often impressive enhancement of the nuclear polarization by strong irradiation of an electron resonance in the sample. Particularly within recent years, DNP technology has evolved considerably to a powerful sensitivity enhancement method in a growing variety of NMR applications.

Laudatio 2010

Awarded Contribution:

M. Karplus, “Contact Electron-Spin Coupling of Nuclear Magnetic Moments“, J. Chem. Phys. 30, 11-15 (1959).

Prize Winner:

Martin Karplus, Professor Emeritus, Department of Chemistry and Chemical Biology, Harvard University, Cambridge, Massachusetts; and Laboratoire de Chimie Biophysique, ISIS, Université Louis Pasteur, Strasbourg, France

The Technology:

The paper introduces a theoretical derivation of the dependence of three-bond J coupling constants on the dihedral angle φ and includes preliminary comparisons with experimental values. The presented equations for J(φ) have been refined over the years and have come to be known as theKarplus equations. They have widely proven themselves as valid for almost all combinations of magnetic nuclei separated by three bonds and therefore are, next to the distance measurement by the Nuclear Overhauser enhancement, the most valuable parameter for structure elucidation, from small molecules to biological macromolecules. The importance of ^{3}J couplings as a structural parameter has triggered the development of a large number of NMR pulse sequences specifically designed to measure them in various circumstances.

Laudatio 2011

Awarded Contribution:

G. A. Morris, and R. Freeman: "Enhancement of nuclear magnetic resonance signals by polarization transfer", J. Am. Chem. Soc. 101, 760-762 (1979).

Prize Winner:

Gareth Alun Morris, Professor of Physical Chemistry, School of Chemistry, The University of Manchester, UK

The Technology:

INEPT is an ingenious pulse sequence, originally devised for signal enhancement in liquid state NMR of insensitive nuclei such as carbon-13 and nitrogen-15, by broadband polarization transfer from proton spins. Since its inception it has evolved, as a means of bi-directional polarization transfer between coupled spins, into a major component of modern multidimensional NMR techniques, with applications in liquids, liquid crystals and solids. The impact of INEPT, transcending its remarkably simple theoretical and experimental foundation, has made it an indispensable component of the state-of-the-art NMR toolkit.

Laudatio 2012

Awarded Contribution:

R. Freeman and W.A. Anderson: "Use of Weak Perturbing Radio-Frequency Fields in Nuclear Magnetic Double Resonance", J. Chem. Phys. 37, 2053-2074 (1962).

Prize Winners:

Raymond Freeman, John Humphrey Plummer Professor of Magnetic Resonance (Emeritus), Department of Chemistry, University of Cambridge, UK and **Weston A. Anderson**, Senior Principal Scientist and Varian Fellow Emeritus

The Technology:

Both authors played essential roles in this contribution: Freeman as experimentalist and Anderson as theorist. This paper offers a first easily applicable approach to the unraveling of complex NMR spectra, and hence of molecular structure. A Hamiltonian-based theory is developed to explain high resolution spectra observed by the CW technique in the presence of a second weak radiofrequency irradiation of a single line, and is illustrated with practical examples. This work suggested many important developments like decoupling and selective excitation. It unlocked the long awaited perspective of using NMR for detailed studies of proteins. Seen as a piece-wise 2D spectroscopy, it served as seed and inspiration for the invention of pulsed 2D techniques.

Laudatio 2013

Awarded Contribution:

L. Frydman, T. Scherf , and A. Lupulescu, "The acquisition of multidimensional NMR spectra within a single scan", Proc. Natl. Acad. Sci. USA, 99, 15858-15862 (2002).

Prize Winner:

Lucio Frydman, Professor and Kimmel Fellow, Weizmann Institute, Israel

The Technology:

The paper, based on an original idea conceived by Lucio Frydman, introduces a novel and unique technique for recording multidimensional NMR spectra in a single scan, and describes the theoretical basis and experimental realization of this ultrafast NMR methodology. The methodology is proving to be invaluable in experiments that capitalize on spin hyperpolarization, and is providing important insights into fast processes, including chemical reactions, biochemical pathways, and protein folding, that are inaccessible on the time scale of conventional multidimensional NMR methods.Frydman's technique has laid the foundation not only for advances in NMR, but also for a robust complement to echo planar imaging (EPI), the currently prevailing single scan methodology for ultrafast MRI, and it has demonstrated the possibility of producing, in high-field preclinical and clinical settings, previously inaccessible diffusion-weighted and functional images.

Laudatio 2014

Awarded Contribution:

A. Bax, A.F. Mehlkopf and J. Smidt, “Homonuclear Broadband Decoupled Absorption Spectra”, J. Magn. Reson. 35, 167-169 (1979).

Prize Winner:

Adriaan Bax, NIH Distinguished Investigator, National Institutes of Health, Bethesda, MD, USA

The Technology:

The indirect dimension in multidimensional NMR spectra allows recording of spectra that cannot be recorded directly in an FID. Constant-time spectroscopy builds on this idea to observe homonuclear decoupled spectra, and has found widespread use in modern multidimensional NMR spectroscopy. In addition to spectral simplification it can also have the added benefits of sensitivity enhancement and pulse sequence simplification. Constant-time COSY was the first useful application and nowadays almost all 3D or 4D liquid-state pulse sequences for biological NMR employ the constant-time building block.