BIOGRAPHICAL MEMOIRS

Anatole Abragam. 15 December 1914 — 8 June 2011

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ANATOLE ABRAGAM
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Elected ForMemRS 1983

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Anatole Abragam, a French physicist of Russian origin, made a profound and lasting impact on the field of magnetic resonance, both electronic and nuclear, through his discoveries, contributions and his eminent educational role. In nuclear magnetic resonance (NMR) especially, he brought to the field theoretical rigour and clarity. Many of the most distinguished scientists in the field consider themselves to be his students, and he is known by many as a ‘giant of magnetic resonance’. Among his main contributions are: theories of the spin Hamiltonian and of core polarization in electron paramagnetic resonance (EPR); the theory of perturbed angular correlations of radioactive emissions in condensed matter; a new theoretical formalism of spin relaxation; the invention of an Earth magnetometer; basic studies of spin temperature; dynamic nuclear polarization in solids and production of polarized targets; nuclear dipolar magnetic ordering studied both by NMR and by neutron diffraction; the discovery of nuclear pseudo-magnetism and its use for measuring the spin-dependent neutron–nucleus scattering amplitudes; and a new spectroscopic technique for muon spin rotation ($\mu$SR).

RUSSIAN CHILDHOOD

Anatole Abragam was born in Griva Semgallen, Russia, to a non-practising Jewish family on 15 December 1914 according to the Julian calendar, then in use in Russia, or 28 December according to the Gregorian calendar. He used either birth date in official documents, which occasionally caused problems.

His father owned a successful button factory, with only a few employees. He had no higher education degree, but had a high respect for culture and acquired an enormous library of

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literary classics, both Russian and translations of foreign works. His mother had battled to obtain a secondary education, a difficult undertaking for a girl in tsarist Russia, and then fought for permission to go abroad to Bern, Switzerland, to study medicine. She obtained her degree, and then worked for two years as a doctor in Berlin before returning to Russia, where she married. She practised medicine until the beginning of World War I, and resumed her activity as a doctor in the Red Army in 1918.

Anatole was practically self-taught, a result of his voracious reading of the books in his father’s large library. This contained all the classic Russian authors and a great many of the principal authors from France, America and England in translation, among whom, and above all, was Shakespeare. One set of books played a pivotal role in his awakening to science, the *Children’s encyclopaedia*, which he received as a seventh birthday present. He had a private teacher until the age of eight, and went to a Soviet school for the last two years of his stay in Russia.

The years following the Soviet revolution of 1917 became increasingly difficult, both in work and in housing. Anatole’s father, owning a factory (however small), was regarded as ‘bourgeois’. Anatole and his elder sister, Alexandra, had no choice but to take apprenticeships (which usually lasted from the ages of 10 to 14) to become manual workers. The deteriorating situation led the family to decide to emigrate to France in 1925. His mother and the two children left first. His father intended to join them after a short delay, but he did not succeed in leaving Russia until 1936, 11 years later.

**EARLY EDUCATION IN FRANCE**

Anatole arrived in France at the age of 10 without knowing a single word of French. He spent his first year at a private school, which brought him more or less to the level of French children of the same age and enabled him to undertake secondary school studies. He was sent to the prestigious Lycée Janson-de-Sailly, the high school for ‘smart people’ – meaning the high bourgeoisie and above. For the first five years, his results were quite outstanding, always coming first and finishing each year with the ‘Prize of Excellence’. The subject that attracted him most was Latin, which he always considered was the only real scientific teaching he received during his secondary school studies.

Matters were not quite so good during his last year in the class of *Mathématiques Elémentaires*, which is usually followed by preparation classes to the most famous scientific *Grandes Ecoles* (namely, the École Normale Supérieure and the École Polytechnique). He had heard about, and disliked the notion of, the so-called ‘struggle for life’ atmosphere that reigned in these schools, and so he looked at the various other choices for higher education. However, none of these seemed to match his interests or tastes. Another cause for unease during this year came from one of his schoolmates in this class, who was none other than Laurent Schwartz, the future great mathematician, who systematically surpassed him academically and won the ‘Prize of Excellence’ at the end of the year.

**IN SEARCH OF A HIGHER EDUCATION**

After much hesitation, he chose to study medicine, his mother’s profession, at the Faculty of Medicine of the University of Paris. He quickly acquired a profound dislike for the teaching,
the experimental training, his teachers, his fellow students and the patients themselves. He had no choice but to give up after the first year. This time was not quite wasted, however, since he had enrolled in parallel on a mathematics course and successfully passed the examination.

He then turned full time to mathematics and physics, but not with a view to competing for the Grandes Ecoles, which would have forced him to go back to a preparation class in a lycée. He chose instead to return to the University of Paris, in the Faculty of Sciences, where he obtained a License-ès-Sciences in 1936, the equivalent of a BSc.

The next step was to undertake a PhD, for which he needed a research director. He chose Professor Francis Perrin, from whom he obtained no guidance, except for the advice that he should look up the Physical Review and find a suitable subject for research there. He began exploring theoretical physics, in particular by attending the seminars of Louis de Broglie and his school. This school maintained a kind of praetorian guard attitude, eager to discourage outsiders bold enough, or foolish enough, to wish to attempt research in such high-brow subjects as wave mechanics, which was reserved for the ‘happy few’—themselves. Nor was Anatole any happier at attempting experimental physics. This period of disillusionment and disappointment lasted for three years, his only comfort being provided by reading and absorbing of Courant and Hilbert’s great book Methods of Mathematical Physics. 1939 would see these problems solved for the following six years.

THE WAR YEARS

Shortly after the beginning of the war, Anatole was mobilized in a heavy artillery regiment. He remained far from the front until June 1940, when his unit was ordered to retreat by bicycle to the far west of France. He was demobilized in September 1940 and went to the south of France to the so-called ‘free zone’, which had not then been occupied by the Germans.

First he went to Cannes and then on to Saint-Raphael, where he stayed for nearly three years. He made a modest living as a teacher in a number of private schools, teaching Latin, then physics and then eventually gymnastics. Teaching gymnastics during these years of general shortage was a definite advantage: regarded as hard manual workers, teachers of gymnastics were given extra food coupons. Initially, Anatole’s extra 50 grams of bread per day was due to a misunderstanding: the clerk delivering the food coupons had confused ‘physics teacher’ with ‘physical education teacher’.

Anatole’s father had chosen to stay in Paris, thinking it was safe as he was a Russian citizen at a time when Russia was in alliance with Germany. He was arrested by the Gestapo the day after Germany launched the invasion of Russia and was sent to a camp in Germany. He died there from hunger and misery. His mother left the Paris area after her husband was arrested and joined Anatole in Saint-Raphael. She lived with him and a young woman, Suzanne, whom Anatole had met and fallen in love with. They could not risk marrying until 1944.

On an autumn day in 1943, Anatole, having fortuitously learnt that Jews in Saint-Raphael would be mass arrested the next morning, left hurriedly for Grenoble, where he subsequently took courses in mathematics in the Faculty of Sciences at the University of Grenoble. At the beginning of 1944 the situation in Grenoble became so dangerous that he moved again, to a small village in the Alps, where his mother and Suzanne joined him from Saint-Raphael. They soon moved into an isolated house, where they stayed until the allied landings in the south of
France on 15 August 1944. He then joined the French military forces through the Resistance until he was demobilized in August 1945.

**BACK TO SCIENCE**

At the age of 30, with only a minor degree in science, no publications and no position, Anatole decided to resume his studies. He attended the Ecole Supérieure d’Electricité from 1945 to 1947, from which he graduated as ‘Engineer in Radio Electricity’. In the autumn of 1946 he was hired by the brand-new Commissariat à l’Energie Atomique (CEA). The years 1946 and 1947 were particularly hard for him, since he was simultaneously studying and working full time in his new position at CEA in the ‘Service of Mathematical Physics’. This research unit consisted of four brilliant theorists, of whom Anatole was the oldest, but not its leader. The group was soon to be known at CEA as ‘The Three Musketeers’.

Initially, it was intended that the group devote itself almost exclusively to technical problems associated with the development of nuclear energy, but the role of the CEA evolved under the authority of its scientific leader, or *Haut Commissaire*, Francis Perrin. He decided that the CEA should also be concerned with fundamental research in physics, in particular with the construction and use of accelerators. The theorists were intended to play an important role in the planning and design of these. Another practice inaugurated by Perrin was to send many young CEA members abroad to learn modern physics. It turned out that Anatole was not eligible to take part in this, but was able to join the initiative supported by the British Council to study at Oxford University, and he then gained a Fellowship at Harvard University, in the United States of America, thanks to the support of John van Vleck.

**FROM OXFORD, UK, TO CAMBRIDGE, USA**

The period 1948 to 1950 saw Anatole’s first venture abroad to the Clarendon Laboratory at Oxford University, where he worked on several problems in electron paramagnetic resonance (EPR) in collaboration with, and under the direction of, Maurice Pryce. They developed the theory of the spin Hamiltonian in 1949, which brought about an enormous conceptual simplification in the theoretical description and understanding of localized paramagnetic ions in non-conducting solids. The technique involved ‘making believe’ that the basic states of an isolated multiplet were those of a spin, and then, in terms of operators of this fictitious spin, ‘inventing’ the Hamiltonian, the eigenvalues of which would fit the observed energies within the multiplet. This theory became very famous and the article describing it was known as ‘the A and P paper’, echoing the name of a then popular US grocery store chain (1)*. In his next work, largely carried out on his own, he developed the theory of core polarization, a major theoretical success that made it possible to explain the anomalous hyperfine structures of copper ions. This was Anatole’s first step towards scientific recognition and won him his DPhil (2–5).

He was then sent to Edward Purcell’s laboratory for nuclear magnetic resonance (NMR) at Harvard University in Cambridge, Massachusetts, in 1952–53. There, besides becoming a world expert in the field of NMR, he worked with Robert Pound to develop the complete

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* Numbers in this form refer to the bibliography at the end of the text.
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theory of perturbed angular correlations in the cascade of two radiations emitted in a nuclear radioactive decay, produced in condensed matter by static or variable electric and magnetic fields. The key point is that these perturbations to the main nuclear energy spectrum influence the rate of evolution towards thermal equilibrium of the intermediate metastable nuclear state. The corresponding articles were referred to as the second ‘A and P papers’ (6, 7). This work initiated the formalism of relaxation theory developed a few years later at Saclay, near Paris, in the Centre d’Etudes Nucléaires, which was opened by the CEA during his absence.

**THE LABORATORY OF NUCLEAR MAGNETIC RESONANCE AT SACLAY**

Back in France, Anatole was first given the task of investigating the theory of the various methods of beam focusing of a cyclo-synchrotron then under study. Among his collaborators was a young physicist, Ionel Solomon, who was to play an important role in what follows.

In 1955, Anatole created the Section d’Etude de la Résonance Magnétique (SERM), devoted to both EPR, under the direction of Jean Combrisson, and NMR, under the direction of Ionel Solomon. EPR gradually became of lesser importance, to the benefit of NMR research, and the laboratory became known worldwide as the Saclay Laboratory for Magnetic Resonance. Anatole would be its director for 30 years until his retirement. His career progressed, with increasing scientific responsibilities—service head, department head and director of physics from 1965 to 1970—as well as his teaching activities at Saclay and at the Collège de France, which will be described later. Ionel Solomon played a fundamental role in creating and then directing the laboratory, and it was thanks to him that it became a true high-level experimental laboratory. He left in 1962 to create his own laboratory. The Saclay Laboratory gave rise to many prominent achievements, both by Anatole himself and from other members of the laboratory, often in collaboration.

Nuclear relaxation is the name given to the progression of nuclear spins towards equilibrium with their surroundings at the temperature of the latter. Its development in 1955–56 was generated alongside the theory of perturbed angular correlations, by the work of Ionel Solomon at Harvard in the 1950s (Solomon 1955; Solomon & Bloembergen 1956), who generalized the Overhauser effect to dipolar interactions and discovered cross-relaxation both theoretically and experimentally. The theoretical discovery by Overhauser in 1953 (Overhauser 1953) was that saturating the spin polarization of conduction electrons in metals resulted in an increase of the nuclear spin polarization to the thermal equilibrium value corresponding to the electronic resonance frequency. The interaction responsible for this effect is the scalar electron–nuclear contact interaction. Anatole’s formalism of relaxation was entirely based on the use of operators and the density matrix. For most cases, it became, and largely remains up to this day, the method for relaxation calculations (8).

Another major achievement was the invention, in collaboration with Jean Combrisson and Ionel Solomon, of an Earth-field magnetometer of unprecedented sensitivity in 1958 (13). It is an auto-oscillator analogous to a maser, whose frequency is the proton Larmor frequency in the Earth’s field. It is based on the Overhauser inversion of the solvent proton polarization by saturating an appropriate hyperfine resonance of dissolved nitroso radicals. This magnetometer has been routinely used in geophysical surveys, in particular in connection with oil prospecting, and for the detection of metallic objects underground or under sea, such as sunken ships, submarines, lost gas pipes, etc., although different methods have been
invented since. As an aside, this magnetometer was used to discover the wreck of the frigate *La Méduse*, sunk off the shore of Mauritania in 1816, because of the change in the local magnitude of the Earth’s magnetic field produced by the 50 tons of cannons on board. The worldwide continued memory of this dramatic wreck is primarily due to the famous painting *Le radeau de la Méduse* (*The Raft of the Medusa*) by Theodore Gericault (1819).

Another ‘first’ was establishing beyond any doubt the validity of the spin temperature concept in the laboratory frame by a series of extremely elegant experiments which Anatole devised and performed in 1957 with Warren Proctor. They involved demonstrating that cooling the spins through contact with liquid helium or by adiabatic demagnetization from a high magnetic field had the same experimental consequences. This was the occasion for a third series of three ‘A and P papers’ (9–11). The first introduction of the spin temperature concept for interpreting puzzling experimental results had been made by Robert Pound and Edward Purcell in 1951 (Pound 1951; Purcell & Pound 1951). A private comment made by Edward Purcell when hearing of the first results of Abragam and Proctor was: ‘The baby has been around for a long time, but you have provided the wedding certificate.’ Equally important was Anatole’s role in clarifying and popularizing the slightly earlier invention by Alfred Redfield of spin temperature in the rotating frame—that is, under radiofrequency irradiation close to resonance—and in showing how the theories for both cases could be cast in a common conceptual frame. This concept was verified by many experiments and practical uses, many of them originating in the laboratory.

In the same year (1957), just a few months after the spin temperature experiments, another invention of fundamental importance was made by Anatole, that of dynamic nuclear polarization (DNP). This was initially called the ‘solid effect’ (12), whereby the polarization of nuclear spins can be made nearly equal to unity, either parallel or antiparallel to the external magnetic field by off-resonance irradiation of paramagnetic centres at low concentration in non-conducting solids. The main objective of this invention was the production of polarized targets for nuclear and particle physics experiments. Initially developed in the Saclay Laboratory, and at the same time in Berkeley by Carson Jeffries, polarized targets became extremely successful, popular and important tools used at the most important accelerator centres around the world. In recent years, polarized targets proved to be indispensable for investigating new and important physical phenomena, such as the experimental study of time reversal and parity conservation violation in neutron–nucleus interactions, and for the investigation of the completely unexpected spin structures of nucleons, that is, protons and neutrons, which are still under study and not yet fully elucidated (Aidala et al. 2013).

A dramatic extension of the use of DNP is currently under way with the name of Dissolution-DNP. In order to increase the signal-to-noise ratio in chemical NMR and in magnetic resonance imaging (MRI) by a large factor, a large nuclear polarization in a sample is obtained by carrying out DNP at low temperatures, that is, in solid form, dissolving it in a hot solvent and then quickly transferring it into the spectrometer or the imager for data acquisition (Ardenkjaer-Larsen 2016).

One of Anatole’s most brilliant ideas was to combine the concepts of spin temperature and DNP in inventing the principle of production of nuclear magnetic ordering. The idea was to perform in succession a polarization of the nuclear spins by DNP followed by a nuclear adiabatic demagnetization, either in the laboratory frame in zero external magnetic field (14) or in the rotating frame when a large external field is present (16). The increase of the nuclear polarization amounts to a lowering of the nuclear entropy, and the role of the...
adiabatic demagnetization is to turn the Zeeman order into dipolar order at constant entropy. At sufficiently low entropy, nuclear spins undergo a phase transition to an ordered state. The interactions are either the full nuclear dipolar interactions, in the laboratory frame, or truncated dipolar interactions, in the rotating frame. In this last case, the interactions depend on the orientation of the single-crystal sample in the external magnetic field. Furthermore, it is possible to choose at will the spin temperature to be either positive or negative. This method was used in the Saclay Laboratory for over two decades and led to the production, in a number of different crystals, of a whole series of nuclear spin orders: ferromagnetic, antiferromagnetic and rotating transverse helical structures, whose study was made both through NMR and neutron diffraction (17).

Anatole’s pondering about the possibility of using neutron diffraction for studying nuclear magnetic ordering initially met with complete scepticism from professional practitioners of magnetic neutron diffraction. The reason is that neutron diffraction by ordered electronic structures relies on the spin-dependent magnetic interaction between the electron paramagnetic ions and the neutrons. Nuclear magnetic moments being about three orders of magnitude smaller than electronic moments, the magnetic scattering of neutrons with nuclear spins, which is proportional to the square of the interaction, is about six orders of magnitude smaller than with electronic spins, which renders its practical use hopeless. Anatole noticed that there is another source of spin dependence of the scattering of neutrons on nuclei—the strong interaction, totally different from the electromagnetic interaction. As one of the consequences of this realization, he conceived the so-called ‘nuclear pseudo-magnetism’. When a neutron travels through a polarized material, the average spin-dependent interaction between the neutron and the nuclear spins has the same form as a Zeeman interaction of the neutron. The corresponding pseudo-magnetic field is proportional to the nuclear spin concentration, their polarization and their ‘pseudo-magnetic moment’. As noted above, the latter has nothing to do with magnetism since it describes the spin-dependent neutron–nucleus interaction originating from the strong interaction. Although the analogy with a Zeeman interaction had been found slightly earlier by two Soviet physicists (Baryshevskii & Podgoretskii 1964), it was to Anatole’s great credit that he pushed the concept to its limits and devised experimental schemes to investigate it at the Saclay Laboratory. After the verification of the reality of pseudo-magnetic precession and resonance, a systematic campaign of measurements yielded the pseudo-magnetic moments of more than 25 nuclear isotopes, providing the practitioners of neutron scattering with information of fundamental importance (17).

During the very last year of his career, and on the occasion of his last course at the Collège de France, Anatole revolutionized the practice of muon spin rotation (μSR) with the idea of level crossing. At the time, physicists used pulsed beams to implant polarized muons into matter and followed the time evolution of their polarization, oscillation or damping through the angular anisotropy of the β emission due to parity violation in weak interactions. Anatole’s idea was to sweep a magnetic field parallel to the initial muon polarization. At those fields where a level crossing takes place in the system, consisting of the muon coupled to other spins, flip-flop processes result in a decrease of the muon polarization, which is monitored. There is a double advantage in this procedure. First, one can use a continuous beam rather than a pulsed one, thereby increasing the counting rate by an enormous factor, and as a consequence the sensitivity of the method. Second, one can detect not only the resonance frequency of the muon itself, but also the level structure of the spins coupled to the muon, which was the
decisive advance that turned $\mu$SR into a completely mature spectroscopic method (18). Both $\mu$SR and level crossing had a long history at the time of this discovery, but nobody had had the idea of combining them together.

THE TEACHER

Anatole had an enormous role in propagating his elaborate and theoretically rigorous ‘wisdom’ concerning magnetic resonance throughout the world, which was thanks to his remarkable pedagogical qualities and his art of making complicated subjects look simple. The first beneficiaries were the members of his laboratory. Each day he visited everyone at their benches and asked questions about what they were doing. He always pushed them towards more precision and detail, until he made them discover the exact nature, significance and value of their current work, which they might not otherwise have suspected. He was as demanding in rigour and precision when they gave a seminar and in his critical reading of their manuscripts.
The great challenge among his students was trying to play him back at his own game, which occasionally worked.

The first formal teaching by Anatole was a course of lectures on NMR that he gave at Saclay in 1955. These were watched by many of the most brilliant physicists in the Paris area and were received with unanimous admiration and enthusiasm, as were the corresponding lecture notes, in French, which reached and benefited the rest of France.

It soon became clear that an official teaching position for Anatole in the area of NMR, and also possibly of EPR, was highly desirable. However, the obvious way to become a university professor was impossible for him in France at that time. The reason was that French university professors were public servants and had to hold an official doctorate from a French university. His doctorate, from such an obscure little foreign university as Oxford University, obviously would not do. The famous atomic physicist, Alfred Kastler, found the solution: Anatole should apply for a professorship at the Collège de France. This prestigious institution was founded in 1530 by King François I for the precise reason of counteracting the rigidity of the French university system of the time. Professors at the Collège de France are chosen for their eminence in their field without reference to academic qualifications; attendance is free and no degrees are awarded. Anatole was elected Professor of Nuclear Magnetism in 1960 and he lectured every year on a different subject until his retirement in 1985.

The worldwide community of scientists had to await the publication of his books, which made a deep impression and became classics. This is particularly true of the first one, *The principles of nuclear magnetism* (15), which covered the whole subject of NMR as it was known at the time, as well as the related subject of nuclear quadrupole resonance (NQR). He insisted on the name ‘Nuclear Magnetism’ to cover both topics, but it was not adopted by the rest of the community. This book, published in 1961 by Oxford University Press, was welcomed as a major event in the scientific literature and became known as ‘The Bible’. Fifty years later, and after all the important developments in NMR since then, it is still regarded as the fundamental basic treatise in the field. Its worldwide success was so important and left such an impression on him that, as he himself remarked with some melancholy, it practically overshadowed all the rest of his scientific achievements.

In addition to his many contributions to research, Anatole was instrumental in changing the way physics was taught in France and in relaxing the rules for election to the Académie des sciences, particularly with the aim of electing more young members.

**PERSONAL INTERESTS**

Besides physics, to which he was addicted, and science more generally, Anatole Abragam had interests in other beaux arts: sports, arts proper and literature.

He was a very good swimmer and went regularly to the swimming pool until the age of 90. He used to take a walk every day, for pleasure as well as for the sake of his health, and was physically fit to the point of enabling him to teach gymnastics during the war years, as previously mentioned. Otherwise, he was notably very keen on watching tennis matches.

Anatole liked visiting museums and art galleries, especially for the paintings. He also regularly listened to classical music. His main interest, however, was in literature.

The word ‘literature’ is not adequate to describe his tastes. He liked to read literary authors and began at an early age. Throughout his life he accumulated an encyclopaedic knowledge of
the great works of literature in the three languages he mastered: Russian, his native language, French, of course, and English by taste. He had a voracious addiction for these books. Not only did he appreciate the authors themselves and the content of their works, but he also liked words as the means of expressing one’s inner self. He analysed, or rather ‘dissected’, the languages themselves, which he knew better than most native speakers, and trained himself to understand, write and speak each one in the most refined way. Among the authors he cherished, particular examples include: in Russian, Alexander Pushkin, he knew by heart the 389 stanzas of his poem *Eugene Onegin*; in French, Anatole France, from whose works school children were advised to read aloud one page every day in order to improve their style; in English, Shakespeare above all, but also P.G. Wodehouse and his character Jeeves, the gentleman’s personal gentleman who quietly and discreetly solves all problems.

Anatole had a delightful sense of humour and an anecdote associated with Pushkin is worth mentioning. In the late 1970s and early 1980s, Anatole and I wrote together a large scientific book eventually published by Oxford University Press in 1982 (17). In accordance with Anatole’s well-entrenched habit, each chapter had an epigram as a subtitle, most of them his choice. Among them were ‘The spin who came in from the cold’ and ‘Big Brother is watching you’, among others. Anatole contacted a Russian editor to have our book translated and edited in the Soviet Union. This editor soon declared that the subtitles were totally unacceptable in his country and should be modified or removed. Anatole instead replaced all of them by citations
from Pushkin’s *Eugene Onegin*. The book was subsequently published in its Russian edition without any problem in 1984. A totally unexpected consequence of the new epigrams is that the curator of the Pushkin Museum, who had been given these epigrams to read, decided to add a copy of the book among the objects displayed in his museum.

Anatole died on 8 June 2011, in his ninety-seventh year. He had lost his wife, Suzanne, from a heart attack in 1992. In 1996, he married a Russian physicist, Nina (Figure 2), who became a French citizen after her marriage, as did her daughter Julia, also a physicist, who came to France and now works at CEA. Both enhanced his life to the end.

**HONOURS AND AWARDS**

Anatole was recognized and honoured in many ways. Among these were:

- 1967 Doctor *Honoris Causa* of the University of Kent
- 1967 President of the French Physical Society
- 1973 Member of the Académie des sciences, France
- 1974 Foreign Member of the American Academy of Arts and Sciences
- 1976 Doctor *Honoris Causa* Oxford University
- 1976 Honorary Fellow of Merton College, Jesus College and Magdalen College, all at Oxford University
- 1977 Foreign Member of the National Academy of Sciences of the USA
- 1981 Foreign Member of the Pontificale Academy of Sciences
- 1982 Lorentz Medal of the Royal Netherlands Academy of Arts and Sciences
- 1983 Foreign Member of the Royal Society of London
- 1986 Doctor *Honoris Causa* of the Technion in Haifa, Israel
- 1986 Medal Antoine Becquerel, France
- 1992 Honorary Fellow of the Ioffe Institute, Russia
- 1992 Medal Matteucci of the Italian Academy of Sciences
- 1994 Honorary Professor of Kazan State University
- 1995 Great Lomonosov Medal of the Russian Academy of Sciences
- 1999 Foreign Member of the Russian Academy of Sciences
- 2004 Foreign Member of the European Academy of Sciences

He has been awarded the following prizes:

- 1958 Grand Prix du Conseil de la Recherche Scientifique
- 1958 Holweck Prize from the Physical Society
- 1958 Prix Hughes from Académie des sciences
- 1970 Grand Prix Cognacq-Jay from Académie des sciences
- 1983 ISMAR Prize from the International Society of Magnetic Resonance

and he has been decorated:

- Commandeur de la Légion d’honneur
Above all, his most outstanding title to fame is that he was a good physicist.

ACKNOWLEDGEMENTS

This memoir is largely based on both the French and the English versions of the autobiographies of Anatole Abragam, especially with respect to his youth and first scientific activities, together with many personal discussions with Anatole. I am indebted to his wife, Nina, for precious additional information. Many thanks for precise bibliographical references are due to Madame Delphine Vidal-Dufort, of the Direction of Fundamental Research, and Madame Sophie Delmas, from the Archives Service of CEA.

The portrait photograph is by Robert Doisneau, and is used with permission from the Gamma Rapho agency (© Robert Doisneau/Gamma Rapho).

AUTHOR PROFILE

Maurice Goldman

Maurice Goldman graduated as a chemist from Ecole Supérieure de Physique et Chimie Industrielles, Paris in 1955, and completed a Doctorate in Physics in 1967 at the University of Paris. He worked in physics research from 1955 to 2005, successively as Physicist at CEA (1955–1969), Laboratory Vice-Director at Collège de France, Paris, and Scientific Advisor at CEA (1969–1983), Physicist and then Research Director at CEA (1984–1993), and Scientific Advisor at CEA (1993–2005). He headed the Magnetic Resonance Laboratory founded by Anatole Abragam (1969–1993). He was commissioned to supervise the development of Biomedical Research at CEA (1983–1989). He was elected Corresponding Member of the Académie des Sciences, Paris, in 1986 and a full member in 2004. He served as President of the International Society of Magnetic Resonance (ISMAR), and was involved as Member of the Council in other major Societies of NMR: the European Groupement AMPERE and the French GERM. His scientific work, essentially in NMR, was principally devoted to Statistical Thermodynamics of spin systems, Nuclear Magnetic Ordering, Relaxation and Dynamic Nuclear Polarization in Solids, and the theory of NMR High Resolution in Liquids. His publications include the book Nuclear Magnetism: Order and Disorder (1982), written jointly with Anatole Abragam.

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