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HISTORICAL NOTE

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Neuroradiological history: Sir Joseph Larmor and the basis of MRI physics

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Abstract The origin of many of the eponymous terms in modern medicine is unknown to many people who utter them daily. As a contribution to understanding the historical background of MRI, we provide a brief account of the life and work of Joseph Larmor, the Irish scientist, whose name is frequently used by chemists, physicists and radiologists alike.

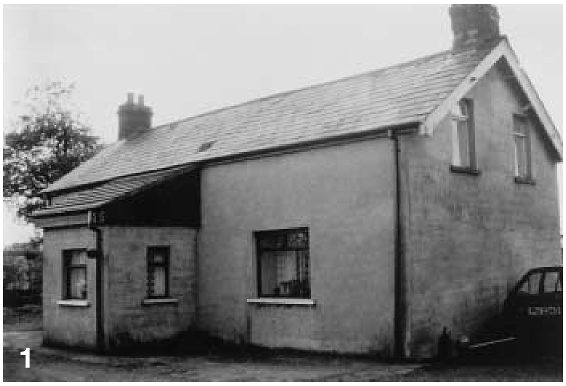
Key words Larmor, Joseph · Magnetic resonance imaging · Neurology history

Joseph Larmor was born in Magheragall in Co. Antrim on 11 July 1857 (Fig. 1), and was one of the last of a group of nineteenth century ‘Scoto-Irish’ physicists whose work influenced heavily the experiments and discoveries of the early 20th century. He attended school at the Royal Belfast Academical Institution, and was brought up in Belfast by his uncle (Fig. 2). He was a thin, delicate, black-haired boy of precocious ability in both mathematics and classics. He obtained a double first in the scholarship examination at Queen’s College Belfast, and ultimately graduated with the highest honours. At Queen’s College he obtained a BA and an MA.

He went to St. John’s College in Cambridge; a severe illness forced him to lose a year but he became senior wrangler and won Smith’s Prize. He took the mathematical tripos in 1880, securing first place in the list, and was elected a Fellow of the College the same year. He was appointed Professor of Natural Philosophy in Queen’s College, Galway, where he worked from 1880 to 1885 (Fig. 3). In 1885, he returned to St. John’s as a lecturer and, on the death of Sir George Stoke, Larmor was made the Lucasian professor at Cambridge in 1903. At this time, the atom was not yet understood and it was 2 years before Einstein published his papers on light quantum and relativity.

In 1909 Joseph Larmor was knighted and was the Unionist Member of Parliament for Cambridge University from 1911 to 1922. He had intense feelings over “the Irish question” and in his maiden speech in 1912 he defended the Unionist position in the debate on Irish home rule. He recalled how he was involved in the defeat of the alternative vote, which he claimed to have secured by a long speech, leading the bewildered House deeper and deeper into mathematics until the Whip gave him the signal that the wanted absentees had arrived [1]. However, his major concern was for education and the universities. He had a strong attachment to his native country, and generally spent part of his summer vacation in Ireland. He never married, and retired aged 75 years in 1932. His last years were spent at Holywood, Co. Down until his death on 19 May 1942 (Fig. 4).

Larmor’s scientific work was wide-ranging. By 1892, he had published some 30 papers on a variety of subjects in applied mathematics, and he was elected to the Royal Society of London that year. Between 1894 and 1897 he published, in the *Philosophical Transactions,* his great



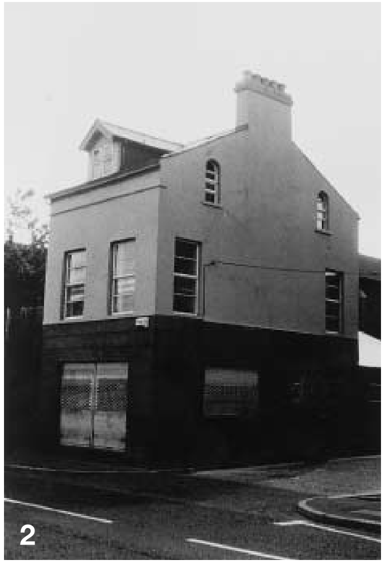


Fig. 1 The house in which Joseph Larmor was born in Magheragall, County Antrim, Northern Ireland

Fig. 2 The house in Antrim Road, Belfast, where Larmor was brought up by his uncle (now a solicitor's office)

Fig. 3 Joseph Larmor (reprinted with courtesy of the National University Hospital, Galway)

memoir 'A dynamical theory of the electric and luminiferous medium' in three parts. The theory was resubmitted a year later as an essay on the theory of the aberration of light and won the Adams prize in the University of Cambridge. The essay was published as a book – *Aether and matter* – in 1900. His writing style has been described as 'difficult' and 'lacking lucidity' [1] and his lectures as ill-ordered and obscure. He was decidedly conservative in his scientific views and a difficult colleague on syndicates and in examining dissertations. His fellow workers described him as "determined but not persuasive", and in the words of D'Arcy Thompson, "Larmor made few friends, perhaps; but while he lived, and they lived, he lost none." [2]

Throughout Larmor's work runs an underlying theme: the principle of least action, or Hamilton's Principle. This states that the motion of a particle over short intervals will minimise that action integral. William Rowan Hamilton (1805–1865) was Ireland's most famous 19th century mathematician and Hamilton quaternions (sets of vectors involving imaginary numbers), are regularly used in computer graphics and space-craft guidance systems today. A child prodigy, Hamilton spoke 13 different languages by the age of 13 years [3].

In the latter half of the 19th century, the existence of the aether was still accepted and ideas about such things as electrons were not common; there was little understanding of matter and energy. Aristotle explained that the heavens were composed of aether (also referred to as quintessence), and this was postulated to explain the workings of the universe which surrounded the earth; it was supposed to be a sort of medium inside which the universe existed. The nature of aether was, however, unclear but it was generally agreed that it existed. Aether was believed to be divided into spheres, naturally perfect, rotating without friction. The planets were believed to be regions of high density within this (transparent) aether. The only changes in these general beliefs from the time of Aristotle to medieval times were in the character of aether and the addition of a quantitative approach to its analysis.

By Larmor's time, aether was the mechanism used to explain how light waves travelled, and could be considered in the same way as water, which also provides a medium for waves to travel. Larmor could not discover direct evidence of the motion of the earth through aether but he did provide a partial explanation, which led to the theories that were part of Albert Einstein's Theory of Relativity [1].

Larmor also made major contributions to electrodynamics and electron theory. He proposed that the electrical charge of an electron might be a measure of its mass and electrons are now measured in electron volts (eV). He effected a new concept called the electron theory of matter and developed its radical implication regarding the nature of mass, the structure of the atom and its relation to radiation, the kinetic theory of heat (equipartition), and the electrodynamics of moving bodies. He also contributed to the progress of what is now called the Lorentz transformation. This transformation, named after the Dutch physicist Hendrik Antoon Lorentz, was first written down in 1887 by Voigt, and in 1889 another Irish physicist – George Fitzgerald from Monkstown in Dublin – had published similar

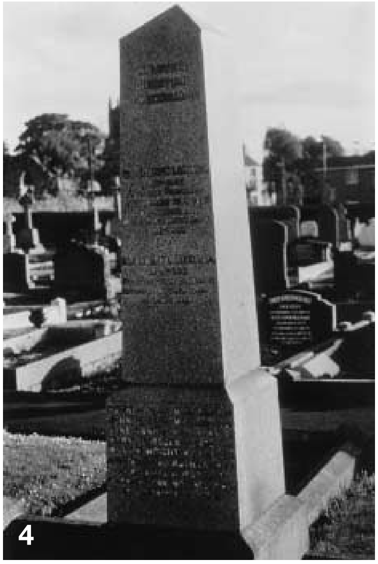


Fig. 4 Sir Joseph Larmor's gravestone at, Holywood County Down

Fig. 5 Sir Joseph Larmor (courtesy of The Royal Society of Medicine)

Fig. 6 Sir Larmor at the unveiling of Lord Kelvin's statue in 1913

ideas in a paper in *Science* entitled 'The ether and the earth's atmosphere'.

Larmor was secretary to the Royal Society from 1901 to 1912 and was the Royal Society's Bakerian Lecturer in 1909. In 1915 he was awarded the Royal Medal and in 1921 the Copley Medal. He was elected to the London Mathematical Society in 1884 and held several offices: council member 1887–1912; vice-president 1890 and 1891; treasurer 1892–1914; and president 1914–1916. He received the De Morgan Medal of the London Mathematical Society in 1914. He received many honorary degrees from universities in Britain, including Glasgow, Aberdeen, Birmingham, St. Andrews, Edinburgh and Durham, as well as from Academies in Washington, Boston, Philadelphia, Rome, Bologna and Paris. He also received the freedom of the city of Belfast [4].

Larmor's proposal of an electrical theory of matter was overshadowed by Einstein's papers on relativity and the development of quantum theory. He is remembered principally as the first person to give the formula for the radiation of energy from an accelerated electron and he was also the first to explain the effect of a magnetic field in splitting the spectrum into multiple lines. Larmor was one of the last physicists to really believe in strict Newtonian mechanics, as physics was being taken over around this time by the theories of relativity and quantum mechanics. His name is given to the Larmor precession, the Larmor frequency, and Larmor's theorem.

Larmor's precession explains the triplication and polarisation of spectral lines which was discovered by Pietar Zeeman (with related work by H. H. Lorentz) when a strong magnetic field was applied to sodium. (Zeeman later won the Nobel Prize) The Larmor frequency is given by the equation: Omega = (e/2m). B (where Omega = the angular momentum of an electron; e = electron; B = magnetic field strength). This theory holds that, with several orbiting electrons, some orbits would be accelerated and some slowed down, while some would remain unaffected by a magnetic field, so that there would be a nett effect of zero (or a very small amount). However, spectral lines would be separate for different speeds. Larmor postulated that electrons orbited around some centre.

The Larmor theorem was an extension of the above and states that: Omega = – (e/2m). B, i. e., that for any charged particle with the same e/m ratio, subject to electric and magnetic fields, the effect of the magnetic field can be negated by a transformation of the frame of reference with this formula. Larmor's formula described ways to calculate the power (P) radiated by an electron's acceleration in terms of charge (e), speed of light (c), and the acceleration (a): $P = 2/3\ e^2 \cdot a^2 \cdot c^3$. This is still applicable at speeds of less than close to the speed of light but is no longer viewed useful in terms of relativity.

In the field of magnetic resonance physics Larmor is best known for his equation describing the effect of an external magnetic field on the precession frequency of protons placed in that field: Omega (ω_o) = $\gamma \cdot B_o$ (where ω_o = the precession frequency of the spinning protons in the magnetic field; γ = the gyromagnetic ratio; and B_o = the strength of the external magnetic field (in Tesla)). The equation states that the precession frequency of a spinning proton becomes higher when the magnetic field strength in which it is placed increases and it is the basic physical equation underling magnetic resonance imaging.

Larmor rejected Einstein's work, and in the 1920 s his own work, and that of his students came to a close (Fig. 5). He finished editing writings of George Stokes and Lord Kelvin (Fig. 6) and revised some of the work of Henry Cavendish. He also wrote substantial obituaries of Josiah Gibbs, George Stokes and Lord Kelvin [5].

Four years after Larmor's death in 1942, in the USA, Bloch and Purcell published the results of their work on magnetic resonance which eventually lead to the development of MRI as we know it today.

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