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## Rutherford, Ernest

1871–1937

Scientist

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Ernest Rutherford was born at Spring Grove in rural Nelson, New Zealand, on 30 August 1871, the fourth child of 12 born to James Rutherford, a mechanic, and his wife, Martha Thompson, who had been the schoolteacher at Spring Grove. He was officially but mistakenly registered as Earnest; in the family he was called Ern. When he was five they moved to a small farm near the new railhead at Foxhill, where he attended Foxhill School.

In 1883, when Ern was 11 years old, his father moved the family to Havelock, at the head of the Marlborough Sounds, to be nearer to the flax mill he was now operating by the Ruapaka Stream. Martha Rutherford ensured that all her children were well prepared for school and all received good educations. In 1887 Ernest won, on his second attempt, the Marlborough Education Board scholarship to Nelson College.

Rutherford boarded at Nelson College from 1887 to 1889. In 1889 he was head boy, played in the rugby team and, again on his second attempt, won one of the 10 scholarships available nationally to assist attendance at a college of the University of New Zealand. From 1890 to 1894 he attended Canterbury College in Christchurch. There he played rugby and participated in the activities of the Dialectic Society (a student debating society) and the Science Society. In 1893 he graduated BA in pure mathematics and Latin (both compulsory), applied mathematics, English, French and physics.

Rutherford's mathematical ability won him the one Senior Scholarship in mathematics available in New Zealand. This allowed him to return for a further (honours) year during which he took both mathematics and physics, and was influenced by Professor Alexander Bickerton. The physics course required students to undertake an original investigation; Rutherford elected to extend an undergraduate experiment in order to determine if iron is magnetic at very high frequencies of magnetising current. He invented two devices: a simple mechanism for switching two electrical circuits with a time interval between them which could be adjusted to be as short as one-hundred-thousandth of a second, and a detector of very fast current pulses. By the end of 1893 he was an accomplished researcher (his first research was published in his second scientific paper in 1895). In 1893 Rutherford obtained an MA with double first-class honours in mathematics and mathematical physics and in physical science (electricity and magnetism). At this time he boarded with a widow, Mary ...wton, who was active in the suffrage movement.

... 1894 Rutherford returned to Canterbury College where he took geology and chemistry for a BSc degree, awarded in 1895. For the research work required of a candidate for an 1851

Exhibition scholarship, he extended his researches of the previous year to even higher frequencies using the damped oscillatory current obtained from discharging a Leyden jar (an electrical capacitor), either alone or via a Hertzian oscillator. He showed that a steel needle surrounded by a loop in the discharge circuit was indeed magnetised for frequencies as high as 500 million per second, and by slowly dissolving the needle in acid he showed that only a very thin surface layer of the needle was magnetised. This work was reported in his first published paper in 1894.

Rutherford was a not particularly successful relieving teacher at Christchurch Boys' High School for a few weeks late in 1894. Having failed for the third time to obtain a permanent job as a schoolteacher he looked to other avenues. He submitted his work of 1893 and 1894 to the University of New Zealand in support of his application for the biennial 1851 scholarship. There were two candidates and the university's examiners in England recommended that James Maclaurin of Auckland University College be nominated. Maclaurin could not agree to the new conditions of the scholarship, which was then awarded to Rutherford.

Ernest Rutherford left New Zealand in 1895 as a highly skilled 23-year-old who held three degrees from the University of New Zealand and had a reputation as an outstanding researcher and innovator working at the forefront of electrical technology. He chose to work with Professor J. J. Thomson of the University of Cambridge's Cavendish Laboratory; he was the first non-Cambridge graduate to become one of its research students. Rutherford adapted his detector of very fast transient currents for use as a frequency meter, and used it to measure the dielectric properties of electrical insulators. To compare its sensitivity as a detector of electromagnetic waves against that of the standard detector of the time, the coherer, he mounted his detector in the receiving circuit of a Hertzian oscillator–receiver unit and found, as had others before him, that he could detect electromagnetic waves over a few metres even when there was a brick wall between the two circuits.

Rutherford was encouraged in his work by Sir Robert Ball, who had been scientific adviser to the body maintaining lighthouses on the Irish coastline; he wished to solve the difficult problem of a ship's inability to detect a lighthouse in fog. Sensing fame and fortune, Rutherford increased the sensitivity of his apparatus until he could detect electromagnetic waves over a distance of several hundred metres. However, Thomson, who was soon to be the first to discover an object smaller than an atom (the electron), quickly realised that Rutherford was a researcher of exceptional ability and invited him to join in a study of the electrical conduction of gases. The commercial development of wireless telegraphy was thus left for Guglielmo Marconi.

Rutherford developed several ingenious techniques to study the mechanism whereby normally insulating gases become electrical conductors when a high voltage is applied across them. When X-rays were discovered a few months later he used them to initiate electrical conduction in gases. He repeated this with rays from radioactive atoms when they were discovered in 1896, but his interest soon switched to understanding radioactivity itself. In 1898 he discovered that two quite separate types of emissions come from radioactive atoms and he named them alpha and beta rays. Beta rays were soon shown to be high-speed electrons.

In 1898 Rutherford accepted a professorship at McGill University in Montreal, Canada. In the well-equipped laboratories there Rutherford, with the later help of a young chemist, Frederick Soddy, unravelled the mysteries of radioactivity, showing that some heavy atoms

spontaneously decay into slightly lighter, and chemically different, atoms. This discovery of the natural transmutation of elements first brought him to world attention. He was elected a fellow of the Royal Society of Canada in 1900 and of London in 1903. His first book, *Radioactivity*, was published in 1904; others on the same subject followed in 1908 and 1913. In 1908 he was awarded the Nobel Prize in chemistry for his investigations into the disintegration of elements and the chemistry of radioactive substances.

On realising that lead was the final decay product of uranium, Rutherford proposed that a measure of their relative proportions and the rate of decay of uranium atoms would allow minerals to be dated. Subsequently, this technique placed an acceptable lower limit on the age of the formation of the earth. Radioactive dating of geological samples is an important part of modern geology.

Rutherford had returned to New Zealand in 1900 to marry Mary Georgina (known as May) Newton, the daughter of his landlady in Christchurch. They were married at Christchurch on 28 June 1900; their only child, Eileen, was born in 1901. The Rutherfords visited New Zealand in 1905 in order to renew ties with their families. In 1907 Ernest was attracted to Victoria University of Manchester where he would be nearer the main centres of science. There he showed convincingly what he had long suspected: that the alpha particle was a helium atom stripped of its electrons. He and an assistant, Hans Geiger, developed the electrical method of detecting single particles emitted by radioactive atoms using a device which evolved into the Geiger–Müller tube.

While at McGill Rutherford had noted that a narrow beam of alpha particles became fuzzy on passing through a thin sheet of mica, so he offered to a young student, Ernest Marsden, the project of measuring the relative numbers of alpha particles as a function of scattering angle. Marsden found that some alpha rays even scattered directly backwards from a gold film. It was, as a surprised Rutherford stated, as if one had fired a large naval shell at a piece of paper and it had bounced back. In 1911 Rutherford deduced from these results that almost all the mass of an atom – an object so small that it would take about a million of them side by side to cross a full stop on this page – is concentrated in a nucleus a thousand times smaller than the atom itself. The nuclear model of the atom had been born. This second great discovery gave him enduring fame. Niels Bohr, a young Dane attracted to work with Rutherford, used his quantum ideas to produce a stable orbit model of the atom. The Rutherford–Bohr atom features in chemistry and physics books used in schools worldwide, and Rutherford scattering is still used today to probe sub-nuclear particles and layers of atoms in microelectronic devices.

Rutherford was knighted in the 1914 New Year's honours list, later visiting Australia and New Zealand for a scientific meeting and a family reunion. After a three-month stay he returned to Britain where he worked on acoustic methods of detecting submarines for the Admiralty Board of Invention and Research. His only patent derived from his development of a directional hydrophone. When the United States entered the First World War in 1917, Rutherford led the delegation to transfer submarine detection knowledge to them. While there he fruitlessly advised the United States government to use young scientists on problems associated with war work and not to waste their lives and skills in the trenches.

Near the end of the war Rutherford returned to the pursuit of atomic science. While bombarding nitrogen atoms with alpha rays, he observed outgoing protons of energy larger than that of the incoming alpha particles. From this observation he correctly deduced that the

bombardment had converted nitrogen atoms into hydrogen atoms. He thus became the world's first successful alchemist and the first person to split the atom, his third great claim to lasting scientific fame.

In 1919 Rutherford became the director of the Cavendish Laboratory. The following decade was one of consolidation, of setting up a first-class research team and of tidying up loose ends.

In 1925 Rutherford once more travelled to Australia and New Zealand to give public lectures and to visit ailing parents. He was then an imposing figure: tall, well built and with bright blue eyes. The six-week tour of New Zealand, his fourth and last visit to his homeland, was that of an international celebrity. Wherever he went he was accorded a civic reception and halls were packed to overflowing to hear him give illustrated talks on the structure of the atom. Rutherford declared that he had always been very proud of being a New Zealander.

He also publicly encouraged the government to reserve some of the most scenic parts of New Zealand for posterity and supported education and research. In particular, he recommended that New Zealand scientists devote special attention to researches of benefit to farmers. His support helped see the establishment of New Zealand's Department of Scientific and Industrial Research in 1926.

Tragedy came to the Rutherfords when their daughter Eileen, who had married Ralph Fowler, a mathematical physicist at the Cavendish Laboratory, died in December 1930, nine days after the birth of her fourth child. This overshadowed Rutherford's elevation to the peerage in the New Year's honours list of 1931, as Baron Rutherford of Nelson. He chose to include in his coat of arms a kiwi, a Māori warrior and Hermes Trismegistus, the patron of knowledge and alchemists. His shield is quartered by the curves of the decay and growth of radioactivity. His Latin motto, 'Primordia quaerere rerum' (To seek the nature of things), was chosen from Lucretius's *De rerum natura*. He spoke only twice in the House of Lords, on both occasions in support of industrial research.

For Rutherford and the Cavendish Laboratory 1932 was a vintage year. James Chadwick discovered the neutron, which a decade earlier Rutherford had predicted must exist. In that same year John Cockcroft and Ernest Walton finally split the atom by entirely artificial means using protons, the nuclei of hydrogen atoms, which had been accelerated to very high speeds in a high-voltage accelerator. The age of big science had begun under Rutherford's guidance.

Rutherford served well his science, his laboratory, his university and his adopted country. He campaigned for Cambridge University to grant women the same privileges as men. He carried out regular public duties such as supporting the freedom of the British Broadcasting Corporation from government censorship, and served on its general advisory council. While on the board of management of the Commissioners for the Exhibition of 1851 he defended the award of scholarships to overseas universities. As chairman of the Advisory Council of the Department of Scientific and Industrial Research he advised the British government on scientific matters and opened many research laboratories. He also advised the New Zealand University colleges on selection of most of their professors of physics. Rutherford accepted many New Zealand students and academic staff for work in his laboratory because he knew they had so little opportunity at home.

Rutherford was one of the first to determine that the energy involved in the radioactive decay of an atom was millions of times that of a chemical bond, and he was the first to be convinced that this energy was internal to all atoms. In 1916, at the height of the First World War, he

stated that it was not then possible for the energy of the atom to be extracted efficiently; he personally hoped that methods for doing this would not be discovered until man was living at peace with his neighbours. Nuclear fission, which made possible the efficient release of energy from uranium, was not discovered until two years after his death.

In 1933 Rutherford helped found, and was president of, the Academic Assistance Council, which aided academics displaced by Adolf Hitler's rise to power in Germany. He presided over a meeting of the Cambridge University branch of the Democratic Front, in which he made a case for an international ban on the use of aeroplanes in warfare.

Ernest Rutherford died at Cambridge on 19 October 1937, the result of delays in operating on his partially strangulated umbilical hernia. His ashes were interred in London's Westminster Abbey, under an inscribed flagstone near the choir screen in the nave. Lady Rutherford retired to Christchurch where she died in 1954. Rutherford's medals, possibly the world's best assemblage awarded to one scientist, were given to Canterbury College.

During his lifetime Rutherford was awarded scientific prizes and honorary degrees from many countries and fellowships of a variety of societies and organisations (such as the Royal College of Physicians of London and the Institution of Electrical Engineers). Among other honours he was elected president of the Royal Society of London (1926–30) and president of the Institute of Physics (1931–33), and was appointed to the Order of Merit (1925).

Death did not stop the public acclamation. Buildings in a number of countries have been named in Rutherford's honour. He has appeared on the stamps of four countries: Sweden in 1968, and Canada, the USSR and New Zealand in 1971. In 1969 element 104 was named rutherfordium in his honour. In 1991 the Rutherford Origin was built on the site of his birth. It incorporates into a garden setting a permanent outdoor display of information about his life and work. In 1992 his portrait featured on New Zealand's new $100 banknote.

Ernest Rutherford is regarded as one of the greatest of all scientists, radically altering our understanding of nature on three separate occasions. Yet he was no solitary genius, and his success at putting whichever laboratory he was leading at the forefront of experimental physics owed much to his ability to draw essential contributions from his fellow workers. Young graduates and prominent scientists from around the world were drawn to work with him. He treated the most famous and the most junior alike as equals. He was generous in giving credit to younger colleagues: often his name did not appear on papers covering important work which he had initiated. His conversation was animated, and he inspired enthusiasm in others. He was unassuming and modest; the tone of his publications was tentative, never claiming more than had been strictly verified. Rutherford enjoyed the warm regard of people of many different nationalities and was capable of giving strong support to colleagues in personal distress. He is remembered alike for his breadth of humanity and his contribution to human knowledge.

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