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The public are mad on radium!
Rutherford, New Zealand and the new physics

. . . The public are mad on radium . . .
— GOVERNMENT BALNEOLOGIST ARTHUR WOHLMANN, 1914[1]

The energy produced by the breaking down of the atom is a very poor kind of thing. Anyone who expects a source of power from the transformation of these atoms is talking moonshine.
— ERNEST RUTHERFORD, 1933[2]

The Rotorua Bathhouse, a large and elaborate complex in the style of a European spa, was for many years the focus of the small town that grew around it. From when it opened in 1908, weary or chronically ill ladies and gentlemen would come to the bathhouse to soothe their arthritic joints with massage and thermal baths, or to smooth mud on their eczema- or psoriasis-ravaged skin. After 1914, they could also treat their depression or constipation with a course of specially prepared glasses of radioactive water.

The enterprising idea of adding radon water to the spa's list of treatments came from Arthur Wohlmann, the balneologist — an expert in the therapeutic use of mineral waters — responsible for New Zealand's government-owned spas at Rotorua, Te Aroha and Hanmer. After a trip to Europe, Wohlmann

In 1914, the luxurious Rotorua Bathhouse added radioactive water — four to six glasses a day were recommended — to the spa's list of therapeutic treatments. OP-2489, Rotorua Museum of Art and History, Te Whare Taonga o Te Arawa, Rotorua, New Zealand.

had declared that treatment by radioactive waters, with their 'alterative effects on metabolism', had come to stay and its 'possibilities were very great'.[3] Wohlmann described radon water as being able to be provided by injection, by vaginal or rectal douches, or insertion into tooth cavities, but at the Rotorua Bathhouse he focused on administering radon through the skin and lungs, by soaking in steaming hot radioactive baths or inhaling radon gas, and by drinking radioactive water, which he described as 'by far the most satisfactory method of administration' as it stayed in the body much longer.[4]

For £250 — quite a sum in 1914 — he bought a 'radium activator': a porcelain jug with a side tap for draining off water. Inside the jug, a small container held a minute quantity of the mineral salt radium bromide, from which a continuous emanation of radon gas irradiated any water used to fill the jug. The radioactive water was drawn off and replenished daily. The radium, with a half-life of 1620 years, could irradiate the water almost indefinitely. But the radon gas — the element that gave the water its radioactive 'curative' properties — had a half-life of less than four days, and so for the treatment to be 'effective' patients were advised that the radioactive water

had to be drunk within 24 hours of being drawn. Wohlmann recommended that each patient take four to six small glasses a day, with the radioactive water promoted as being especially valuable in treating gout, diabetes and constipation, as well as for soothing the nerves and, according to the local newspaper, 'tightening loose teeth'.[5] As word of the new therapy spread, many patients were sent to Rotorua for radon treatment: in 1916, more than 8500 glasses of radon water were sold.

To imbibe radioactive water as a 'treatment' for chronic illness seems preposterous in light of what we now understand about it, but Wohlmann was no charlatan: he was a medical doctor and a scientist, striving to keep up to date with, or ahead of, the rest of the world when it came to the latest applications of his science. In giving radioactive water to his patients, Wolhmann was acting on scientific beliefs based on work by Marie Curie, and others, that suggested that moderate doses of radioactivity promoted 'the multiplication and growth of healthy cells and the decay of morbid ones'.[6] His patients, in turn, were seeking the assurance of having the latest treatments on offer. New Zealanders in the early twentieth century were, therefore, as enthusiastic about subjecting themselves to unnecessary radiation as people from any Western nation. While some harmful effects of radiation were already evident, they were not well understood, and radiation technologies had proved so beneficial in the diagnosis of disease and the treatment of cancer that radon water treatment was, for many, seen as a natural extension of the benefits of this marvellous yet poorly understood new phenomenon called radiation.

A NEW SCIENCE IS BORN

When Wohlmann began offering radon water treatment, in 1914, it was less than two decades into the revolution in physics that had begun with the discovery of first x-rays, and then naturally occurring radioactive elements like radium. It began in 1895, when German physicist Wilhelm Röntgen observed the mysterious and invisible electrically generated rays, which he called 'x-rays', that could pass through paper, wood, rubber, copper and even thin sheets of most metals, but not through bones or lead. By placing opaque objects between the source of the rays and a photographic plate, Röntgen discovered he was able to take x-ray pictures.

News of Röntgen's discovery spread quickly to the popular press, where it caused an international sensation. Responding to public excitement about the discovery, Röntgen appeared at packed public lectures to demonstrate the workings of his x-ray machine, training it on the skulls, arms, and legs of enthusiastic volunteers. Some people were alarmed by his discovery. There was talk of banning x-rays in opera glasses for fear of insulting the virtue of the female singers by seeing through their clothes — one company even started to market x-ray-proof underwear. Others were quick to take up the relatively simple science involved. Doctors saw the potential to use x-rays as a diagnostic tool, and in February 1896 Canadian surgeons used x-rays to help locate and remove a bullet from a man's leg. Doctors also began to use x-rays for ostensibly therapeutic purposes — to treat dermatitis, cancer and tuberculosis.

In New Zealand, the media — concerned mainly with colonial news, the price of mutton in London, and the latest shipment of British goods to arrive at Ballantynes or Kirkcaldie & Stains — were more subdued, responding only after the discovery of x-rays had made news in Britain. The *New Zealand Mail* reported that London doctors were using Röntgen's discovery to take pictures of gallstones and injuries to the bones, achieving 'astonishing results'.[7] The new discovery caused great excitement in the New Zealand medical and scientific communities, and x-rays were discussed at meetings of the New Zealand Medical Association and at the scientific societies that made up the New Zealand Institute. *The New Zealand Medical Journal*'s London correspondent described the new photography developed by Röntgen for New Zealand readers, exclaiming that never 'has a scientific discovery excited more general interest, been followed up with such rapidity, and attained such extended success'.[8] Lawyer and naturalist William Travers, in his 1896 presidential address to the Wellington Philosophical Society, provided a detailed account of the discovery of 'Röntgen Rays', which he described as 'a most remarkable event in the history of physical and chemical science'.[9] In the years that followed, first x-rays, and then radium and radioactivity, were occasional topics for popular lectures, always with experiments and demonstrations, at universities and scientific and philosophical societies around New Zealand.

But the New Zealand medical profession did more than just talk about the new discovery, they started to use it. The technology was easy to reproduce: all that was needed was 'one spark coil, one battery, one Crookes tube and some

William Hosking, medical superintendent of Masterton Hospital, was one of the first New Zealand doctors to offer x-ray diagnosis and therapy. He offered his services, and later radium therapy, to paying customers from a clinic set up in his home. 02-6/7.digital, Wairarapa Archive, Masterton, New Zealand.

facility in handling photographic plates',[10] and some medical practitioners and businessmen were quick to experiment with the new technology and start charging for its use. Just months after Röntgen's discovery made the papers, New Zealand's largest drug and fertiliser company, Kempthorne, Prosser and Co., began establishing a Dunedin laboratory offering x-ray photography to the medical profession. In August 1896, they demonstrated the new technology to Dunedin doctors at a local meeting of the New Zealand Medical Association. In the North Island, William Hosking, medical superintendent at Masterton Hospital, imported a six-inch coil that he installed at his home, and began offering diagnostic and therapeutic x-rays to paying customers. For Hosking, and many of these other early adopters, the new technology pre-dated the supply of mains power, and an outdoors generator or battery was needed to power the electrical equipment.

Other entrepreneurs and doctors followed, finding the new technology particularly useful for identifying broken bones and lung disease. Hospitals

initially contracted radiological services from local doctors or electricians who had purchased and installed their own x-ray equipment, but by 1898 the Auckland, Wellington and Christchurch hospitals each had their own x-ray equipment. Dunedin Hospital followed in 1904. It wasn't just doctors who found x-rays fascinating and useful. Amateurs and hobbyists were also attracted to the new technology. One North Otago sheep farmer found the battery-powered six-inch spark coil he imported in the late 1890s useful for 'radiographing dogs' legs, locating foreign bodies, and even the examination of broken wrists'.[11]

But these early x-ray machines, while incredibly useful — their ability to see inside the human body was extraordinary for the time — were also very dangerous. The primitive equipment, poorly understood physics, and a lack of comprehension of the medical effects of x-rays meant that radiation burns and even electric shocks were commonplace. While a simple chest x-ray today usually involves radiation exposure of less than one second and provides a radiation dose equivalent to ten days' natural background radiation, early x-rays came from much weaker and more primitive equipment: they took a long time and, while they were inconsistent in the amount of radiation they produced, they delivered much higher radiation doses than today. Pioneering Dunedin radiologist Harry de Lautour — who between January 1899 and October 1900 took 157 'radiographs' of patients — advised x-ray exposure times of 'four or five minutes for a hand or foot; eight or ten minutes for an ankle, leg or forearm; twenty to twenty-five minutes for a thigh, shoulder or chest', reassuring the reader by saying: 'so far I have not yet had any experience of burning'.[12] How the patients managed to keep still for that long, he doesn't say.

DISCOVERY OF RADIOACTIVITY AND RADIUM

Röntgen's discovery of x-rays had set off a chain reaction in physics research. First, French physicist Henri Becquerel discovered that uranium — a mineral used to colour pottery and glass a range of yellows and oranges — was spontaneously emitting rays similar to Röntgen's x-rays. Physics student Marie Curie then began testing other elements, and found that thorium, as well as uranium, emitted the rays, which she called 'radio-activity'. Working at the Cavendish Laboratory at the University of

Cambridge, New Zealander Ernest Rutherford concluded, after studying the radiations emitted by uranium and thorium, that uranium emitted 'at least two distinct types of radiation — one that is very readily absorbed [it could be stopped by a piece of paper or a few centimetres of air], which will be termed for convenience the α [alpha] radiation, and the other of a more penetrative character, which will be termed the β [beta] radiation'.[13] In 1900, French physicist Paul Villard discovered a third type of radiation, a form of high-energy penetrating x-rays, which he named gamma (γ) radiation. Rutherford later demonstrated that beta radiation was a stream of negatively charged electrons and that alpha radiation consisted of positively charged helium atoms ejected during radioactive decay.

Curie continued her research into radioactive elements, and, after years of painstaking work, she and her physicist husband Pierre found that pitchblende, a black, shiny ore from which uranium was extracted, contained two previously unknown elements, polonium and radium, each of which was more radioactive than uranium. The remarkable thing about radium was its incredible energy output — each gram of the highly radioactive element could inexplicably heat a gram of water from freezing to boiling point in less than an hour.

By now, Rutherford was working in Montreal where, with chemist Frederick Soddy, he discovered that in the process of emitting radiation an element is spontaneously transformed into another element. This remarkable discovery — a transmutation which they described as 'modern alchemy' — helped to explain the seemingly inexhaustible supply of energy from radioactive elements like radium. Rutherford and Soddy also discovered that all of the radioactive elements had a distinct 'half-life' — the time it takes for half of the atoms of the original sample of an element to decay into a new element. The half-lives of the elements they tested varied wildly: uranium's half-life was calculated at 4.5 billion years, radium's half-life was 1620 years, and a decay product of thorium had a half-life of only 22 minutes. Other decay products were found to have half-lives of only fractions of a second.

Compared to x-ray technology, radium was, for most scientists and doctors, prohibitively expensive. Even so, several New Zealanders managed to get samples of radium soon after it began being manufactured in Europe, mostly by virtue of connection with Rutherford or other European scientists.

WIDESPREAD USE OF X-RAYS IN NEW ZEALAND

Over the following decades, an enthusiastic medical profession and paying public ensured that first x-rays and then radium became an integral part of mainstream medical diagnosis and treatment. Awareness and understanding of the hazards of working with radiation, however, were slower to develop.

The new technologies of x-rays and radium were linked, in that they both produced penetrating (and what we now know as ionising) forms of radiation that could be used in diagnostic or therapeutic medicine. While the public were unlikely to be aware of the physical differences between, for example, x-ray therapy and radium therapy, they were in fact two very different processes: an x-ray machine produced an electrically generated form of electromagnetic radiation emitted by electrons that could be used in diagnosis or therapy; radium, or its daughter product, radon gas, was used mostly as a close-range therapy for the alpha particles it emitted. Radium had applications outside of medicine, too: when mixed with beryllium, scientists could use it as a source of neutrons for physics experiments.

By the second decade of the twentieth century, diagnostic x-rays were in widespread use in New Zealand's hospitals and dentists' rooms. However, specialised medical attention like x-rays came at a cost to the patient. An x-ray 'radiograph' cost between half a guinea and three guineas in 1917 (up to $100 in 2012 New Zealand dollars), thus limiting its application to wealthier patients. The First World War saw the development of new x-ray apparatus and the standardisation of x-ray techniques, most of which reached New Zealand by 1920. The technology was becoming more sophisticated, but New Zealand, with its small population, did not yet have the trained professionals to use it. While some hospitals employed lay radiographers, x-ray equipment was just as likely to be used by hospital engineers, electricians and nurses — whoever was available at the time. One nurse described taking her knitting into the x-ray room: 'it worked out something like half a row of sock for an ankle and up to two rows for a lumbar spine'.[14]

As the technology became more advanced and established, medical applications for x-rays expanded beyond diagnosing bone fractures and joint conditions. Chest x-rays became an important tool for confirming the diagnosis and extent of pulmonary tuberculosis, which only a few decades earlier had been the number one killer of New Zealanders. By injecting or feeding patients with solutions that were impervious to x-rays, such as

From a handful of x-ray machines at the turn of the century, New Zealand had an estimated 450 x-ray installations by 1944. This advertisement ran in the *New Zealand Journal of Health and Hospitals* in 1920. H1, box 1816, 53/119, alt 28289, Archives New Zealand, Wellington, New Zealand.

compounds containing barium or iodine, soft tissues such as the digestive and urinary tracts could be examined by x-ray.

Today, the developing fetus is understood to be vulnerable to any form of ionising radiation, and exposure of pregnant women to x-rays and other forms of avoidable radiation is minimised. But in the 1920s, decades before ultrasound scanning technology was developed, x-rays offered an exciting and unprecedented way to observe the fetus. In 1926, by which time 44 New Zealand hospitals had x-ray equipment, the Director-General of Health proudly announced that arrangements had been made for pregnant women to have x-rays for the diagnosis of conditions such as multiple pregnancy, hydrocephalus and malformation of the fetal skeleton. The practice of offering antenatal care to all pregnant women was new, launched only two years earlier as part of the Department of Health's Campaign for Safe Maternity. With the new x-ray screens and (for the time) fast films now in use, the Department of Health assured there was 'no danger either to

mother or child'.[15] By the mid-1930s the antenatal x-ray was on the list of standard x-ray procedures offered by New Zealand hospitals, available for an outpatient charge of 5 shillings a film.

X-rays were popular and the public was happy to pay for them: as well as being offered in hospitals, x-ray machines were used in health spas (to diagnose joint conditions) and by chiropractors. In shoe shops, sales staff with no training in radiography operated 'pedascopes' or 'shoe-fitting fluoroscopes'. Most pedascopes had no limits on radiation exposure time, and children could play unsupervised on the machines, irradiating their feet and watching their foot bones on the screen.

X-RAY AND RADIUM THERAPY

X-rays were used diagnostically as soon as it was discovered that the rays did not pass through human bones, but their therapeutic use followed experiments to determine their effect on skin diseases. X-rays were perceived to have a beneficial effect on skin conditions like acne, ringworm and skin cancer, although it was soon noticed that radiation also caused skin burns and hair loss.

As with the adoption of diagnostic x-rays, experiments with radiation therapy in New Zealand followed close behind the first international publication of the new techniques. Radiotherapy trials in New Zealand began in 1901, but more advanced therapy was taking place in London, and some New Zealanders travelled there for treatment. In 1902, *The Press* described how a Christchurch patient, Craig Robertson, who had suffered for 26 years from 'rodent ulcer' (now known as basal cell carcinoma), was treated in London with the new 'X-Rays Light Cure'. Before leaving for London, Robertson had been through fifteen operations to treat his condition, which affected his face, and the 'ulcer, which started in his cheek, just to one side of the mouth, had extended close to his eye . . . and he was in great fear that it would go to the brain'.[16] On arriving in England, Robertson received treatment at London Hospital. *The Press* described his treatment:

> The light . . . is administered through a round globe . . . . The patient sits down before the battery, with the globe placed on a wooden stand at about the level of his head, and from twelve to eighteen inches in front of him. Two small coils

> are attached to points at the two ends of the globe, from the battery. A leaden mask is placed over the patient's face, with a small hole cut in it just over the place where the ulcer is, and the apparatus is placed so that the light from the X-Rays will fall exactly upon that spot. The mask is used to prevent the rest of the face being shrivelled away. A tap is given to the battery in the manner of touching a spring, and the process begins. When it has lasted for ten minutes a second touch with the finger cuts off the light. An exposure of the ulcerated place to this light during ten minutes each day, for six days a week, forms the whole of the simple process.[17]

Following his treatment, which involved ten-minute x-ray sessions, six days a week, for several months, Robertson declared, 'I felt noticeably better after only eight days, and in from five to six months I was quite well.'[18]

Enthusiastic reports like Robertson's promoted x-ray therapy as a near-miraculous treatment, and New Zealand was keen to keep up to date with the latest therapies being offered in the United Kingdom. New Zealand medical practitioners were quick to master the new technology, and it was not long before individual practitioners in New Zealand were offering paying patients radiotherapy services. In Masterton, Hosking added radium and x-ray therapy to his private x-ray diagnostic services, and it was reported that he used radium to cure a carcinoma of the lip soon after the turn of the century. When it came to therapy, an advantage of radium over x-rays was that it could be used to treat cancers that were difficult to reach externally, and was therefore used for inter-cavity treatments, like cancer of the uterus, or for direct insertion into tumours. By emitting alpha particles, which travel only a few millimetres, the radium was able to destroy the cancerous tissue into which it was inserted without damaging the healthy tissue surrounding it. Radium, however, was much more expensive than x-ray equipment and was hard to obtain, and so it took longer to become established for medical use.

Marie and Pierre Curie had first extracted radium in 1902, and by 1907, in recognition of its medical benefits, radium was being extracted in one Austrian and two French factories. By 1913, however, they had together made available only 20 grams of radium. The United States were the next to enter the market, and between 1913 and 1926 they put about 200 grams of radium on the market, about half of which was used in medicine, with the rest being used in luminous paints. When Belgium and Canada entered the radium market in the 1920s, this precious substance became more available