

The Braggs: X-Ray Crystallography and a Nobel Centenary

In 1872 Australia finally joined the UK and Europe by way of an overland telegraph line built from Darwin in the north of Australia to Adelaide in the south.

This single wire line covered 3200 kms and required 36000 poles and insulators some of which remain today and was constructed through some of the most inhospitable country in the world. It took nearly 2 years to build.

It was constructed under the supervision of Charles Todd, a small, energetic scientist who had been appointed Post Master General, Royal Observer and Meteorologist to South Australia in Adelaide, following a career in meteorology at the Royal Observatory in London and at Cambridge University. Todd and his young wife Alice are remembered by the naming of Alice Springs and the Todd River in the central Australia. Todd was later admitted as a Fellow of the Royal Society.

In 1885, Todd was visiting London and was contacted about the possible appointment of a new Professor of Physics at Adelaide University – the person in question was a 24-year-old young Cambridge Physics Graduate named William Henry Bragg who was born on a farm in Cumbria. William had entered Trinity College, Cambridge in 1881 as a shy and quiet 19 year old. His Professor at the Cavendish Laboratory. J.J. Thompson had suggested Bragg apply for the position. Bragg's quiet, teetotal demeanor was thought by Todd to be a good fit for quiet, teetotal conservative Adelaide, the capital of South Australia and so William Bragg was appointed and took up his position in February 1886. He finally met up with Charles Todd and his family in Adelaide on his first day in the Colony.

William fitted very well into Adelaide Society including its still enthusiastic sporting culture. He was a fine tennis and lacrosse player which he had enjoyed in Cambridge, and became a fine scratch golfer. He played a significant role in establishing and laying out the Royal Adelaide Golf Club which remains in the top 10 Australian courses to this day.

News of the discovery of X-rays

When news of Roentgen's discovery of X-rays in November 1895 spread around the world, it reached Adelaide via Todd's overland telegraph, having been sent to Darwin, Australia via an undersea cable from London to Java and travelling down the country via many remote repeater stations along the single wire in Morse code.

Charles Todd had a habit of eavesdropping on the Morse signals at his home in the Old Observatory and he passed news of the discovery on to Bragg who by now had married Todd's young daughter Gwendoline, thus completing the circle which started in London with Todd's support of Bragg's job application in 1885. The Todd family included Gwendoline's older brother Charles Todd Jr., a Medical Practitioner who became firm friends with the Braggs.

William Bragg, like many of his scientific colleagues around the world immediately replicated Roentgen's experiments and enthusiastically embraced this new and exciting field of 'x-ray science'.

In fact Bragg became something of a celebrity in Adelaide holding public lectures and demonstrations of the wonders of X-rays being one of the pioneers of the art in Australia. He even radiographed his 6 year old son's elbow in early 1896 when young Lawrence Bragg fell off his bicycle - Lawrence later recalled the occasion:





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This early immersion into the world of X-rays inspired William Bragg who was encouraged by Dr Charles Todd who established the earliest X-ray clinic in his practice. William's elder son Lawrence soon joined his father in the Physics department at Adelaide University as a brilliant undergraduate having been dux of St Peter's College at the age of 15 years.

The discovery of the Bragg Peak

In the early 1900s both Braggs worked closely together to study the characteristics of X-rays and Alpha rays and in particular their absorption and diffraction through matter.

William Bragg's early work led to the discovery of the Bragg Peak used today as the basis of Proton Therapy.

By now William had been nominated for Fellowship of the Royal Society - nominated in fact by the likes of J.J. Thompson and Ernest Rutherford no less. This event was all the more significant when you consider his relative isolation on the other side of the world. Despite this tyranny of distance William had established close friendships with the likes of Frederick Soddy and the New Zealander Rutherford which stood him in good stead.

Rutherford - the "Father of the Nuclear Age"

Rutherford, born near Nelson in the South Island of New Zealand was, like Bragg, of rural farming stock but became a brilliant scientist who, after graduating in Arts and Science from Canterbury University in Christchurch studied at the Cavendish in Cambridge as their first Research Fellow. Rutherford also studied under J.J. Thompson and began by studying the new discovery of the age - X-rays. He moved on to McGill University in Montreal, Canada and worked with Frederick Soddy. At McGill he carried out the research which would result in him becoming known as the "Father of the Nuclear Age". Like William Bragg, his regular scientific communicator, Rutherford moved back to the UK in 1907 to take up the physics Professorship at Manchester University. He was awarded the Nobel Prize for Physics in 1908 for his work in nuclear physics.

He was knighted in 1914 and made a Life Peer as Baron Rutherford of Nelson in 1931. Indeed his work and scientific life paralleled that of his close friend William Bragg. Rutherford died in 1937 at the young age of 66 years. He is buried in Westminster Abbey which highlights his influence on world science.



Swedish stamp shows William Henry Bragg and William Lawrence Bragg, circa 1975

It is amazing that these three scientists with their antipodean roots had such an impact on the scientific world.

> cc It is amazing that these three scientists with their antipodean roots had such an impact on the scientific world 33

Many copies of scientific but very friendly correspondence between Rutherford and William remain and clearly show William's praise for Lawrence's work. They remained good friends - indeed young Lawrence Bragg would eventually follow Rutherford both at Manchester University and at the Cavendish.

Burgeoning careers

To further his own and his son's brilliant careers William moved the family back to England in 1909 where William took up the Physics Chair at Leeds University. All were sad to leave Adelaide and William and the family were given a warm farewell. They retained very fond and warm memories - indeed the present Bragg family descendents still visit and love the city which warmly welcomes them on their frequent visits. The saddest farewell was from Sir Charles Todd, Gwendoline's father who by now was very elderly and unwell. Todd died in January the following year.

Both Braggs' careers blossomed further following the return to England. Whilst William was at Leeds, Lawrence studied further at The Cavendish and they regularly communicated and discussed their joint research on X-ray crystallography in 1912 and 13 which followed on from



the work of von Laue reported in 1912 for which he was awarded the Nobel Prize in 1914.

It was Lawrence Bragg who finally was able to come up with a scientific explanation of Laue's work – it was first presented to the Cambridge Philosophical Society on 11th November 1912 and subsequently published in *The Proceedings of the Society* and noted in *Nature*. Throughout his life, Lawrence felt it necessary to emphasise that this was his original work, although he always acknowledged his father's significant work as well.

There was great excitement internationally over their work on X-ray crystallography including the Bragg equation or Bragg's law as it became widely known.

Due to his greater standing in the scientific community, it was William who spent much of the time on presentations to major scientific societies in England, America and most notably the 1913 Solvay Conference where he presented their joint work on the Conference theme "The Structure of Matter" alongside J.J. Thompson and von Laue. Following the Conference, Lawrence was sent messages of congratulations from Marie Curie, Einstein, Rutherford and Laue who had also attended the prestigious Conference.

Full acknowledgement however was interrupted by the outbreak of the First World War which saw both Lawrence and his younger brother Robert – also born in Adelaide – enlist to serve their Country. William also became involved in sonar research.

Lawrence had an outstanding military career using his science background on the front line of the Western Front in the development of sound ranging techniques to locate enemy artillery. He was awarded the Military Cross and mentioned in dispatches three times.

In 1915, in the midst of hostilities came news of the awarding of the Nobel Prize jointly to William and Lawrence "for their work in the analysis of crystal structure by means of x-rays".

It is interesting to note that whilst Laue had been awarded the Nobel Prize in 1914 by the Physics Committee, due to the conflict which commenced that year, this information was not publicly communicated and when nominations were called in 1915 some people again nominated Laue and some Laue together with the Braggs. However Theodore William Richards, President of the Wolcott Gibbs Memorial Laboratory at Harvard University, in 1914 nominated only the Braggs.

Both "have risen into remarkable prominence on account of the highly interesting work which they have done upon the intimate structure of crystals as investigated with the help of the Rontgen ray,"

"This work seems to me so important, so intelligently and sanely carried out, and so sound in its conclusions, that I now hereby venture to nominate these two men for the prize in Physics in 1915, proposing that each be awarded half of the prize in the manner more than once effected in the past"²

So Laue was recognised for the discovery and the Braggs for its application. Lawrence received the news from his father whilst on the battle front.

This wonderful news was, however, tempered by the news just a few weeks previously in August 1915 that his younger brother Robert had died at Gallipoli as a result of an explosion – he had been buried at sea off the coast of Anzac Cove. His name is recorded in the War Memorial in Adelaide. This tragedy had a profound effect on the entire family but most notably on Gwendoline, Robert's mother who never fully recovered from this tragic event which overshadowed William and Lawrence's great work.

Due to the hostilities, the 1915 Nobel awards were not presented until 1920 – William and Lawrence chose not to attend the event but Lawrence did attend in 1922 to accept the award and give an acceptance speech. He also attended the 50th Anniversary in 1965 and delivered the first Nobel Guest Lecture.

Father and son continued to be recognised for their contribution to science with many International awards including Copley Medals and subsequent Knighthoods.

Lawrence attended the 1927 Solvay Conference where he proudly stood with the likes of Marie Curie, Einstein, Rutherford, Neil Bohr, Max Planck, Lorenz and Langevin – the picture of this group is considered "the most intelligent picture ever taken" with 17 Nobel laureates among the 29 attendees.

Both William and Lawrence were to hold Directorships of the Royal Institution and William was also awarded the Order of Merit and the Presidency of the Royal Society from 1935-40.

Lawrence was appointed head of the Cavendish in Cambridge in 1938 and served in that capacity until 1953, following on from Rutherford as he had done at Manchester. Following the end of the Second World War he controversially changed the direction of research and encouraged the study of biological molecules using X-rays. This supported a focus on Perutz and Kendrew and Crick and Watson, all Nobel Laureates in 1962 on Lawrence Bragg's watch. Indeed James Watson is quoted as saying of that time under Lawrence at The Cavendish "... the fact that the X-ray method he (Bragg) had discovered forty years before was at the heart of a profound insight into the nature of life itself." 3



Lawrence Bragg was also awarded the Roentgen Plaque in Lennep in 1955 and gave his acceptance speech in German, written by his young daughter Patience Bragg - in 2009 the Royal Institution in Australia was opened in Adelaide where Lawrence had been born in 1890. Dr Uwe Busch was invited to deliver the inaugural address - Patience Bragg was in the audience and Uwe gave Patience a copy of a recording of her father's acceptance speech. Also in the audience that day was Patience's sister Margaret and her husband David Thompson.

David is remarkably the grandson of J.J. Thompson, the Nobel Laureate who first suggested to William Bragg in Cambridge that he apply for the Chair of Physics in Adelaide. David's father is also George Thompson, Physics Nobel Laureate so Patience Thompson (nee Bragg) and her husband have 4 Physics Nobel laureates as fathers and grandfathers! In fact Patience has told me of her memories of a Sunday lunch in Cambridge when 8 Nobel Laureates were present including her relatives and Linus Pauling and Niel Bohr.

A timely celebration

The Bragg family members will again be in Adelaide in late November this year when a small group of us have arranged for a bust of William Bragg to join that of his son Lawrence on North Terrace. A celebratory Dinner will be held in the old family home, Catherwood House which William designed and had built on East Terrace, Adelaide - it is now the Public Schools Club.

This grand old home proudly displays a foundation stone laid by Sir Charles Todd, William's father-in-law on the 9th of the September 1899 when Lawrence Bragg was just 9 years old.

And so this remarkable story with all these connections continues - much like the world of Radiology.

From the early days of X-rays and radiography 120 years ago this week we have seen the development of Molecular Imaging with its strong links to the work of the Braggs recognised by their Nobel Prize a mere 100 years ago this month – a truly remarkable period of which we should be very proud to have been a small part.

I leave you with two very important and relevant quotes, the first from Professor G. Granqvist, Chairman of the Nobel Committee for Physics of the Royal Swedish Academy of Science:

CThanks to the methods that the Braggs, father and son, have devised for investigating crystal structures, an entirely new world has been opened.... 33

"The significance of these methods, and of the results attained by their means, cannot as yet be gauged in its entirety, however imposing its dimensions already appear to be."4

The second quote comes from Baroness Susan Greenfield, the recent Director of the Royal Institution in London:

"The Bragg's contribution was the first step towards the mapping of the genome, molecular biology, and all the genetic modifications, for good or ill, that will characterise much of our lives, and much of those of our children and grandchildren in the 21st century"5

Fascinating books and a DVD on William and Lawrence Bragg

John Jenkin has produced arguably the definitive work on the father and son and their work, "William and Lawrence Bragg, Father and Son: the Most Extraordinary Collaboration in Science" and this has been a significant resource for this article, as has "William Henry Bragg", written by Lawrence's sister Gwendolen Caroe who with the help of her brother wrote on the life of her father.⁶

The DVD -"Driven to Diffraction" is produced with the support of the South Australian Government and available from Ronin Films in Australia for about A\$35.

Robert George FIR

Adelaide, Australia

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