The Braggs in Adelaide
Like sunshine and fresh, invigorating air

John Jenkin

William Henry (W.H.) Bragg recorded late in his life 'For seventeen years I worked steadily in Adelaide until 1903, it had never entered my head that I should do any research work'.

This hides a more complex and interesting reality. Similarly, the joint award of the 1915 Nobel Prize in Physics to W.H. and W.L. Bragg is widely seen as rooted in Britain. But the foundations for the parallel and illustrious careers of the Braggs were firmly laid in Adelaide in the period 1886-1908, where they first encountered X-rays and learnt to harness their power.

The development of X-ray crystallography (finding the structure of crystals using X-rays) was based on a piece of pure science - the fundamental question: 'What are X-rays?' Are they particles, waves or a combination of both? Bragg's exploration began with his appointment (at the age of 23) to the combined chair of Mathematics and Physics in Adelaide.

He reportedly said that he knew nothing about physics, and what he did know he had learnt on the boat from England, but looking back to one of his references we see that he studied waves and sound at Trinity College, Cambridge.

He also said that he did not think about research until 17 years after he came to Adelaide, but this too was a 'little white lie'. It is true that he was doing a lot of teaching in Adelaide - he was responsible for all the teaching of Pure and Applied Mathematics and Physics at all levels, including honours without an assistant. He was also a fine sportsman and married Gwendolyn Todd, daughter of Charles Todd - the father figure of science in Adelaide and the man who built the overland telegraph line. (See Electric telegraphy in Australasian Science Spring '93)

But with Todd, Bragg did the first serious radio experiments in Adelaide. A small hut housed the radio equipment and they sent Morse code radio messages from Adelaide to Henley Beach. He began to learn to do research.
There were a number of parents whose children have also won Nobel Prizes, but only W.H. and W.L. Bragg were awarded the prize jointly, Nobel laureates – parents and their children.

<table>
<thead>
<tr>
<th>Name</th>
<th>Field</th>
<th>Year</th>
<th>Prize Description</th>
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<tbody>
<tr>
<td>JJ Thomson</td>
<td>Physics</td>
<td>1906</td>
<td>electrical conductivity in gases</td>
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<tr>
<td>GP Thomson</td>
<td>Physics</td>
<td>1937</td>
<td>interference of electrons in crystals</td>
</tr>
<tr>
<td>Neils Bohr</td>
<td>Physics</td>
<td>1922</td>
<td>atomic structure and radiation</td>
</tr>
<tr>
<td>Aage Bohr</td>
<td>Physics</td>
<td>1975</td>
<td>collective motions of nuclei</td>
</tr>
<tr>
<td>Marie Curie</td>
<td>Physics</td>
<td>1903</td>
<td>radioactivity</td>
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<tr>
<td>Pierre Curie</td>
<td>Chemistry</td>
<td>1911</td>
<td>Radium and Polonium</td>
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<tr>
<td>Irene Joliot-Curie</td>
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<td>W.H. and W.L. Bragg</td>
<td>Physics</td>
<td>1915</td>
<td>X-ray crystallography</td>
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Swedish stamp, 1975, commemorating the 1915 Nobel Prize for Physics

Development – Roentgen Rays’ and took an X-ray photo of a mouse at the University of Adelaide.

**News travelled fast**

W.H. Bragg was making other important contacts. He met Richard Threlfall in Sydney in 1886 at the first AAAS (ANZAAS) meeting, and saw the wonderful facilities that he was developing at the University of Sydney.

Richard Threlfall, Professor of Physics, and James Pollock, Demonstrator of Physics at the University of Sydney, published a paper in the London, Edinburgh, and Dublin Philosophical Magazine and Journal of Science in 1896 on some experiments with Roentgen’s Radiation.

These experiments were performed during April and May of this year, and were made with the object of elucidating the nature of radiation. It was thought that the following possible explanations should be tested: material particles; an ‘aether wind’; aether vortices; aether waves; electromagnetic waves; a phenomenon of a new order.

None of these models seemed to fit the experiments.

Ten years later W.H. pursued the question of whether X-rays were waves or particles, and was convinced that they were particles. He proposed the ‘neutral pair hypothesis’ – the X-ray or Gamma rays were a combination of a negative electron and a positive particle.

He thought that these rays were a negative-positive particle pair, and that
W.H.'s research papers from Adelaide are exemplary. He was a superb experimentalist. At the top of the page he gives a title and date. He has a drawing of the apparatus and records his observations in detail. This is unlike W.L., whose notes could be rather scrappy.

the reason that the photoelectric effect was so prominent was that when the rays hit a material, the heavier positive particle stayed behind and the negative electron just kept going.

Indeed he had a vigorous argument in the pages of Nature with Charles Barker, who said they were waves. They were later found to be both particles and waves.

Bragg was experimenting with higher energy Gamma rays which were behaving like particles and Barkla was dealing with low energy X-rays which were behaving, in many ways, like waves.

In 1898 Bragg received study leave, and the family went back to England. In order for his students to win an 1851 scholarship, Bragg pointed out that they had to have demonstrated some ability in research (Bragg had been thinking about research from quite an early period.).

Ripples and waves

The problem of the nature of X-rays was not solved easily or quickly. In 1921, Bragg explained the difficulties in the following way, in a paper in Nature – Aether, Waves and Electrons on 19 May 1921:

'... it is not known how the energy of the electron in the X-ray bulb is transferred by a wave motion to an electron in the photographic plate or in any other sub-

stance on which the X-ray falls. It is as if one dropped a plank into the sea from a height of 100 ft and found that the spreading ripple was able, after travelling a 1000 miles and becoming infinitesimal in comparison with its original amount, to act upon a wooden ship in such a way that a plank of that ship flew out of its place to a height of 100 ft. How does the energy get from one place to the other? ...'

Return to England

In Leeds, England he was still grappling with the question of the particle vs wave dichotomy. His wife was unhappy, the facilities minimal to non-existent and he was trying to get a department reinvigorated. Lawrence was learning Physics at Cambridge and went to the Cavendish laboratory. He became a research student yet found few projects worth doing.
Then von Laue did his experiment, which indicated clearly that X-rays could behave like waves. The question is, how did the Braggs find out about it?

Lars Vegard, a Danish scientist who had worked with Bragg in Leeds for a short time and was then in Germany, heard von Laue describe his experiment and wrote to Bragg as follows:

Wurzburg
26/6/1912
Dear Professor Bragg,

During my stay in Germany this last year, I have occasionally had the opportunity of discussing the Roentgen-ray problem. The current idea here is that they are aether pulses, and by several occasions I have attempted to put forward the difficulties involved in the wave theory and which I think is present no one has been able to overcome by means of mechanically intelligible conceptions.

Recently, however, certain new curious properties of X-rays have been discovered by Dr Laue in Munich. As I thought the matter would interest you, I asked Dr Laue — who gave an account of his discoveries here at Wurzburg — to give me a copy of one of his photographs to send to you. Without entering into any special conception as to the nature of this phenomenon, it may be described in the following way:

(Then follow many details of the experiment and its tentative explanation by von Laue)

As you will see, the matter is not yet clear... but whatever the explanation may be it seems to be effect of a most fundamental nature...

Yours sincerely
L. Vegard

William and Lawrence went to the laboratory in an attempt to show that X-rays were channelled down the interstices of the crystals and that produces the spots on the plate. The experiment was inconclusive. Lawrence went back to Cambridge and remembered that he had just attended a course of lectures (by CTR Wilson) on optics and the whole business of diffraction gratings had been dealt with.

With that background Lawrence developed Bragg’s Law. William Bragg developed the apparatus with an ionisation chamber rather than photographic plate. Lawrence provided mathematical and physical insights and collaborated actively with his father during vacations from Cambridge. Lawrence had defended his father’s view of X-rays as particles until he was convinced otherwise. Bragg’s Law was the beginning of X-ray crystallography.

The 1915 Nobel Prize was a true partnership of equals — father and son. The Nobel Prize, although claimed by the English, is equally an Australian prize. As William said, ‘My time in Australia was like sunshine and fresh, invigorating air.’

The Prize also illustrates that scientific progress is long and tortuous. Bragg went through a long apprenticeship before he reaped the reward. Most science is like that and does not happen overnight.

The development of (Lawrence) Bragg’s Law: reflected X-rays reinforce each other if \( n \lambda = 2d \sin \theta \).

If one measures the angle \( \theta \) at which the most intense diffraction is observed, it is possible to deduce either \( \lambda \) (X-rays) or \( d \) (crystal) when one of these quantities is known. If the crystal of a known structure (\( d \)) is used, the energy spectrum (\( \lambda \)) can be determined. Commonly a strong characteristic line emission (\( \lambda \) known) is used to calculate \( d \), the atomic spacing in a crystal.

Dr John Jenkin works in the Faculty of Humanities at La Trobe University, pursuing his interests in the history and philosophy of science. He held a Readership in Physics at La Trobe University. He is a graduate of the University of Adelaide and the ANU and has held positions at AERE-Harwell in England and the Universities of Minnesota and California-Berkley in the USA. He has spent a major part of his mature academic career at La Trobe University, where his research in physics was concerned with the electronic properties of materials and where his current interest is the history of Australian science. John published a comprehensive history of the Braggs in Australasian Science Magazine, Issue 4, 1986.