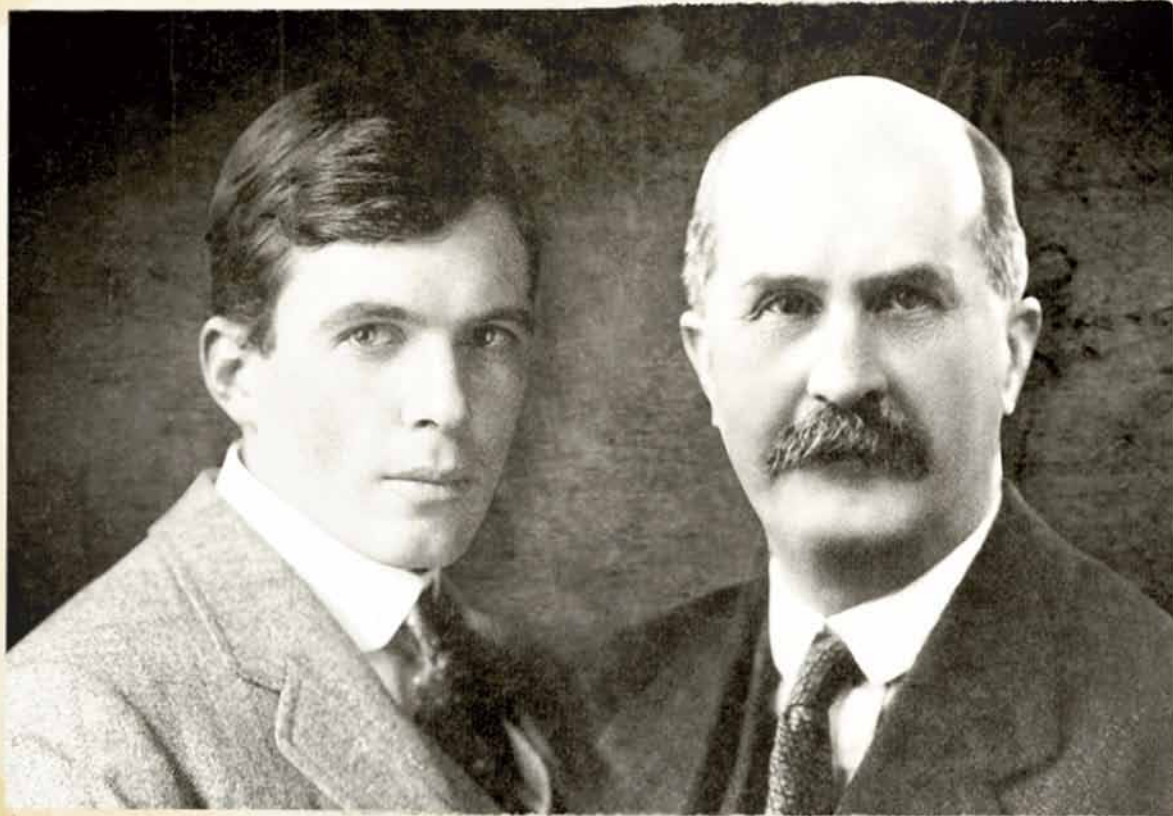


DRIVEN TO DIFFRACTION

THE STORY OF WILLIAM AND LAWRENCE BRAGG



kojc

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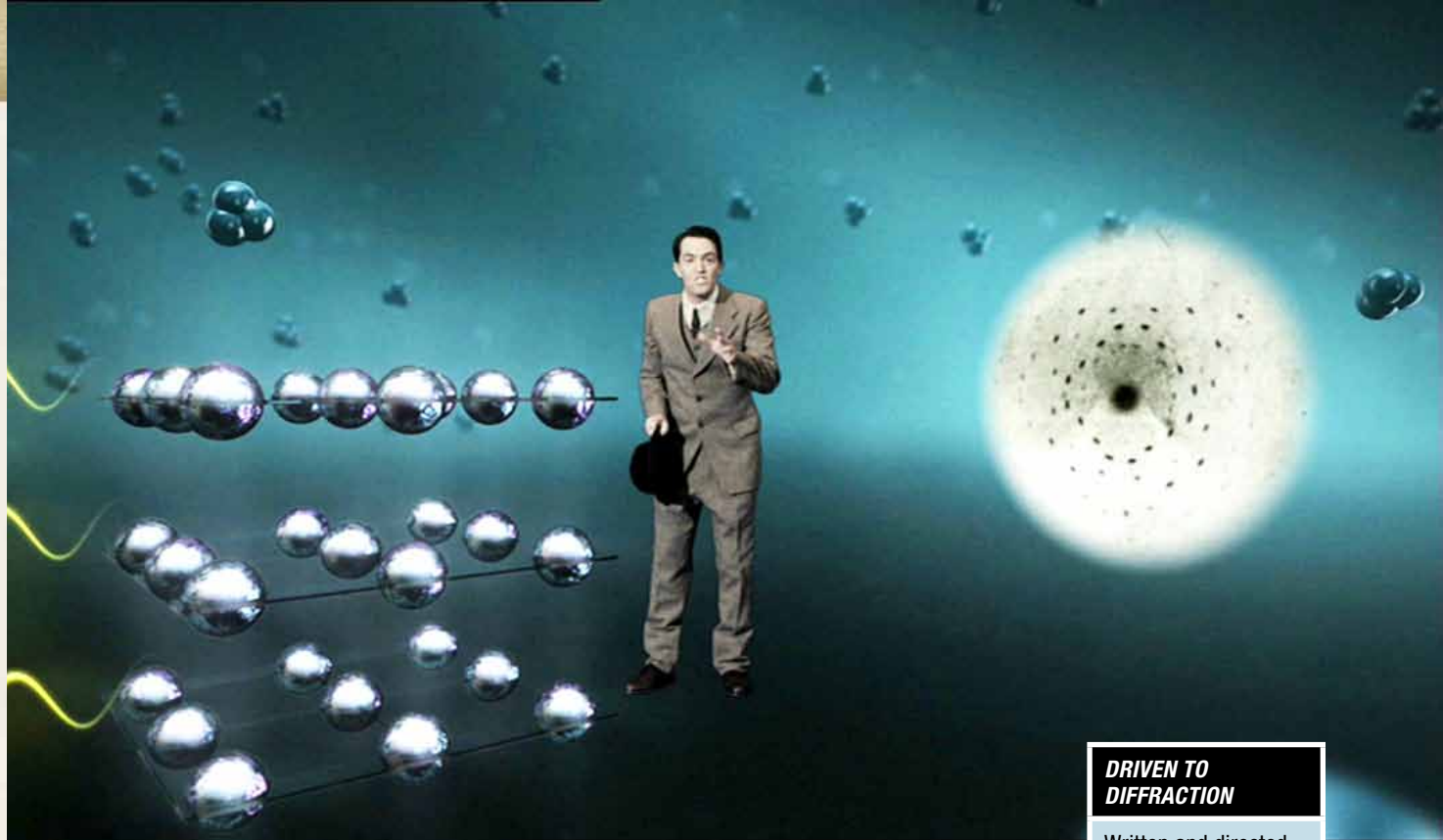
A **STUDY GUIDE** BY KATY MARRINER & ERYN O'MAHONY



<http://www.metromagazine.com.au>

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<http://www.theeducationshop.com.au>



Above L-R: Stephen Sheehan as William Lawrence Bragg in a still from the film

‘It is with a feeling of awe that we examine the new science.’

– William Henry Bragg

D*riven to Diffraction* tells the story of father and son physicists, William Henry Bragg and William Lawrence Bragg. Part human interest story and part science lesson, the documentary explores the discoveries and legacy of the Nobel Prize winning duo. Regarded as two of the most important scientists of the twentieth century, the Braggs’ development of X-Ray crystallography made possible an astonishing list of scientific advancements in DNA, cancer therapies, solid state electronics, modern pharmaceuticals and radio astronomy.

As a classroom resource, *Driven to Diffraction* promotes the importance of understanding science and highlights science as a human endeavour.

What’s a scientist?

- Describe your perception of a scientist. What do they look like? What do they wear? Where would they work? What would they do for leisure?
Do William and Lawrence Bragg fit with your perception of a scientist?
- What skills and qualities do you need to be a scientist?
Discuss your answer to this question with others in the class.

Use your notes to write an advertisement for a scientist that would appear in the employment section of a newspaper.

After you have watched *Driven to Diffraction*, review the draft of your advertisement. What do you need to change?

Famous scientists: a research project for Years 7 and 8

- Can you name any famous scientists? Why are they famous?
Had you heard of William Henry Bragg and William Lawrence Bragg before watching *Driven to Diffraction*?
- William and Lawrence Bragg are often referred to as Australian scientists, even though William was not born in Australia and Lawrence only spent his childhood and adolescence in Australia.
Can you name any other Australian scientists, past and present? What contributions have they made to scientific understanding?
- Working with a partner, make a digital story about the achievements of another Australian scientist. Your subject may be a scientist from the past or the present.
- Why is it important to know the history of Science?

DRIVEN TO DIFFRACTION

Written and directed by Richard Jasek for Kojo Productions.

This study guide has been written for secondary students at all year levels.

This guide provides information and suggestions for learning activities in Biology, Chemistry, History, Laboratory Skills Certificate 111, Media, Science and Physics. *Driven to Diffraction* is also an excellent resource for use by Science faculties to support professional learning.

The Australian Curriculum: Science provides opportunities for students to develop an understanding of important science concepts and processes, the practices used to develop scientific knowledge, of science’s contribution to our culture and society, and its applications in our lives. The story of William and Lawrence Bragg as told in *Driven to Diffraction* reflects these understandings.

DURATION: 55 min



INTRODUCING WILLIAM HENRY BRAGG

William Henry Bragg was born on 2 July 1862 in Cumberland, England.

- What do we learn about William Bragg's childhood and adolescence in *Driven to Diffraction*? Why are these details important?

Having graduated from Cambridge in 1885, William Bragg was appointed Elder Professor in Mathematics and Physics at the University of Adelaide in Australia. During his time at the university, Bragg became an able and popular lecturer. He encouraged the formation of the student union, and the attendance, free of charge, of science teachers at his lectures. At the end of 1908, Bragg returned to England. During Bragg's twenty-three years in Australia, he saw the number of students at the University of Adelaide almost quadruple, and was responsible for the development of its excellent science school. Whilst in Adelaide, Bragg played tennis and golf, and as a founding member of the North Adelaide and Adelaide University Lacrosse Clubs, contributed to the introduction of lacrosse to South Australia.

- Detailed biographies of William Bragg can be read online at:
<http://adb.anu.edu.au/biography/bragg-sir-william-henry-5336>
http://en.wikipedia.org/wiki/William_Henry_Bragg
<http://www.asap.unimelb.edu.au/bsparcs/exhib/nobel/braggw.htm>
<http://www.eoas.info/biogs/P000252b.htm>
<http://www.nndb.com/people/533/000099236/>



INTRODUCING WILLIAM LAWRENCE BRAGG

William Lawrence Bragg was born on 31 March 1890 in Adelaide, South Australia.

Lawrence Bragg received his elementary education at St. Peter's College and entered Adelaide University in 1904 to study mathematics, chemistry and physics when he was fifteen. He graduated with first class honours in 1908.

When the family moved to England in 1909, Bragg entered Trinity College, Cambridge. After initially excelling in mathematics, he transferred to the physics course in the later years of his studies, and graduated with first class honours in 1911. In 1914, Bragg was elected to a Fellowship at Trinity College. Bragg graduated from Cambridge University with first class honours in 1912. After finishing his studies, he stayed on to work at the Cavendish Laboratory at Cambridge University.

- What do we learn about Lawrence Bragg's childhood and adolescence in *Driven to Diffraction*? Why are these details important?
- Detailed biographies of Lawrence Bragg can be read online at:
<http://adb.anu.edu.au/biography/bragg-sir-william-henry-5336>
http://en.wikipedia.org/wiki/William_Lawrence_Bragg
<http://www.asap.unimelb.edu.au/bsparcs/exhib/nobel/braggl.htm>
<http://www.eoas.info/biogs/P001998b.htm>
<http://www.nndb.com/people/538/000099241/>



INTRODUCING GWENDOLINE BRAGG

Born in 1871 in Adelaide, South Australia, Gwendoline Todd was the daughter of Charles Todd, Postmaster General and Government Astronomer of South Australia.

In 1889, she married William Bragg. They had three children, a son William Lawrence born in 1890, a son Robert Charles born in 1891 and a daughter Gwendolen Mary born in 1907.

Prior to her marriage to William Bragg, Gwendoline studied painting at the Adelaide School of Design. Both Gwendoline and her husband painted landscapes in watercolours and exhibited at the South Australian Society of Arts in 1896.

- View examples of Gwendoline Bragg's watercolours at:
<http://nla.gov.au/nla.pic-an5836938>
http://www.friendsasa.com/sasa/historyproject_Update.html
- What credit does Gwendoline Bragg deserve for her husband and son's successes?

Above L-R: William Henry Bragg, c. 1926; William Lawrence Bragg, c. 1906; Michaela Cantwell as Gwendoline Bragg



William Bragg's early experiments

Radio waves

William Bragg worked with his father-in-law Charles Todd to pioneer radio transmission in Australia. In his role as Superintendent of Telegraphs, Todd was responsible for the building of the overland single-wire telegraph line that linked Australia to the rest of the world in 1872. His interest in communication technologies turned to radio transmission in the late 1890s. Bragg demonstrated Guglielmo Marconi's radio technology in Adelaide in 1897, and then went to England to meet Marconi and learn more about wireless transmission. In 1899, working with Arthur Rogers, Bragg sent the first wireless telegraph messages in Australia.

- Radio is the transmission of signals from one place to another through the use of radio waves.
Why was the discovery of radio waves important?
- Working as a class, make a list of the ways that we now use radio waves.
- How are radio waves transmitted and received? Which materials block radio waves? Which materials allow transmission of radio waves?

Röntgen Rays

Wilhelm Conrad Röntgen was a German physicist. In 1895, Röntgen produced and detected electromagnetic radiation in a wavelength range today known as X-rays. His achievement earned



him the first Nobel Prize in Physics in 1901.

Assisted by Robert Chapman and Arthur Rogers, William Bragg's attempts to replicate Röntgen experiments pioneered Australia's use of X-rays. William made the first X-ray tube in Australia. When a six-year-old Lawrence fell from his tricycle and broke his elbow, his father made use of the new technology. This incident is the first recorded surgical use of X-rays in Australia.

This is also an excellent example of how science and technology are interrelated. The glass tube that William produced allowed him to apply his scientific understanding and produce X-rays. The tube would have been produced by glass blowing. Glass blowing is a technique employed by both scientists and artists.

- Watch the YouTube clip on glass blowing at <http://www.youtube.com/watch?v=O1xb48Y6EdA>.
Do you think many modern scientists produce their own instruments using the glass blowing technique?
- How would scientists have studied bone structure prior to the discovery of X-rays?
- Visit <http://nobelprize.org/educational/physics/x-rays/> to learn more about X-rays.

Lawrence Bragg's first discovery

Lawrence Bragg's first scientific discovery was the discovery of a species of cuttlefish. *Sepia braggi* was named in his honour. Bragg's interest in the natural sciences stemmed from the considerable amount of time he spent alone in the garden and walking along the beach.

- 1: William Lawrence Bragg (left) with William Henry Bragg
- 2: William Lawrence Bragg, Cambridge 1915
- 3: Cambridge street scene
- 4: The DNA double helix



This page:
 Scenes from the film, featuring Michaela Cantwell as Gwendoline, Brad Williams as William Lawrence and Stephen Sheehan as William Henry

It is common in science for a new species to be named after the person who made the discovery. Some scientists, however, name insignificant or ugly specimens after their enemies.

- *Lepidocephalichthys zeppelinii* is a newly identified species of fish, named after Led Zeppelin. Information about how the species got its name can be accessed at <http://www.youtube.com/watch?v=UEHoTAMe5rM>.
- The mineral Braggite is named after both William and Lawrence Bragg. Your task is to find out why.



Ionisation and the Bragg Peak

Inspired by the recent discoveries of radium and radioactivity by Pierre and Marie Curie, William Bragg began his own research into ionisation.

Ionisation is the physical process of converting an atom or molecule into an ion by adding or removing charged particles such as electrons or other ions.

The Bragg Peak is a pronounced peak on the Bragg Curve that plots the energy loss of ionising radiation during its travel through matter. For protons, α -rays, and other ion rays, the peak occurs immediately before the particles come to rest. When a fast charged particle moves through matter, it ionises atoms of the material and deposits a dose along its path. The phenomenon is exploited in particle therapy of cancer, to concentrate the effect of light ion beams on the tumor being treated, while minimising the effect on the surrounding healthy tissue.

- Why is ionisation important?
- Working as a class, make a list of real world applications of the Bragg Peak.

Waves or particles?

William Bragg believed that X-rays were made up from particles whereas Charles Barkla proposed the theory that X-rays were due to waves. William and Lawrence discussed these opposing views for some time until Max von Laue's X-ray diffraction experiment seemed to prove that X-rays were indeed waves. Scientists believed crystals were made up of regular repeating patterns. The problem was that there were some unexplained patterns in Max von Laue's data. Lawrence pondered this and eventually came up with a theory that explained these dots.

Lawrence believed that the crystal structure was made up of a series of sheets of atoms, laid one on top of another, with each sheet behaving like a mirror. So the intricate pattern of dots that were produced by passing X-rays through a crystal is caused by a series of interactions in which the X-rays are reflecting off the sheets of atoms and then some meeting up again forming dark dots while single waves were causing lighter dots.

From this experiment Lawrence formulated his Bragg equation, which connects the wavelength



1

1: Stephen Sheehan as William Henry with X-ray spectrometer 2: Green glow of the X-ray tube 3 & 4: The X-ray spectrometer

the structure of atoms. Later William and Lawrence Bragg were able to prove the atoms were arranged in a lattice form that was an extension of Von Laue's Theory.

Do you think it was fair that Max Von Laue won a Nobel Prize when his theory wasn't 100 per cent correct?

Do you think that some current scientific theories that we believe today may be proven to be incorrect in the future?

- Lawrence Bragg based his theory on data from Max Von Laue's experiment that showed lighter and darker dots.

Will all scientists come to a similar conclusion when given the same data?



2

X-ray Crystallography and X-ray Spectroscopy

'It was a glorious time ... We worked far into the night with worlds unfolding before us. It was like discovering a new goldfield where nuggets were just waiting to be picked up from the ground.'

– Lawrence Bragg

William and Lawrence Bragg were a powerful combination, as between them they had combined expertise in both technology and science. William had extensive background in designing machines and technology so he designed the X-ray spectrometer, a device that could examine the reflections of X-rays from crystals. Lawrence's mathematical and science ability was essential for analysing all the data they collected.

Together they showed how it is possible to identify the structure of a crystal by passing X-rays through it and examining the pattern of dots that are produced by the reflected rays.

of X-rays (λ), the distance between successive sheets of atoms in a crystal (d) and the angle at which the X-rays strike these sheets (θ). Or as the equation states: $n\lambda = 2d \sin\theta$ where n is a whole number.

- For further explanations of Bragg's law, visit:
http://en.wikipedia.org/wiki/Bragg%27s_law
<http://hyperphysics.phy-astr.gsu.edu/hbase/quantum/bragg.html>
<http://www.eserc.stonybrook.edu/ProjectJava/Bragg/>
http://www-outreach.phy.cam.ac.uk/camphy/xraydiffraction/xraydiffraction_exp.htm
- Scientific understanding, including models and theories, are contestable and are refined over time through a process of review by the scientific community.

Describe a time when you and a classmate had a different point of view. How did you resolve your disagreement?
 How did William and Lawrence Bragg resolve the issue when they both had different theories to explain the nature of X-rays?
 Max Von Laue won a Nobel Prize for his discovery on the nature of X-rays and



3



4

- How do you think William and Lawrence Bragg felt when they were working out the structure of various crystals?

- Advances in scientific understanding often rely on developments in technology and technological advances are often linked to scientific discoveries.

Describe a modern scientific invention that is based both on science and technology.

- What is Rational Drug Design? Explain the link between X-ray crystallography and rational drug design.

Diffraction manifests itself in the apparent bending of waves around small obstacles and the spreading out of waves past small openings. Diffraction



Above: Brad Williams as William Lawrence (left) and Stephen Sheehan as William Henry

provides a powerful tool for studying the geometry of objects that are too small to be viewed directly. One of the most famous historical cases was the revealing of the double helix structure of DNA.

- Who discovered the structure of DNA? Who was Rosalind Franklin? Why is she significant? What role did William and Lawrence Bragg play in this scientific discovery? Who else should be given credit for the discovery of the structure of DNA? Begin your research online at:
http://nobelprize.org/educational/medicine/dna_double_helix/readmore.html
<http://www.dnai.org/timeline/>
<http://www.nature.com/scitable/topicpage/discovery-of-dna-structure-and-function-watson-397>

The 1915 Nobel Prize for Physics

Since 1901, the Nobel Prize has honoured men and women for outstanding achievements in physics, chemistry, medicine, literature, and for work in peace. A prize for economic sciences was added in 1968.

The Nobel Prize was initiated by inventor and businessman Alfred Nobel, whose 1895 will left much of his wealth to the establishment of a prize to reward those whose achievements had best benefited mankind. Nobel's family opposed the establishment of the prize and it was five years before the first Nobel Prize could be awarded in 1901.

- Information about Alfred Nobel and the Nobel prize can be found online at:

http://nobelprize.org/educational/nobelprize_info/gradeschool.html
<http://nobelprize.org/mediaplayer/index.php?id=1335>

Physics was the prize area that Alfred Nobel mentioned first in his will. At that time, in the end of the nineteenth century, many people viewed physics as the foremost of the sciences. His own research was also closely tied to physics. In 1901 the very first Nobel Prize in Physics was awarded to Wilhelm Röntgen for his discovery of X-rays.

- Visit [Nobelprize.org](http://nobelprize.org/nobel_prizes/physics/) at <http://nobelprize.org/nobel_prizes/physics/> to learn more about the Nobel Prize in Physics.

William Henry and William Lawrence Bragg were awarded the Nobel Prize for Physics in 1915, for their services in the analysis of crystal structure by means of X-Rays. In announcing the Braggs as recipients of the prize, Professor G. Granqvist, Chairman of the Nobel Committee for Physics of the Royal Swedish Academy of Sciences acknowledged,

Thanks to the methods that the Braggs, father and son, have devised for investigating crystal structures, an entirely new world has been opened and has already in part been explored with marvellous exactitude. 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. In consideration of the great importance that these methods possess for research in the realm of physics, the Swedish Royal Academy of Sciences decided that the 1915 Nobel Prize in Physics should be divided between Professor W.H. Bragg and his son W.L.



Bragg, in recognition of their services in promoting the investigation of crystal structures by means of X-rays.

- Information about the Braggs' Nobel Prize for Physics can be read online at http://nobelprize.org/nobel_prizes/physics/laureates/1915/.

Nobel Prize Laureates: a research project for Years 9 and 10

- How many Australians have been awarded a Nobel Prize for Science?
- Who are Australia's Nobel Prize Laureates for Science?
- Has an Australian woman ever received a Nobel Prize for Science? If so, what was her name? When did she receive her award?
- Who was the first Australian Nobel Prize Laureate?
- Find out when the most recent Nobel Prize was awarded to an Australian. Who received this award and why?
- Working with a partner, research the story of a Nobel Prize Laureate. The laureate may have been awarded a Nobel Prize for his or her outstanding achievements in physics, chemistry, medicine, literature, economic sciences or the promotion of peace. You will be required to share your research with the class in the form of an interview. You will need to write a script and rehearse your presentation. The interview should explain why the laureate was awarded the Nobel Prize; provide relevant biographical information and acknowledge the laureate's other achievements.



Sound ranging

Lawrence Bragg's research work was interrupted by both World War One and World War Two. During both wars, he worked on sound ranging methods for locating enemy guns.

Sound ranging was one of three methods of locating hostile artillery that rapidly developed in World War One. In land warfare, sound ranging is a method of determining the coordinates of a hostile artillery battery using data derived from the sound of its guns or mortar or rockets firing. The same methods can also be used to direct artillery fire at a position with known coordinates.

- Learn more about sound ranging at http://en.wikipedia.org/wiki/Sound_ranging.

British physicist Dr Henry Moseley died during World War One. Moseley was killed fighting at Gallipoli in 1915 at the age of 27. At the time of his death, he had already made important scientific discoveries and developed theories of significance. The loss of a scientist of the calibre of Moseley prompted change.

Britain introduced the Military Training Act in 1939. The terms of the act meant that all men between the ages of 20 and 21 had to register for six months' military training. At the same time, a list of reserved occupations was published. Those employed in the listed occupations were exempt from conscription. One of the listed occupations was 'scientist'.

- Do you think it was a wise idea to recommend that scientists should not serve in major conflicts?

1: Stephen Sheehan as William Henry 2: Brad Williams as William Lawrence



1: The Royal Institution of Australia, Adelaide
2: Michaela Cantwell as Gwendoline

The Royal Institution of Great Britain and The Royal Institution of Australia

'Don't talk to them about science, show it to them.'
– Lawrence Bragg

The Royal Institution of Great Britain (RI) was established in London in 1799. Its aim was then, as it is now, to facilitate scientific education and to provide opportunities for scientific discovery and research. William Bragg became Superintendent of the House at the RI from 1923 to 1942. Lawrence Bragg was appointed Director of the RI in 1954. He held the position until 1966.

Based in Adelaide, the Royal Institution of Australia (RiAus) is the first sister organisation of the Royal Institution of Great Britain. Established in 2009, the RiAus is a national scientific organisation. Its objectives are to bring the findings of science and technology to the broader community and foster informed debate. Like the RI, the RiAus strives to highlight the importance of science in everyday life. The use of real and virtual spaces allows people to listen, talk and think about science.

- What roles did William and Lawrence Bragg play at the RI in Britain?
- Learn more about the RI in Britain and Australia by watching a video clip from the ABC science program *Catalyst*. The video clip can be accessed at <<http://www.abc.net.au/catalyst/stories/2715201.htm>>. It is approximately 8 minutes in length and suitable for secondary students at all levels.
- Visit the RI of Great Britain online at <<http://www.rigb.org>>. Visit RiAus online at <<http://www.riAus.org.au/science/home.jsp>>.
- Why choose Adelaide as the site of RiAus?



- Why are institutes like the RI in Australia and Britain important?
- The RI is well known for its public science program, including the annual Christmas Lectures. The lectures, originally founded by Michael Faraday, are given by notable scientists and are a means to teach adults and children about the science of everyday things. A video archive of the lectures can be accessed at <<http://www.rigb.org/content/Control?action=displayContent&id=00000004959>>.

Popular science

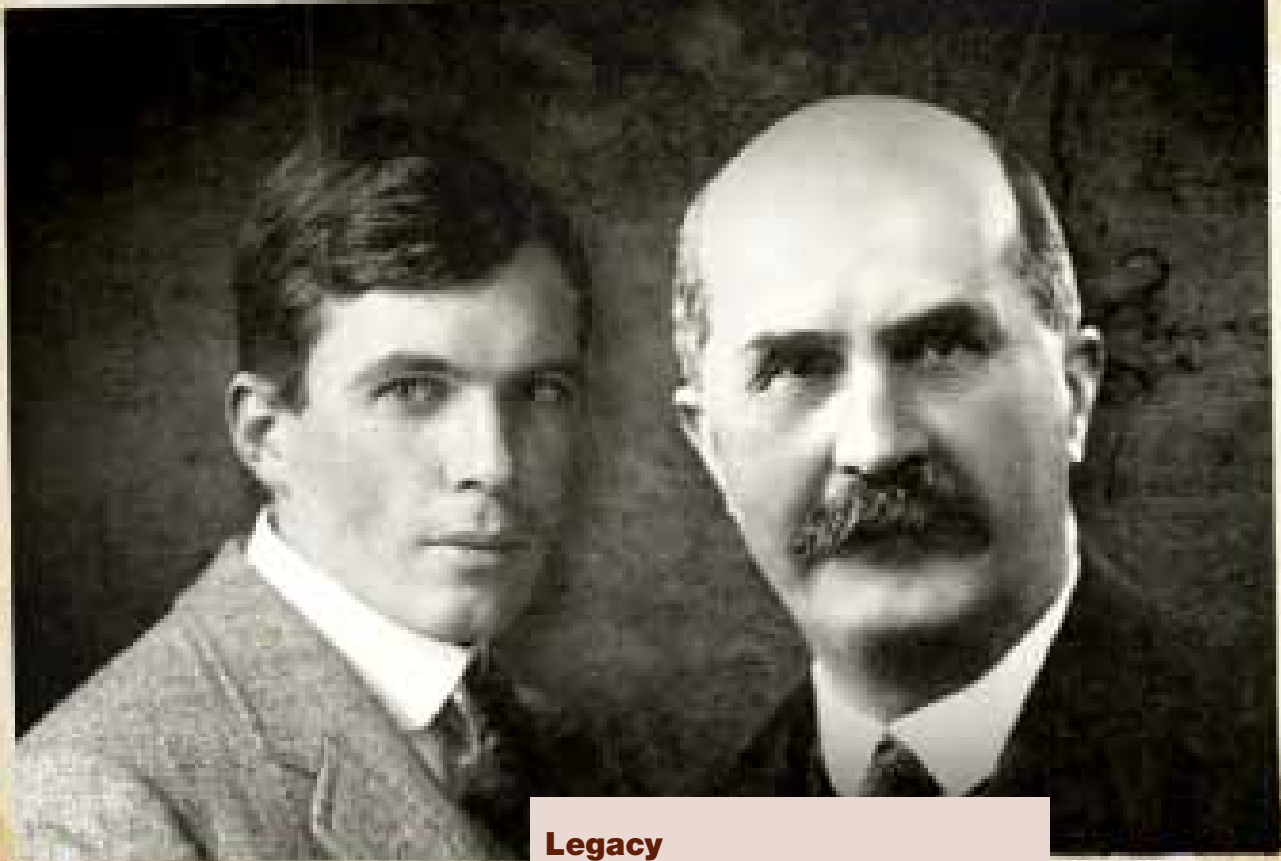
Ever watched an episode of *Mythbusters*?
Listened to Dr Karl Kruszelnicki's podcasts?
Visited the HowStuffWorks website?

If you have, then you have experienced what is known as popular science.

Popular science can be defined as an interpretation of science intended for a general audience. Popular science is broad ranging, often written by scientists as well as journalists, and is presented in many formats, which can include books, television documentaries, magazine articles and web pages. The aim of popular science is to explain abstract and often difficult scientific concepts for an audience with little or no scientific background.

While William and Lawrence Bragg's scientific research extended scientific knowledge in significant ways, they were both interested in teaching others about the science of everyday things.

- Can you name people and organisations that are proponents of popular science?



Legacy

‘The important thing in science is not so much to obtain new facts as to discover new ways of thinking about them.’ – William Henry Bragg

William Bragg died in 1942, aged 79. Lawrence Bragg died in 1971, aged 81. Their discoveries shaped and continue to shape scientific knowledge. The Braggs worked in the area of physics yet their discovery has led to many advances in other branches of science.

The influence of the Braggs is evident in the following areas of scientific understanding:

- Radio astronomy pulsars and quasars
- Properties of liquid helium superconductors
- Solid State Electronics
- Metal Physics
- Enzyme structures
- Protein structures
- DNA structure

- Drawing on the comments made in *Driven to Diffraction*, explain how contemporary scientists regard the Braggs.

Write a description of the film style of *Driven to Diffraction*. Your description should comment on the four elements of film style: mise en scène, cinematography, editing, and sound.

William Lawrence (left) and William Henry around the time of them being awarded the Nobel Prize for Physics in 1915.

- Do you think that the contribution of ‘popular scientists’ counts?
- Working with a peer, teach your class something about the science of everyday things. Your presentation may be submitted in the form of a podcast, PowerPoint, demonstration in front of the class, magazine column, web page, blog or video clip. Need inspiration? Begin your research at http://en.wikipedia.org/wiki/Popular_science.

Production values

Driven to Diffraction is a documentary.

A documentary is a film composed of real life footage, and in the case of *Driven to Diffraction*, dramatised footage, in order to represent and comment on events that have actually occurred.

- Why is the documentary called *Driven to Diffraction*?
- An actress playing the part of Gwendoline Bragg narrates the story of her husband and her son.
Why choose Gwendoline as the narrator?
Who else tells the story of William and Lawrence Bragg?
- Film style refers to the visual elements of a film. Filmmakers use visual elements to evoke ideas and to elicit emotional responses.

NAME: _____

LIKE FATHER, LIKE SON

Lawrence Bragg was the first Australian to receive a Nobel Prize for Science. He is also the youngest person to ever receive a Nobel Prize.

Watch the following clip from *Driven to Diffraction*.

Peter: Clip 1 runs from 12.22 – 15.01. It begins with the title card ‘Lawrence’s Development’

Answer the questions in the space provided.

- Compare Lawrence’s childhood with other children of that time. Remember compare means to describe the things that are similar and what is different.

- How do you think other scientists felt when Lawrence Bragg won the Nobel Prize at age twenty-five?

SCIENTISTS WORKING IN TEAMS

Science knowledge can develop through collaboration and connecting ideas across the disciplines of science.

Watch the following clip from *Driven to Diffraction*:

Peter: Clip 2 runs from 37.03 – 38.22. It begins with the title card ‘Credit’

- Why did father and son make a good team? Were there any drawbacks to the partnership?

NAME: _____

- How are scientific ideas communicated in the twenty-first century?

- How important was it for William and Lawrence Bragg to communicate with other scientists?

- Name those scientists who were mentored by William and Lawrence Bragg. Next to each scientist's name, state what he or she discovered, and the branch of science in which he or she worked.

- How were scientific ideas communicated during the time of William and Lawrence Bragg's significant discoveries?

NAME: _____

- Why was it important for the Braggs to establish communities of scientists working in teams?

- Science discoveries have the potential to improve the quality of human life. In what ways have the Braggs' discoveries improved the quality of everyday life?

ONE SCIENTIFIC DISCOVERY LEADS TO ANOTHER

'Structure determines function and that's why X-ray crystallography is such a very important science.'

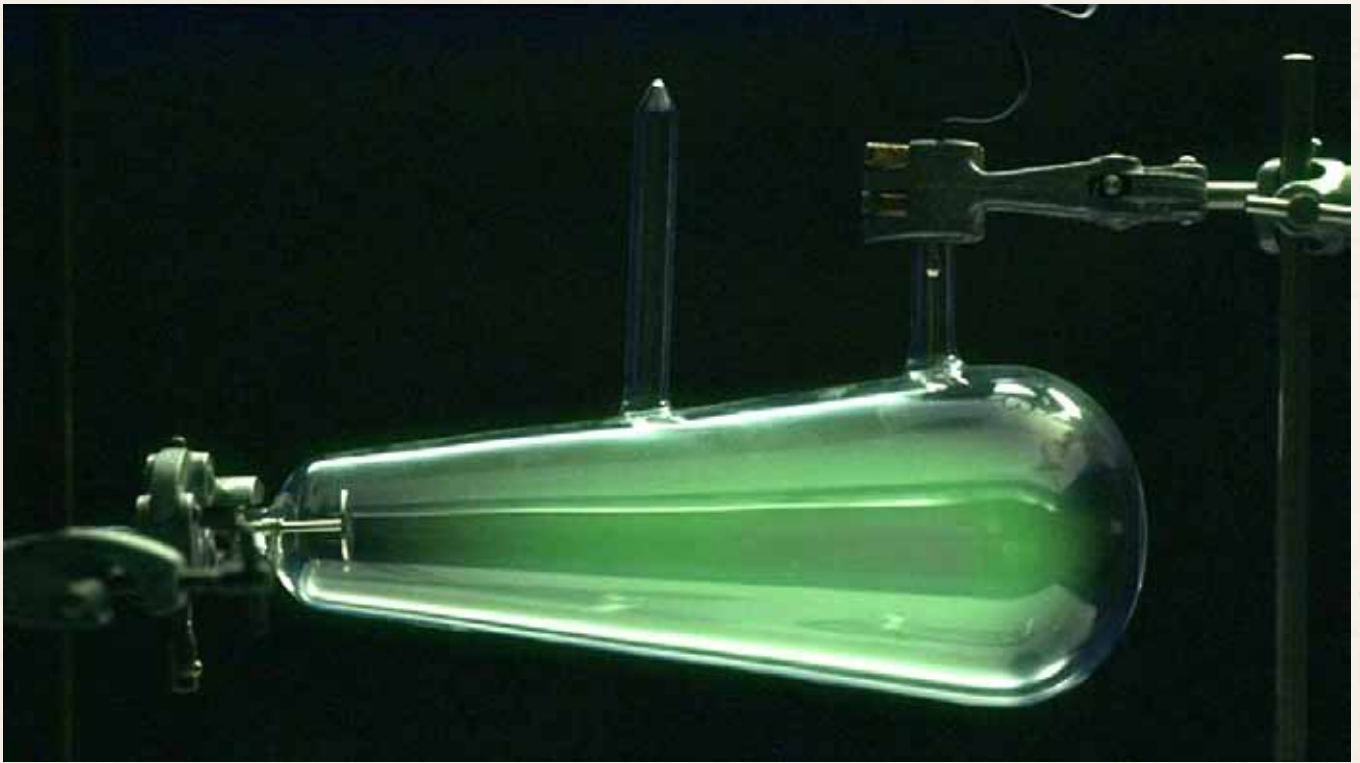
– Professor Peter Colman

Scientific knowledge changes as new evidence becomes available, and some scientific discoveries have significantly changed people's understanding of the world. William and Lawrence Bragg worked in the area of physics, yet their discovery has led to many advances in other branches of Science.

Watch the following clips:

Peter: *Clip 3 runs from 2.00 – 3.07. The clip consists of the scientists commenting on William and Lawrence's Science. Clip 4 runs from 34.30 – 36.59. Once again, the scientists comment on the applications of the Braggs' discoveries.*

Can you think of an example of when a scientific discovery has had an adverse effect on people's lives?



Above: X-ray tube



Driven to Diffraction is available on DVD from Ronin Films

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