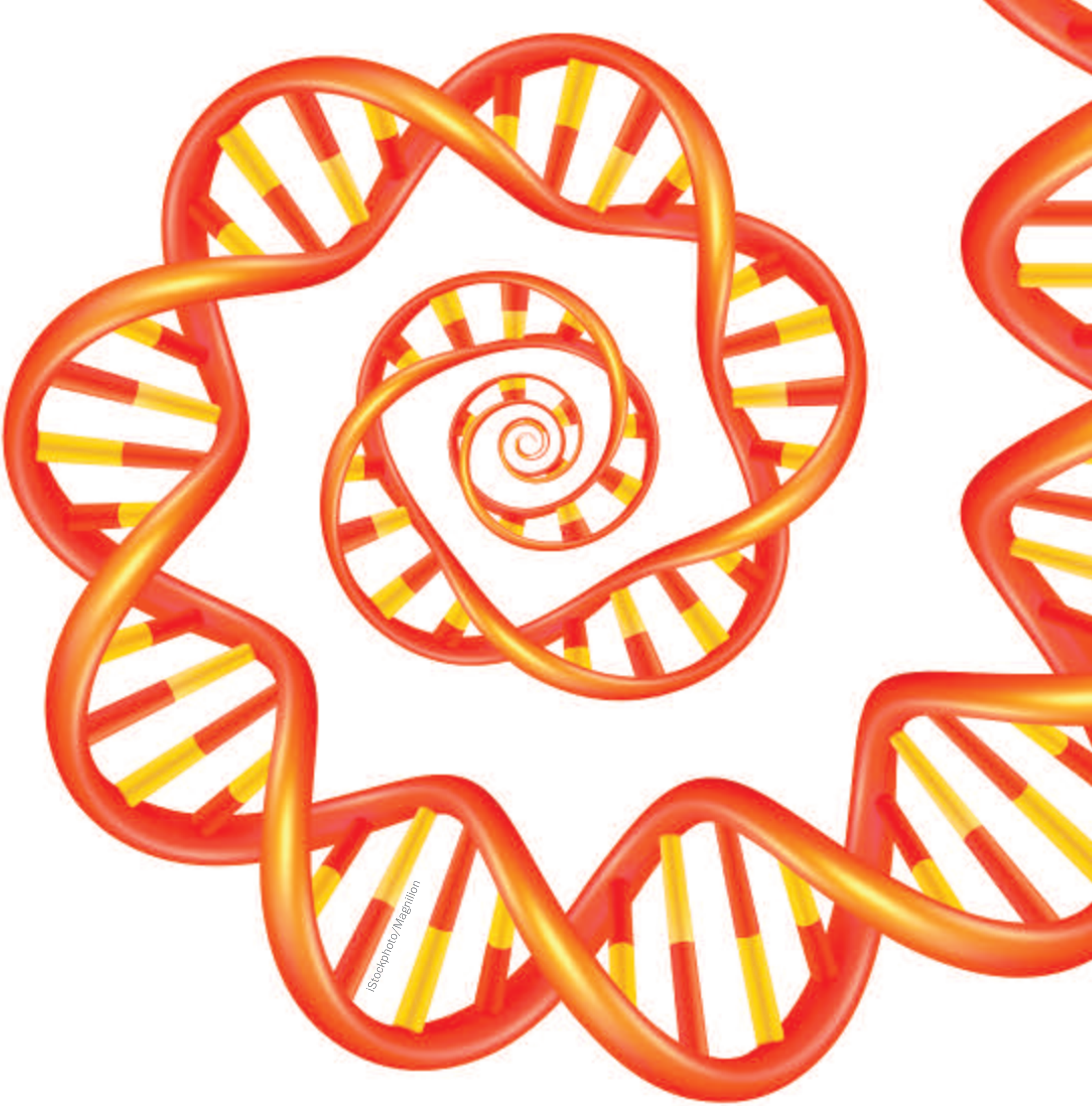

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BY **DAVE SAMMUT**

This year is the International Year of Crystallography, an area of science important to me due to my own family ties (see box p. 20). Given the connection, I have been keen to write something to acknowledge the celebration.

I initially thought along the lines of Australia's Bragging rights to the science, most particularly because William Lawrence Bragg was born and raised in Adelaide. It is, after all, a grand Australian tradition to lay claim to its share of the accolades of its sons and daughters, no matter how far flung their exploits. Indeed, the tradition can stretch to our country's nephews and nieces, and any immediate neighbours who have ever resided here, no matter how fleetingly (I'm looking at you, Russell Crowe).

However, as I continued to read, I found myself utterly compelled by the great race that took place following the initial establishment of the science. The competition between research houses, between the great luminaries of the day, and between the internal factions and personalities makes for a simply thrilling story.

THE INNER SPACE RACE

The emergence of X-ray crystallography is the story of an earnest dash to the then-elusive double helix.

William Lawrence Bragg (1890–1971) was born into the Australian colonies at a time of great change. Just months before, Henry Parkes had delivered his Tenterfield address, and the colonies were wrangling with the formation of a new nation. Within just four years, the South Australian parliament would be only the second in the world to grant women the vote. Shortly after his tenth birthday, the first electric lights would appear on the streets of Adelaide.

Before Lawrence was even a teenager, new discoveries had revolutionised physics. In 1895, Wilhelm Roentgen discovered the existence of X-rays, although at that point they were still considered a particle. Henri Becquerel and Marie Curie had both made key discoveries in the radioactive properties of uranium and other elements. Indeed, the first recorded surgical use of X-rays in Australia was by William Henry Bragg (Lawrence's father and future co-recipient of the Nobel Prize), investigating five-year-old Lawrence's broken arm after he fell from his tricycle.

A brilliant young man, Lawrence graduated at age 18 from the University of Adelaide; then, moving back to England with his family, he went on to graduate with honours from Cambridge at age 22. He was just starting as a research student at Cambridge when it was announced that Max von Laue had observed the diffraction of X-rays by crystals, for which he won the Nobel Prize just two years later in 1914. The rapidity of the awarding of this honour shows just how evident was the importance of this discovery. And after just three years of work, the two Braggs published the seminal work *X rays and crystal structure* in 1915, for which they were awarded the Nobel Prize the same year.

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From there, Lawrence Bragg's rise was meteoric. He became the professor of physics at Manchester University in 1919, and the head of the Cavendish Lab in 1938 – succeeding Ernest Rutherford in the role.

Across the Atlantic, a rival was emerging – Linus Pauling (1901–94). Inspired by the Braggs' book, Pauling had conducted his own first determination of molybdenite crystal structure in 1922. On a Guggenheim Fellowship, Pauling studied revolutionary quantum mechanical theory under Niels Bohr and Erwin Schrodinger. Returning to the USA, he spent five prolific years to 1932, during which he published approximately 50 papers, was awarded the Langmuir Prize by the American Chemical Society for the most significant work in pure science by a person 30 years of age or younger, and produced the seminal work 'The Nature of the Chemical Bond', published in the *Journal of the American Chemical Society*.

During this time, both Pauling and Bragg developed sets of rules for interpreting X-ray diffraction patterns from more complicated crystals. But to Bragg's chagrin, Pauling published first, and a rivalry was established that would last for another 20 years.

In the years that followed, X-ray crystallography was applied to increasingly complex molecules. New discoveries were being compared against theoretical considerations – in some cases as sophisticated as cutting pieces of paper into the shapes of molecular subunits (such as the amino acids that make proteins) and then pushing them around to consider and eliminate alternatives. In combination, these pieces of information were being used to elucidate the structures of the molecular building blocks to life itself.

The British took the lead in the 1920s, with William Astbury working in Bragg's group at the Royal Institute to provide the first X-ray diffraction pictures of fibrous protein. By the 1930s, Astbury had correctly showed that globular protein modules such as haemoglobin are made up of long-chain proteins (polypeptides) that are folded to make balls.

However, the Americans were not to be outdone. Caltech researchers Roscoe Dickinson (doctoral adviser to Pauling) and Albert Raymond definitively showed in 1923 that

A crystallography career

My late father-in-law, Don Craig (1936–2009), will have been known to many RACI members through his 54-year career in crystallography at the University of New South Wales, stretching right back to the days when it was still the Technical Institute. The UNSW School of Chemistry wrote that Don 'will always be linked with crystallography at UNSW. His tireless work, enthusiasm and encyclopaedic crystallographic knowledge benefited many UNSW postgraduate students over his 51 years of service to the University, resulting in over 400 peer-reviewed articles.'

Don is remembered at the university through the Don Craig Memorial Prize to honour the very significant contributions that he made to the School and the field of crystallography. The prize was won in 2014 by PhD student Matthew Gyton, with the prize presented by Don's long-standing friend, Emeritus Professor Brynn Hibbert.

As a loving family member, I would add that Don had the rare gift of being able to recognise what he loved doing in life, and the determination to stick with it. He didn't want promotion or wealth. For the love of science, he just did his research, raised a family and a social 'cleansing ale', and was content with his life. He will always be missed.

molecules have a three-dimensional arrangement and that within a crystal these molecules are discrete and separated by distances greater than the molecular covalent bonds.

In the mid-1930s, Pauling struck out from his early interest in inorganic molecular structures to biological, citing Astbury's work in his considerations.

Both sides were severely interrupted by the war, but by the late 1940s, both were actively working towards the problem of coiling a polypeptide in three dimensions.

Bragg's group published first in 1950, but their model was shown to be flawed, and he was once again trumped by Pauling's team with the correct solution in 1951 – the helical structure of fibrous protein. The Caltech team published no fewer than seven papers in the May 1951 *Proceedings of the National Academy of Sciences*, laying out the detailed chemical structure of hair, feathers, silk and other proteins.

The obvious next step was DNA itself, first identified in the 1940s. The race was in full swing, but politics and personality came to play a critical role. Both of the facilities in Britain capable of conducting the research were funded by the Medical Research Council. With limited funding available, a gentleman's agreement was made that the team at King's College under Maurice Wilkins would get the first go at the DNA problem. But within the King's team personalities, and apparently also misogyny, meant that the gifted young researcher Rosalind Franklin was being frozen out by Wilkins.

It therefore fell to an interloper team – US chemist James Watson and British physicist Francis Crick, with the latter working unofficially from a deep interest in the issue. Indeed, Crick was reportedly twice told by Bragg to leave DNA to the King's team and concentrate on his own PhD. According to my reading, Bragg only came to support the work when in late 1952 Pauling claimed in a letter to his son (at Cambridge) that his team was coming close to solving the problem.

X-ray diffraction photographs were critical to this work, but the only images available were those from Astbury from 1938. The images were not improved until Franklin took up the subject, and Watson's work was hampered by the lack.

Watson attended a talk given by Franklin at King's, which by his own later account (*The double helix*) he did not fully understand, but based upon which he and Crick came up with a first model of DNA that was presented to Franklin and Wilkins. This was so roundly criticised as to leave the pair thoroughly chagrined.

Serendipitously, in 1952 the pair chanced to have two critical conversations. Discussing the issue with mathematician John Griffith, Crick first raised the idea that nucleotide bases might somehow fit together to hold the DNA molecule. And in a chance discussion with biochemist Erwin Chargaff (inventor of Chargaff's rules, of which Watson was ignorant), it was noted that samples of DNA always contain equimolar base ratios of adenine and guanine, thymine and cytosine. Together, this pointed Watson and Crick to a DNA structure involving pairs of long-chain molecules, linked by A–G and C–T.

Armed with an advance copy of Pauling's paper incorrectly proposing a three-stranded DNA model, Watson visited Wilkins at King's, who responded by showing him (without Franklin's knowledge or permission) one of Franklin's best X-ray photographs. The photo was the critical piece of missing evidence, and in combination with the information from Griffith and Chargaff, Watson and Crick were able to finish their work.

This major breach arguably cost Franklin her due recognition and her share of the ensuing Nobel Prize. Just one day before the event, she had finished the first draft of her own paper, which appeared alongside that of Watson and Crick, and a third paper by Wilkins and his colleagues in the 25 April 1953 issue of *Nature*. Franklin died of cancer in 1958, never receiving her due acknowledgement in the 1962 awarding of the Nobel Prize in Physiology or Medicine (awarded to up to three recipients per year; Nobel Prizes were rarely given posthumously), which went to Crick, Watson and Wilkins. Had Franklin lived, would she have received a Nobel Prize? Watson was only to come clean on the matter in his autobiographical account in 1968.

This was neither the first controversy in the relentless advance of science, nor was it the last, but who could fail to be inspired by the race to discover our inner space?

William Henry Bragg's X-ray spectrometer as used by him and his son William Lawrence Bragg to investigate the structure of crystals

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