

William Thomas Astbury (1898–1961)

William Thomas Astbury studied the structures of fibrous materials, including fabrics, proteins, and deoxyribonucleic acid, or DNA, in England during the twentieth century. Astbury employed X-ray crystallography, a technique in which scientists use X-rays to learn about the molecular structures of materials. Astbury worked at a time when scientists had not yet identified DNA's structure or function in genes, the genetic components responsible for how organisms develop and reproduce. He was one of the first scientists to use X-ray crystallography to study the structure of DNA. According to historians, Astbury helped establish the field of molecular biology as he connected microscopic changes in the structure of materials to changes in their large-scale properties. Astbury and his images helped scientists to understand the structure of DNA and its role in genetics.

Astbury was born on 25 February 1898 in Longton, England. Astbury's father, William Edwin Astbury, made pottery as his profession. Astbury had three younger siblings and three older siblings. In a memoir about Astbury, John Desmond Bernal, a historian of science and a researcher who worked with the same scientists as Astbury, wrote that Astbury's mother and teachers recognized Astbury's intellect early in Astbury's life. Astbury received a scholarship to attend Longton High School in Longton, England, where, according to his biographer, Kersten Hall, he became interested in science. Hall states that, in addition to science, Astbury was interested in the arts, including writing, drawing, and music. Astbury could play the piano and would play compositions by artists such as Bach, Mozart, and Beethoven. Hall states that Astbury remained interested in music throughout his entire life.

Astbury received the only scholarship offered by Jesus College in Cambridge, England and began attending the school in 1917. At Jesus College, Astbury studied chemistry, mathematics, and physics. Later in 1917, Astbury briefly left school to serve as part of the Royal Army Medical Corps in Cork, Ireland, during World War I. While serving, Astbury had his first experience working with X-rays for medical purposes, which included viewing bone injuries. During that time, he met Frances Gould. They later married and had two children.

In 1919, Astbury returned to Jesus College where he continued to study physics and chemistry. During his college education, Astbury took a crystallography course with lecturer Arthur Hutchinson. Crystallography is a technique that scientists use to determine the structure or arrangement of building blocks, such as atoms, ions, or molecules, in a solid material. In 1921, Hutchinson recommended that Astbury work with William Henry Bragg at University College London in London, England. Bragg, along with his son, William Lawrence Bragg, had won the 1915 Nobel Prize in Physics for their work developing X-ray crystallography. X-ray crystallography is a technique in which scientists analyze how a beam of X-rays scatters off a crystal to determine that crystal's structure. That technique later became a major part of Astbury's career. In 1921, Astbury joined the Physics Department at University College London. In 1923, Astbury began working with Bragg.

Astbury worked under the mentorship of Bragg at University College London for five years. From 1923 to 1925, Astbury studied the crystal structures of organic compounds, which are compounds that contain the chemical element carbon bonded to other elements. With that work, Astbury helped further the mathematical framework used to perform X-ray crystallographic analyses. In 1926, at the request of Bragg, Astbury began studying the crystal structures of fibrous materials, starting with wool. To do that, Astbury obtained X-ray diffraction patterns of wool by allowing X-rays to scatter off a crystal and to strike a film. That process produced dark marks on the film that provided visual information about the crystal's microscopic structure. Astbury continued to study the structure of fibers when he moved to the University of Leeds in Leeds, England, where he worked

as a lecturer in textile physics, in 1928. Textile physics focuses on the materials used to make fabrics, like wool and silk, and the physical properties of those materials. Those properties include the molecular structure and how far they can be stretched without breaking. That information can be used to improve the production of new fabrics.

During his early years at the University of Leeds, Astbury started a Textile Physics Research Laboratory with the purpose of studying the structure of wool. In a memoir about Astbury, Bernal quotes him saying that at the time, all he and his research team knew about wool was that it was made of a protein called keratin and that many scientists found keratin to be an uninteresting protein. When reflecting on his work with wool later in his career, Astbury stated that he studied wool because it was different from other textile fibers in that it was more elastic and could return to its original length if stretched.

Astbury collected and analyzed over one hundred diffraction patterns of wool, and, from 1931 to 1935, published three articles on the structure of keratin. Astbury showed how stretching the wool caused changes in keratin's molecular structure and related the properties of wool to other keratin containing materials, such as hair and feathers. He also connected those properties to properties of other fibrous proteins, which are a class of proteins with an extended, chain-like structure. In 1935, Astbury studied globular proteins, which were tightly folded structures with variable shapes rather than long fibers. Astbury found that when he denatured the globular protein, or unfolded it, the protein took on a fiber-like structure. He interpreted that finding to mean that all proteins, globular and fibrous, had the same fundamental structure. While some scientists debated the details of Astbury's protein structure models, Astbury was still able to connect properties of large-scale biological materials, such as wool, with changes in their molecular structure at the microscopic level. Some historians credit Astbury's approach to be the beginning of the field of molecular biology.

In addition to studying the structure of fibrous proteins, Astbury also studied the structure of other fibrous biological materials, nucleic acids, which are chains of repeating units called nucleotides. Astbury included DNA in his study of nucleic acids. At that time, scientists had not yet determined that DNA was the main component of genes. Therefore, those scientists did not think DNA was the molecule responsible for properties of inheritance, such as the passage of genetic traits from parents to offspring. In 1938, at the Symposium in Cold Spring Harbor, New York, Astbury presented X-ray diffraction images of DNA that his graduate student, Florence Bell, had collected. Those images were the first X-ray diffraction images of DNA ever obtained. Astbury deduced some structural details from those images that scientists later verified. Astbury and Bell also proposed a structural model of DNA, called the pile of pennies model. In that model, DNA existed as a single-stranded fiber with nucleotides stacked one on top of another perpendicular to the DNA backbone. Scientists later disproved Astbury and Bell's model.

Astbury contributed to scientists' understanding of the role of DNA as genetic material. In the 1930s, the prominent structural theory about DNA, called the tetranucleotide hypothesis, stated that the nucleotides in DNA, of which there were four kinds, had a fixed sequence. According to that hypothesis, those four nucleotides were always arranged in the same repeating order. Based on his diffraction patterns of DNA, Astbury suggested that the exact sequence of nucleotides was not necessarily set and that there could be some variation. That sequence variation would allow DNA in genes to account for genetic differences in organisms, such as fur color or eye color. Astbury also proposed that proteins interacted with DNA and that proteins also functioned as genetic material. Scientists later found that Astbury's model of how DNA interacted with proteins was inaccurate, but that the attachment of proteins to DNA did play a role in how genes produced characteristics in organisms. Despite that, Astbury made early findings that DNA had more structural variation than scientists previously anticipated.

Following his investigation of the structure of DNA, Astbury returned to studying the structures of other fibrous proteins. In 1938 and 1939, he researched the structure of collagen, a protein found in skin and connective tissues. He studied keratin and related fibrous proteins in the 1940s, when he started using electron microscopy, a type of high-resolution microscopy, to study fibrous material structure.

Astbury's study of nucleic acids continued in the late 1940s and early 1950s. In 1945, Astbury

became a professor of biomolecular structure at the University of Leeds and established a new department devoted to studying the structures of biological molecules. In 1947, Astbury's technician, Mansel Davies, collected more X-ray diffraction images of DNA. The main structural information Astbury obtained from those images was that DNA, or at least a large component of DNA, had a repeating structure, while other sections of the molecule could still have variability. Then, in 1951, another one of Astbury's technicians, Elwyn Beighton, collected improved diffraction images of DNA.

According to historians, Beighton's 1951 diffraction images of DNA were the clearest Astbury had seen, but he never published them. Those images were of B form DNA, the most common structural form of helical, double-stranded DNA. Rosalind Franklin, an X-ray crystallographer who was also collecting X-ray diffraction images of DNA in the 1950s in England. Franklin coined the term B form in 1951 based on her own diffraction images. She also determined that year that Astbury's published diffraction images of DNA from 1938 contained a mixture of B form DNA and another, less common structural form of DNA that she called A form. Historians have debated Astbury's reasoning for not publishing the 1951 X-ray crystallography images. Historian Robert Olby argues that Astbury was more focused on the idea that DNA was important for its interaction with protein, and Beighton's images were of DNA alone. Historians Horace Freeland Judson and Hall claim that the 1951 images contradicted Astbury's established views about the structure and function of DNA. In 1953, James Watson and Francis Crick used Rosalind Franklin's 1952 X-ray diffraction images of DNA to develop their structural model of DNA, which, as of 2018, continues to be the accepted model of B form DNA.

Astbury worked at the University of Leeds for the rest of his life. In addition to studying DNA in the 1950s, Astbury also studied bacterial flagella, or tail-like structures that some bacteria use to swim and move. He was a member of many scientific organizations, including the Royal Society headquartered in London, England. The University of Leeds named a molecular biology research center the Astbury Centre for Structural Molecular Biology in honor of Astbury. He died on 4 June 1961 from damages to his lungs and heart resulting from blood clots.

Sources

1. Astbury, William T., and Florence O. Bell. "X-ray Study of Thymonucleic Acid." *Nature* 141 (1938): 747.
2. Bernal, John Desmond. "William Thomas Astbury, 1898-1961." *Biographical Memoirs of Fellows of the Royal Society* 9 (1963): 1-35. https://www.leeds.ac.uk/heritage/Astbury/bibliography/Bernal_Astbury_obit.pdf (Accessed August 24, 2018).
3. Bragg, William H., and William L. Bragg. "The Reflection of X-rays by Crystals." *Proceedings of the Royal Society A* 88 (1913): 428-38. <https://doi.org/10.1098/rspa.1913.0040> (Accessed September 7, 2018).
4. Davies, Mansel. "W. T. Astbury, Rosie Franklin, and DNA: A memoir." *Annals of Science* 47 (1990): 607-18.
5. Franklin, Rosalind E., and Raymond G. Gosling. "Molecular configuration in sodium thymonucleate." *Nature* 171 (1953): 740-1.
6. Hall, Kersten. *The Man in the Monkeynut Coat: William Astbury and the Forgotten Road to the Double-Helix*. Oxford: Oxford University Press, 2014.
7. Hall, Kersten. "William Astbury and the Biological Significance of Nucleic Acids, 1938-1951." *Studies in History and Philosophy of Science Part C: Studies in History and Philosophy of Biological and Biomedical Sciences* 42 (2011): 119-28.
8. Judson, Horace Freeland. *The Eighth Day of Creation*. Cold Spring Harbor: Cold Spring Harbor Laboratory Press, 1996.
9. Olby, Robert Cecil. *The Path to the Double Helix: The Discovery of DNA*. Seattle: University of Washington Press, 1974.
10. University of Leeds Museum of the History of Science, Technology and Medicine. "Elwyn Beighton's 1951 photograph of DNA." University of Leeds. https://www.leeds.ac.uk/heritage/Astbury/Beighton_photo/index.html (Accessed September 7, 2018).

11. Watson, James D., and Francis H. C. Crick. "Molecular Structure of Nucleic Acids." *Nature* 171 (1953): 737-8. <https://www.genome.gov/edkit/pdfs/1953.pdf> (Accessed September 7, 2018.)