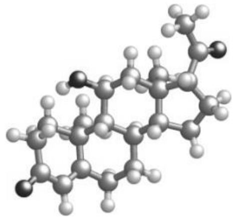

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<u>Biography #1 – Dorothy Crowfoot Hodgkin (1910 – 1994)</u>

• Dorothy Crowfoot Hodgkin, 1910 – 1994.

One day in 1935, Dorothy Crowfoot, then twenty-five years old, took an X-ray diffraction picture of a crystal of insulin. She shone an X-ray beam through the crystal and onto a photographic plate. That night, after developing the film and seeing a regular diffraction pattern, she walked through the streets of Oxford, almost delirious with joy at the thought that she might be able to deduce the structure of the molecule so important in treating diabetes. At the time, she had no way of knowing that solving the puzzle would take her thirty-four years.

Dorothy was born in Cairo, Egypt, on 12th May 1910. Her father was an archaeologist and educator, and her mother was an expert on ancient weaving who also illustrated texts on botany. Dorothy and her younger sisters spent most of their childhood apart from their parents. Throughout the years of World War I and beyond, the girls stayed with friends or relatives in England while their parents lived mostly in Egypt and Sudan. Both Dorothy's independence and her motherly nature may have grown from those years when she watched over her sisters' welfare.

Shy, quiet, gentle and independent, Dorothy got a patchy education from a series of small schools. The year she was ten, a government course introduced a project growing crystals. Repeating the experiment at home, Dorothy fell in love with chemistry. Three years later, when she and her sister Joan spent six months with their parents in Sudan, Dorothy prospected for minerals. She enlisted the help of a family friend, soil chemist A. F. Joseph, to analyse them. He gave her a box of reagents, and once Dorothy was home in England again, she set up an attic laboratory for herself. Then, for her sixteenth birthday, her mother gave her a children's book in which physicist William Bragg, winner of the Nobel Prize, described shining X-rays through crystals to discover their atomic structure. Dorothy was captivated by the idea of actually being able to "see" how atoms are arranged.

As a teenager, Dorothy Crowfoot became politically active. Her mother's four brothers had been killed in the world war, and along with her friends, Dorothy joined and volunteered for organisations promoting world peace.

After graduating from high school, Dorothy studied Latin and botany so she could pass the entrance exams to Oxford. At Oxford, studying chemistry, she decided to specialise in the new field of X-ray crystallography. Determining structures from X-ray photographs was harder than Bragg's book had made it sound. First Dorothy had to make crystals of a compound and shine X-rays at them from every angle. Finally she had to analyse the photographs mathematically.

Upon graduating from Oxford, Dorothy joined the laboratory of J. D. Bernal at Cambridge University. Bernal was a communist, a visionary scientist, and a believer in equal rights for women. His laboratory was an exciting and sometimes dangerous place to work. Electrical wires hung loose from the ceiling, and there was so much static electricity that Dorothy's hair often stood on end.

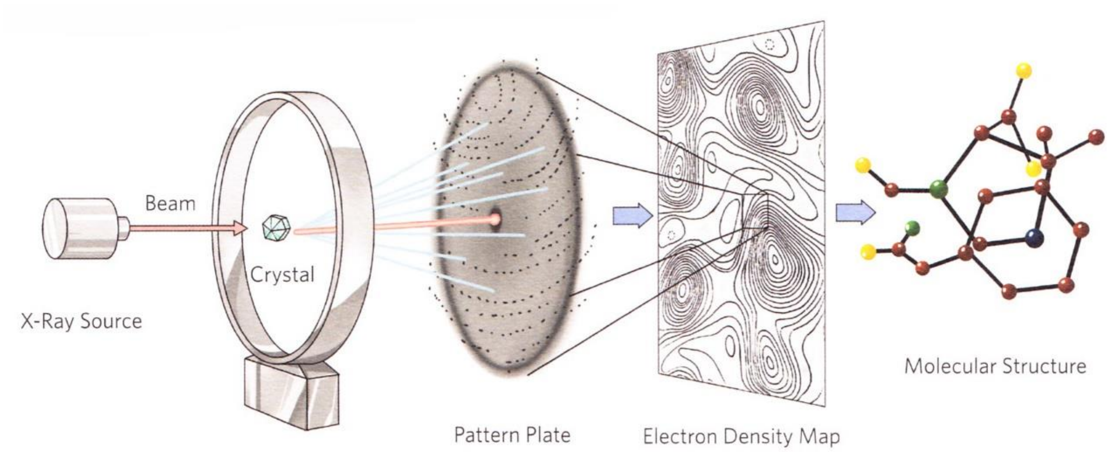
While at Cambridge, Dorothy began to suffer from swollen, aching joints in her hands. A specialist diagnosed rheumatoid arthritis, a painful, lifelong and often crippling disease. In the 1930s there was no effective treatment, but Dorothy soldiered on. Her work showed her to be quite patient, adept and determined. Her mentor J. D. Bernal said later, "She was one of those masters whose method of work is as exciting and beautiful to follow as the results that flow from it." Handling the samples Bernal's colleagues sent him to study, Dorothy skilfully created X-ray images of vitamins, hormones, and protein crystals.

Even before she received her Ph.D. in 1937, Dorothy Crowfoot received a fellowship at Somerville College, Oxford. That same year, she married Africa scholar Thomas Hodgkin, who like Bernal, was an idealist and a Communist. Together they had three children and maintained a warm, chaotic home where international visitors, whether refugees or eminent scholars, came and went with great informality. Thomas did most of the cooking.

Despite her marriage, Dorothy Hodgkin found Oxford lonely at first. The university chemistry club did not allow women to attend meetings. Hodgkin's laboratory was located in the basement of the Oxford University Museum among dinosaur skeletons and medieval stonework. Her equipment was so antiquated that she had to convince a senior professor to apply to a chemical firm for funding to buy more. The professor found it hard to turn down a request from a gentle, direct, and well prepared junior researcher. Asked years later if she felt that being a woman had hindered her career, Dorothy Hodgkin focused her reply on individual kindness rather than institutional barriers. "As a matter of fact," she answered, "men were always particularly nice and helpful to me because I was a woman."

Hodgkin set up her polarizing microscope on a high gallery in front of the sole, high, Gothic window in her basement laboratory. To reach the microscope, she climbed a ladder, clutching her thin crystal preparation in one arthritic hand and pulling herself up with the other. Then she and her students analysed their data at a large table in the X-ray room, which bore a sign reading "Danger – 60 000 Volts."

Throughout her life, Hodgkin took on challenges in crystallography that others thought were impossible. At Oxford, she began by studying the structure of cholesterol. Although we think of cholesterol mostly in the context of disease, it is an essential part of all animal cell membranes. Chemists had already determined its formula – how may atoms of each chemical element one molecule contained – but not how they were arranged in two or three dimensions. When Hodgkin and her student Harry Carlisle deciphered cholesterol's shape, it was the first time X-ray crystallography had determined a structure that other chemists could not figure out.



• The process of X-ray crystallography.

In those days, before calculators and computers, solving molecular structures required painstaking calculations with pencil, protractor, and a slide rule. The calculations could take many months, or even years, to complete. But in 1936, Hodgkin spent five pounds on an early version of a calculator: two boxes of paper strips, covered in values of sines and cosines of every imaginable X-ray angle. Hodgkin kept the strips carefully organised, and they saved her many hours of figuring.

In 1940, Hodgkin addressed a new challenge – penicillin. Alexander Fleming had discovered penicillin in 1928, but it had to be harvested in small batches from mould cultures. Penicillin was a small enough molecule that Hodgkin thought that she could solve its structure. She hoped the structure would allow chemists to synthesise penicillin in large enough amounts to treat Allied soldiers in World War II. But despite its small size, penicillin proved tricky. It crystallised in different arrangements under different conditions, and no one knew which chemical groups made up the molecule. Hodgkin deduced that the heart of the molecule contained a beta-lactam ring, but her colleagues were sceptical. One said, “If penicillin turns out to have the beta-lactam structure, I shall give up chemistry and grow mushrooms.”

By the middle of the war, Hodgkin had managed to arrange night-time use of an early IBM analog computer that tracked ship cargoes during the day. By 1945, she had solved penicillin’s structure, but for reasons of national security, she did not publish her results until 1949. But even earlier, her colleagues recognised the scientific quality of her work. In 1946 she was officially appointed an Oxford lecturer and demonstrator. The following year, she became the third woman in almost three hundred years to be elected a fellow of the Royal Society of London.

In 1948, Hodgkin decided to tackle the structure of vitamin B12. People deficient in vitamin B12 cannot make enough red blood cells and suffer from neurological problems such as limb weakness, shooting pains, depression, and difficulty thinking. But compered to penicillin’s seventeen non-hydrogen atoms, vitamin B12 has nearly a hundred. Most chemists had concluded that the molecule was too complex to solve with X-ray diffraction. Dorothy Hodgkin thought it was worth a try.

By now, Hodgkin ran a large lab filled with international students, both men and women. She mothered and encouraged them. Together they took thousands of X-ray photographs and gathered mountains of data. Then, in 1953, Hodgkin began collaborating with an American scientist named Kenneth Trueblood, who had helped program an early, high-speed computer to do the calculations needed for crystallography. The computer was housed at the University of California, Los Angeles, so Hodgkin and Trueblood communicated by mail or telegraph. In 1956, after eight years of work, Hodgkin announced the structure of vitamin B12. Many chemists considered it the most important structural finding of the decade, just as penicillin had been the decade before.

In the 1950s, although her scientific accomplishments brought her honour, Dorothy Hodgkin’s political activities brought her attention of another sort. After World War II ended, she had helped form the International Union of Crystallography. The Union included scientists from East Germany and even from the Soviet Union. She also joined a group called Science for Peace that included several Communists. In 1953, Linus Pauling invited her to a conference in California, but the United States State Department refused to grant her a visa. Instead of visiting America, Hodgkin travelled to Moscow to discuss ways to improve the exchange of scientific information. In the 1960s and 70s, she continued to work for peace. She opposed the Vietnam War and visited both China and North Vietnam. In 1975 she became president of the Pugwash Conferences on Science and World Affairs, a society established in 1955 to campaign for nuclear disarmament and world peace.

Back in Oxford, Hodgkin returned to the insulin puzzle, as she had many times over the years. Insulin regulates sugar uptake and energy use in the body, and lack of it causes the most dangerous form of diabetes. Eight times the size of vitamin B12, insulin presented a daunting challenge. But in 1951, chemist Fred Sanger identified the sequence of amino acids in the molecule. With computing power rapidly increasing, Hodgkin thought she could decipher the threedimensional structure at last. To do so, she analysed thousands of X-ray photographs. In 1969, she and her team announced their solution to the molecule's structure. They showed that insulin consists of six identical sequences arranged in a triangle around two central atoms of zinc.

Throughout the 1950s and 60s, Thomas Hodgkin had been spending more and more time in Africa. Dorothy was visiting him in Ghana in October 1964 when she learned that she had won the Nobel Prize in Chemistry. In her Nobel Biography, she pointed out that at the time of her prize award, her three children were also dispersed across the globe, working in Algeria, Zambia and India.

In 1965, Queen Elizabeth II gave Dorothy Crowfoot Hodgkin the Order of Merit, making her the first woman to receive that honour since Florence Nightingale. In 1977, Hodgkin retired to a stone house in the Cotswolds, north of Oxford. She continued to travel to international conferences on science or peace, despite her crippling arthritis and a broken pelvis. In 1990, she finally received an unrestricted visa to visit to America. Although she was over eighty and confined to a wheelchair, Hodgkin immediately scheduled a lecture tour of the United States. She spoke to standing-room only crowds about insulin and the history and future of crystallography.

Dorothy Crowfoot Hodgkin died of a stroke in 1994. Her former student M. Vijayan wrote of her, "It is difficult to adequately describe her legendary achievements, but it is still harder to describe her personality in a few words. She was warm, simple, affectionate and caring." Max Perutz, himself a Nobel Prize winner, agreed. "There was magic about her person. She had no enemies, not even among those whose scientific theories she demolished or whose political views she opposed."

- Noyce, P. (2015). *Magnificent Minds* (pp. 117-123). Boston, MA: Tumble Home Learning, Inc.