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The Search for the Structure of DNA

Ethics in the Science Classroom Case Study #4

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Description

This historical case discusses the controversy surrounding the discovery of the structure of DNA and the resulting competition and sexism in science surrounding this dispute.

Abstract

This is one of six cases from Michael Pritchard and Theodore Golding's instructor guide, "Ethics in the Science Classroom."

Categories of Ethics/Values Illustrated by This Case: Competition vs. cooperation, and sexism in science.

Body

1. Introduction

In 1953, an article was published in the British science journal, *Nature,* by James Watson and Francis Crick on the structure of DNA. Like most important scientific discoveries, this result was based on the work done by a large number of investigators over many years. It has become known as the Watson-Crick model and has laid the foundation for the tremendous advances made in genetics and molecular biology in the ensuing decades. The double helix structure of DNA and the genetic code it incorporates is regarded as one of the most important scientific discoveries of the century. On the basis of this work, the 1962 Nobel Prize for Medicine and Physiology was awarded to Watson, Crick and Maurice Wilkins. High school and college biology students throughout the world learn about the Watson-Crick model.

In 1968 James Watson published a book entitled *The Double Helix* (New York: Atheneum, 1968) giving his own account of the events leading to the solution of the DNA structure. The Norton Critical Edition of this book edited by G.S. Stent in 1980 contains the six original published articles, as well as 13 reviews of the book that appeared in journals. These reviews express the viewpoints of other scientists regarding the discovery of the structure of DNA and Watson's account of the work. Watson's portrayal of the personal lives of the people involved and the events leading to the discovery proved to be highly controversial. Harvard University Press refused to publish this book, considering its style and content to be irreverent of the scientific research process. In 1975 Anne Sayre's book entitled *Rosalind Franklin and DNA* (Norton) appeared and presented a different perspective on the discovery by describing Rosalind Franklin's outstanding X-ray diffraction studies on DNA and making the case that the Watson-Crick model would not have been postulated by them without access to Franklin's data, which they obtained by rather devious means. Anne Sayre was a personal friend of Dr. Franklin and was unable to recognize the "Rosy" that Watson described as the Rosalind she knew. An amusing 1987 made-for-TV film, "The Race for the Double Helix,", is loosely based on Watson's book and illustrates the concerns raised by Ms. Sayre. (See Readings and Resources, below.)

2. Background

By the early 1940's it was known that genes were the chemical constituents of plant and animal cells that carried the hereditary information. What was not known was

their chemical identity and structure. The many researchers who were avidly seeking the answer were divided among those who thought that genes were specific types of proteins and those who thought evidence made it more likely that they were nucleic acids (e.g., DNA). While some scientists thought it unreasonable to understand the complexities of genetics in terms of the structures of "lifeless" chemicals, others believed that the molecular structure of the genes carried by the chromosomes held the key to understanding how genetic information is inherited and expressed. It seemed logical to consider proteins as the carriers of genetic information due to their greater complexity than DNA, which contains only four different nucleotide bases. In the 1920's DNA was found by staining to be concentrated in the chromosomes, but was commonly thought to play an auxiliary role in hereditary.

Although DNA was isolated in 1869 by Miescher, there was not much interest in it for several decades. Levene subsequently determined correctly that each nitrogenous base was attached to a sugar molecule and phosphate group. However, he postulated that they existed as a tetra-nucleotide cluster which repeated over and over to form the DNA molecule. Such a simple, monotonous structure could not be envisioned to carry genetic information, and since Levene's theory was given great weight by his renown as a biochemist, scientists looked to proteins for many years. It wasn't until 1950 that Erwin Chargaff published results indicating that the bases were not present in equal proportions. He found a correlation between the amount of adenine to thymine and cytosine to guanine providing the important clue to the coupling of these pairs of bases in the DNA structure.

It was correctly anticipated that if DNA was the carrier of genetic information, determination of its three-dimensional structure would provide answers to how it functioned. X-ray crystallography is a technique uniquely suited to this task. However, by mid-twentieth century scientists had only just begun to apply it to large biological molecules. For many of these it was difficult to obtain suitable crystals. Although today macromolecular structures are routinely solved with the aid of fast computers, in the 1950s the determination was mathematically very tedious.

3. The Case

Rosalind Franklin was brought to Kings College, London in 1951 to set up and be in charge of an X-ray diffraction laboratory. She came with considerable experience, particularly in working with macromolecular materials that do not readily form crystals, and which give diffraction patterns that are difficult to interpret. She set to the task of determining the structure of DNA by X-ray diffraction of DNA fibers. In March of 1953 she presented a research report that included the following key results based on her experimental evidence: that DNA contained two polymeric strands arranged in a coaxial helical structure with a type of symmetry described as "C_2," and that the phosphates were on the outside of the helix. She had also determined the number of molecules of water per structural unit, the molecular diameter and repeat distance, and the number of nucleotides per turn of the helix. The important missing piece of information was precisely how the nucleotide bases fit into the structure.

Watson and Crick collaborated at Cambridge to work on determining the structure of DNA. Each of them had been assigned to work on another problem, but recognizing its key importance, they talked about and worked on the DNA problem extensively at the expense of their official responsibilities. They did not actually perform experiments, but based their theorizing on bits of information published in the literature, as well as on Dr. Franklin's results, which they obtained, without her knowledge, from an unpublished report she had written for her research director. They relied on the relatively new technique of using physical models incorporating approximate distances and angles of atomic groupings from known molecular structures.

By guessing the correct position and structural pairing of the nucleotide bases, they were able to construct a model that was consistent with the known facts and that could account for the biological role of DNA. This was the structure that Watson and Crick published in their famous 1953 paper, which resulted in their receiving worldwide recognition as the discoverers of the DNA structure, and ultimately led to the Nobel prize. No mention of Franklin's key contribution appears in their paper. Franklin's co-worker, physicist Maurice Wilkens, (whom Watson mistakenly refers to

as Franklin's boss in his book) did share the Nobel Prize with Watson and Crick. Franklin died of cancer before the awarding of the Prize, which can not be received posthumously, so it cannot be assumed that the Nobel Committee considered Wilken's work more important than Franklin's. If she had lived, they could not both have been honored because Nobel stipulated that no more than three people can share the prize. What is unquestionably true is that little recognition is accorded to Franklin's important role in most descriptions of the quest for the DNA structure, and her name does not appear in most high school or college biology texts in association with the discovery.

Anne Sayre's book stresses the difficulties faced by a woman scientist in England during the period in question. The small female minority were not even allowed into the lounges in scientific research institutions, where many of the important discussions among male scientists took place. The influence that contemporary attitudes toward women had on Watson's (and subsequently on the scientific world's) evaluation of Franklin's contribution to the DNA work warrants serious consideration.

4. Readings and Resources

The two key books that should be read in connection with this case are:

- *The Double Helix,* by James Watson (New York: Atheneum, 1968). [As noted above the 1980 Norton Critical Edition of this book, edited by G. S. Stent includes valuable reviews and other documents related to this case.]
- *Rosalind Franklin and DNA* by Anne Sayre (New York: Norton, 1975).

An amusing feature-length video loosely based on Watson's narrative and illustrating many of the concerns raised by Sayre is:

- "The Race for the Double Helix," a British Broadcasting Corporation (BBC) / Horizon Films / Arts & Entertainment Network (A&E) 1987 production. [This video is owned by many libraries and is currently distributed by Films for the Humanities and Sciences, P.O. Box 205, Princeton, NJ 08543-2053.]

Articles that discuss other cases involving questions regarding the assignment of credit for scientific discoveries include:

- "Discovery of Pulsars: A Graduate Student's Story," by Nicholas Wade, *Science,* 189, pp 358-363, August 1, 1975.
- "My Work with Millikan on the Oil-Drop Experiment," by Harvey Fletcher, *Physics Today,* June 1982, pp 43-47.
- "Masters and Apprentices," (Chapter 8) in *Betrayers of Truth* by William Broad and Nicholas Wade (New York: Simon and Schuster).

5. The Issues

Significant questions of ethics and values raised by this case:

- Many scientists objected to the very personal and irreverent nature of the style that Watson chose in relating the tale of his quest for the structure of DNA. This manner of describing a highly significant historical episode in scientific research was certainly unusual, if not unprecedented. Is it in any way unethical or morally questionable to adopt colloquial, perhaps even flippant reportorial approach to the description of historically important scientific events?
- Watson, and to a lesser extent Crick, displayed a highly competitive attitude toward other researchers during their collaboration on the DNA research. One

of the norms traditionally associated with scientific work is that of cooperation among researchers. Does Watson's description of his and Crick's competitiveness constitute such an extreme departure from this norm as to be viewed as unethical?

- Sir Lawrence Bragg, Director of the laboratory in which they were employed, did not want Watson and Crick *fishing in other people's ponds* by working on the structure of DNA.. To what extent is science territorial, and to what extent is such territoriality: beneficial or harmful; necessary or unnecessary; ethical or unethical?
- Watson and Crick clearly made use of the ideas and results of other scientists in pursuing their goal, including those of Linus Pauling, Erwin Chargaff and Rosalind Franklin. This is, of course, a commonly accepted practice. What was it, then, that led Ann Sayre to suggest that Franklin had been treated unethically as a result of the use of her findings in the construction of the Watson-Crick DNA model? Is Sayre correct in her assessment? If so, were Pauling's and Chargaff's scientific conclusions or predictions also appropriated improperly?
- Franklin's approach to the DNA problem was painstaking and methodical. She clearly eschewed guesswork. Watson and Crick, on the other hand, did no labor intensive experiments, ventured many guesses about the DNA structure based upon the results of other scientists, and finally triumphed because this informed speculation allowed them to build a model that uniquely conformed to all the known properties of the molecule. Is there anything inherently unethical or of questionable values in the less conventional approach of Watson and Crick?
- It is clear that in the 1950s Watson held the very chauvanistic and derogatory attitudes toward women that were common among male scientists in that era. Does Watson's narrative support Sayre's assertion that these attitudes resulted in his devaluing of Franklin's research?
- To what extent do the social values that Franklin had to confront justify her reticence to engage in discussions about her research progress with her male colleagues.?
- Do you agree that there is sufficient evidence to conclude that Franklin has not been given the credit she deserves for her role in the discovery of the DNA structure?

Additional ethics and values questions related to assigning credit for scientific discoveries, sharing of data and results, and prejudice in science.

- Credit for a scientific discovery is generally accorded to the person(s) who first publishes the finding in an accredited scientific journal. Do you see any ethical problems with this accepted practice?
- Can you think of any objective criteria for deciding how significant a scientist's contribution to a discovery or a result should have to be in order to merit receiving credit for it and/or being listed as one of the authors of the research paper that describes it?
- Frequently scientific papers or reports are authored by a several scientists, each of whom made a distinct contribution to the work. Sometimes the contributors include those with very different scientific expertise. In such cases, should all of the authors be held responsible for everything included in the publication?
- Frequently research directors have received all, or most, of the credit for work that has been actually carried out by their students. Is this ethical? Does it matter if the principal ideas for the research were those of the research director?
- Competition can frequently stimulate rapid progress and scientific research. On the other hand, competition can also impede the sharing of ideas and interim results, which are generally of great value for the healthy development of science. Can you think of any guidelines that might result in an appropriate balance between these opposing values?
- Under what circumstances should a scientist feel justified in refusing to share his/her results with a competing scientist?
- Racial, sexual and ethnic prejudices that impede an individual's full development as a scientist are clearly unethical in a just society. Aside from limiting the scientific development and career opportunities of individual scientists, what other negative scientific impacts can you think of that have resulted from such prejudice?

Rights

Resource Type

Case Study / Scenario

Parent Collection

Ethics in the Science Classroom

Topics

Collaboration
Discrimination in the Workplace
Diversity

Discipline(s)

Genetics and Genomics
Research Ethics
Authoring Institution
Center for the Study of Ethics in Society at Western Michigan University