CHAPTER 16

Science, Power, Gender: How DNA Became the Book of Life

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Natural science, which is what we usually mean by *science,* involves interacting with nature in ways that produce certain kinds of interpretations of how nature works. There are different styles of doing science, depending on what aspects of nature scientists are exploring, but all of them are constrained by rules of what constitutes evidence and what conclusions are considered permissible. The different ways in which scientists pursue their work, however, do not easily fit into male/female categories.

The fact that, in the United States, many more physicists are men than women has to do with the social and economic structure of domestic life, with processes of education and professionalization, and with the social history of the disciplines, not with the intrinsic nature of physicists' knowledge base or the nature of women and men. We live in a gendered society, and it should not surprise us if women and men tend to develop different tastes in the kinds of knowledge they seek and the ways they seek it, but this fact cannot be used to predict the practices of individual scientists. Besides, science imposes a hegemony within which all its practitioners must operate if they want what they do to be acknowledged as science.

In this essay, I want to describe the contributions two outstanding women scientists have made, in the course of the twentieth century, to our under- standing of how genes function and to raise the question of what ways gender can be said to have entered their scientific accomplishments and careers. But, first, I need to review briefly how, during this period, genes and DNA have come to be the iconic objects they currently are.

I

Genetics, of course, starts with the Czech monk Gregor Mendel. Using pea plants as his experimental objects, Mendel examined the transmission of flower color and of the shape and texture of the seeds to successive generations. He deliberately chose discrete traits, such as red or white petals, or smooth or wrinkled seeds, rather than traits that vary continuously, such as weight or size. He also only kept track of the mathematical regularity with which these traits are transmitted and did not speculate about what processes inside the plants are involved in transmitting the traits. He simply assumed that "factors" inside the plant mediate their transmission.

The publication of Mendel's paper, in 1865, provoked little notice. But by 1900, when the paper was "rediscovered," it aroused immediate interest. The reason

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is that, in the intervening years, scientists had learned a great deal about the internal structure of cells and about what happens when a cell divides and gives rise to two daughter cells. Stainable bodies, called chromosomes, had been observed in the cell's nucleus, and scientists had noted that different cells of the same organism all contain the same number of chromosomes. Scientists also noted that, when cells divide, their nuclear chromosomes split in two, which is how each daughter cell ends up with the same number of chromosomes as were present in the parent cell. On the basis of such observations, by 1900 biologists accepted that chromosomes have something to do with the way traits are trans-mitted from parents to offspring, and Mendel's hypothetical "factors" came to be conceptually associated with the chromosomes.

The Danish botanist Wilhelm Johannsen, in 1905, invented the word *genetics* to signify biological inheritance, and, in 1909, he coined the word *gene* to lend more concrete reality to Mendel's "factors." At a time when invisible atoms and quanta were being accepted into the world of chemistry and physics, biologists had little problem accepting that heredity is mediated by invisible material particles, carried on the chromosomes. And soon, as biological chemists came to identify all sorts of molecules that function in cells, one of the questions they tried to answer was what kinds of molecules the chromosomes and genes are made of and how they function.

Once chemical analyses had shown that chromosomes contain two types of very large molecules, proteins and DNA, some scientists suggested that DNA provides the chromosomes with a structural framework to which proteins attach themselves to form the genes. What gave this model plausibility was that DNA, though very large, is a relatively simple molecule, containing large numbers of just one kind of sugar and phosphate and four different kinds of the "bases," whose designations—A, G, T, and C—have become part of our ordinary vocabulary (as has the acronym DNA). It seemed hard to imagine how combinations of only these six subunits could specify all the different characteristics organisms inherit from their parents. Protein molecules, by contrast, are composed of some twenty different subunits and come in many different shapes and sizes. It therefore was logical to assume that genes were made of proteins.

By the early 1950s, however, experiments with bacteria and viruses showed quite clearly that heritable characteristics are transmitted by DNA, not by proteins. Thus DNA was generally accepted as the substance that mediates inheritance—in a word, the gene.

II

This brings us to April 1953, when three papers appeared side by side in one issue of the British science weekly *Nature*. The first, from Cambridge University, was coauthored by James D. Watson and Francis Crick; the other two, from King's College, London, were authored by, respectively, Rosalind Franklin and Maurice Wilkins with their coworkers. The Watson and Crick paper announced the now-familiar double-helical structure of DNA. The other two offered evidence in support of this structure. James Watson has described how he and Crick arrived at the DNA structure in his best-selling memoir, *The Double Helix,* published fifteen years later, in 1968.

What immediately got scientists excited about the Watson-Crick model was that it can be made to explain how DNA—"the gene"—gets copied when cells replicate. The point is this: Let us picture the double helix as two railings of a spiral staircase, each of which is composed of a long, invariant sequence of sugar-phosphate-

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sugar-phosphate-sugar-phosphate units. The two railings are connected by a regularly spaced series of rungs, which make them run parallel to each other. Each rung is composed of a pair of bases, and the geometry of the double helix is such that, for two bases to form a rung, an A on one railing must meet a T on the other and a G on one railing must meet a C on the other.

This geometrical requirement means that, when cells divide and their chromosomes and genes get copied, the two strands of the double helix need merely unravel bit by bit. The sequence of bases on one strand then specifies the base sequence for the synthesis of its partner. Thus, DNA ("the gene") gets copied by virtue of the requirement that an A on one strand of the double helix meet a T on the other and a G on one strand meet a C on the other, an incredibly simple and exciting outcome.

Yet this very simplicity conceals a conceptual trap, because it led scientists to describe DNA as a "self-replicating" molecule. And this has endowed the gene with the supposed power of not just participating in the metabolic and synthetic activities of cells and organisms but of masterminding and directing them. But, of course, DNA does nothing of the sort. Without the metabolic activities of cells, DNA is neither copied nor does it participate in specifying traits. Indeed, left to itself, DNA is one of the most inert and stable molecules in biology, which is why it can be isolated, still intact, from ancient fossils.

Only by ignoring the participation of the rest of the cell and organism have molecular geneticists enshrined the magic of DNA—the autonomous, all-powerful gene that does not just specify traits but produces and controls them. The fact that biologists, who are not usually known for their religious commitments, have selected "the Holy Grail" and "the book of life" as their metaphors for DNA—not to speak of President Clinton's referring to DNA as "the language in which God created life"—underlines the ideological content of molecular genetics.[1]

III

What relevance does all this have to gender? To answer this question, I want to look at the contributions two outstanding women scientists have made to our understanding of genetics and DNA. I refer to Barbara McClintock and Rosalind Franklin. I have written about Franklin's contributions before (Hubbard 1990, chap. 5), but as DNA has come to occupy not only a central role in biology but a larger-than-life role in the culture, certain elements of both her story and McClintock's story have taken on new significance.

Born in 1902 and dying in 1992, Barbara McClintock's life spanned the twentieth century. She earned a Ph.D. in botany from Cornell in the early 1920s and stayed on at Cornell's College of Agriculture on fellow- ships for several years, working on the structure of the cells and chromosomes of corn (maize) and on its genetics. At Cornell, McClintock had access to a good-sized plot in which to breed corn. She needed that because she felt she had to get to know the individual, living plants if she was to make sense of what she observed when she later studied the detailed structure of their chromosomes under the microscope.[2] When it became clear that she was not going to be offered a position on the Cornell faculty, McClintock began to look around and eventually ended up accepting an assistant professorship at the University of Missouri. There she spent a few scientifically productive, but otherwise not very satisfying, years. The facilities were not all that good, so she needed to maintain her plantings at Cornell and shuttle back and forth. She also did not interact too well with some of her colleagues,

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nor did she particularly enjoy teaching. When she was passed over for promotion, she felt it was time to move on. With strong support from older, established (male) colleagues, McClintock was invited to spend a year at the laboratory of the Carnegie Institution at Cold Spring Harbor, Long Island, and it became her permanent home. McClintock's lack of academic success did not stand in the way of her recognition within the profession. She was elected vice president of the Genetics Society of America in 1939 and its president in 1945. More important, she was elected to the National Academy of Sciences in 1944—only the third woman member since its founding by President Lincoln. And she won a Nobel Prize in 1983—only the second woman scientist to win an unshared Nobel, the other being Marie Curie.

From the start, McClintock made pathbreaking contributions. But since she was committed to looking at genes in the context of the whole organism, which was not the usual perspective in her field, many of her fellow geneticists simply did not understand her experiments or the way she interpreted them. When she concluded that genes can change their positions on the chromosomes, along with their functions, in response to changes within the plant and around it, this was so contrary to what geneticists believed possible at mid-century that many of them simply wrote her off. Not until the 1970s and 1980s, when comparable observations were made with bacteria, was what McClintock had been saying accepted into the canon of the field.

So what does any of this have to do with gender? Certainly, McClintock's failure to be promoted within academia had a lot to do with it, though it must also be said that she was not an easy colleague; but neither are many male academics. That colleagues chose to ignore her rather than make the effort to understand what she was saying suggests that they may not have taken her as seriously as they would have taken a male colleague of comparable experience and stature. The degree to which McClintock was something of an outsider and a loner in her scientific life (though she always had close friends) probably also had something to do with gender. But the content of her science?

Some people have suggested that McClintock relied more on intuition than do most male scientists. Probably so, but so do some men. In a recent biography of Henry Wallace, Franklin Roosevelt's two-term secretary of agriculture and one-term vice president, who was a world-famous plant breeder (and founder of Pioneer-Hi-Bred, the foremost supplier of hybrid corn), I found the following story. Late in Wallace's life, a group of New York writers and artists asked him to what he attributed his success as a plant breeder. Wallace responded, "Sympathy with the plant" (Culver and Hyde 2000, 518), quite like McClintock's "feeling for the organism," her phrase that Evelyn Fox Keller uses as the title for her biography.

IV

Rosalind Franklin's is a much sadder story. Franklin was born in 1920 into an established Anglo-Jewish family in London. She graduated from Cambridge University during World War II with a degree in physical chemistry and went to work doing war-related research on different configurations of carbon in coal. At the end of the war, she moved to Paris and took a position in a French government laboratory, using X-ray diffraction techniques to analyze the structure of different types of coal. After four happy years there, she reluctantly decided to return to England and, because she wanted to learn about molecules of biological interest, accepted a fellowship in the biophysics unit at King's College, London, directed by Professor John Randall.

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The unit was working on the structure of DNA, and Randall asked Franklin to build a high-resolution camera with which to make more detailed measurements of the X-ray diffraction patterns of DNA than had previously been possible.[3]

King's was a much less collegial and more hierarchical place than the laboratory in which Franklin had been working in Paris, with gender- segregated "combination rooms" where the staff took their tea and morning coffee. Also, intentionally or not, Randall put Franklin into a highly ambiguous situation by leading Maurice Wilkins, the unit's assistant di-rector, to believe that Franklin and he would be working on DNA together, while telling Franklin she would be doing the X-ray diffraction studies on her own.[4] When personality conflicts began to develop between Franklin and Wilkins, she decided they would not be able to work together and set about to build a powerful X-ray camera with which she and Wilkins's former graduate student R. G. Gosling began to make a series of groundbreaking observations on DNA fibers. And before long, she obtained the sharpest X-ray diffraction image of DNA in existence that clearly showed that DNA can form a helix.

Shortly after Franklin joined the group at King's, James Watson came to Cambridge University planning to work with Francis Crick on the structure of DNA, which the two of them considered to be "the secret of life." As Watson recounts in *The Double Helix*, his first encounter with Franklin was a disaster. Soon after coming to Cambridge, Watson went to King's to attend a seminar by Franklin, but he was too busy critiquing her clothes and hairstyle to listen properly. Having misunderstood her presentation, he told what he remembered of it to Crick, and they promptly decided to use his recollection to build a model of DNA. They then invited the King's group to come and look at their model. Franklin immediately realized that it was completely inconsistent with the data she had presented at the seminar Watson had attended and decided he was not to be taken seriously. In consequence of this fiasco, their superiors at Cambridge told Watson and Crick to keep their hands off DNA and leave it to the group at King's. (Watson tells all this in the *The Double Helix*.) During the next months, unbeknownst to Franklin, two crucial things happened. One was that Wilkins showed Watson Franklin's best X-ray diffraction image, which clearly indicated that DNA forms a helix. The other was that Max Perutz, a senior researcher at Cambridge, received a research report the King's group had submitted to their funders. Knowing of Watson's and Crick's interest in DNA, he showed them the report, which included the conclusions Franklin had drawn on the basis of her X-ray image, conclusions that specified all the critical dimensions of the DNA helix.

At just about this time, Watson and Crick found out that the famous U.S. chemist Linus Pauling was about to propose a transparently incorrect structure for DNA. With that, they decided they no longer needed to consider DNA the property of King's. Armed with Franklin's calculations against which to check possible models, they went into a frenzy of model building and, within about six weeks, came up with the now-famous double helix.

The first time the group at King's realized that Watson and Crick had gone back to working on DNA was when Wilkins received in the mail a copy of the note Watson and Crick were submitting to *Nature*. He promptly decided to write an accompanying note with his coworkers Stokes and Wilson, and so did Franklin with her coworker Gosling. Franklin framed her note as though her data confirmed the Watson-Crick structure, since she had no idea that those data had been in their hands while they puzzled out the structure. And she

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never realized it because five years later, in 1958, at thirty-seven years old, she died of cancer. She was dead when Watson, Crick, and Wilkins shared the Nobel Prize in 1962 and, of course, when Watson published *The Double Helix* in 1968.

In fact, Watson could never have published that book had Franklin been alive. In addition to the personal jabs and the book's crude sexism, until Watson wrote *The Double Helix* only he and Crick knew that they were in possession of Franklin's calculations while they constructed their model. Clearly, except for Franklin's closest friends, the book's readers continued to overlook that fact. But certainly Franklin would have noticed!

As it was, in 1953, when the three *Nature* papers appeared in print, Franklin was in the process of moving from King's to the much more collegial laboratory of J.D. Bernal at Birkbeck College, which is where she spent her few remaining years doing outstanding work on the structure of viruses.

So, again, how does gender come into this story? Gender no doubt had something to do with Franklin's unsatisfactory experience at King's. It probably also had something to do with the way Watson and Crick dealt with her data (though the misappropriation of data need not involve gender). It perhaps also was at least partly responsible for Franklin's lowly academic status, though she was still young and, at the time of her death, was in the midst of negotiating a move to a research position with secure, long-term funding at Cambridge University for herself and her principal collaborators at Birkbeck.[5]

Perhaps the most interesting aspect in terms of gender politics, however, is the way Watson used sexist stereotypes to obscure what should have become a scientific scandal. As Franklin's friend Anne Sayre recognized the moment she began to read *The Double Helix,* the creation of "Rosy," the humorless, dowdy, castrating female who, rather than help her dedicated male "superior" Wilkins, as she was meant to do, insists on imposing her own ideas, has the function of getting the reader not to notice that Watson and Crick had access to Franklin's unpublished data while they made their biology-shaking discovery.

If not for the fact that Franklin had long since died, Watson could not have written that story the way he did—or, more likely, at all. That he wrote it and that his breezy description of the way he and Crick came to the double helix succeeded in burying the unsavory details can surely be attributed to sexual politics. But, as I have argued before, gender was not an issue in Franklin's science any more than it was in McClintock's.

That McClintock's science was highly individual is clear. Indeed, some have argued that her scientific iconoclasm was not unrelated to the apparent comfort she took in her outsider status, which must have at least partly had to do with being a nontraditional woman. Also, Franklin's work was probably influenced by her exclusion from the King's/Cambridge fraternity, though she, too, did not let that stop her. Other women, in addition to McClintock and Franklin, have been at the forefront of genetics and molecular biology. The fact that news stories about this highly publicized field usually feature male scientists (and especially Watson) simply illustrates the gender politics of our culture.

All this is not to say that being a woman or a man is irrelevant to the way one does science. No doubt, our experiences affect what aspects of the world interest us and how we come to think about them, but ovaries or testes do not directly affect what science we do and how we do it.

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NOTES

This essay is based on a talk, given in February 2001, as part of a series of lectures organized by the Radcliffe Institute for Advanced Study on "Feminism and Science in Civil Society."

1. "Reading the Book of Life: White House Remarks on Decoding of the Genome," *New York Times* (June 27, 2000), 8.
2. My information about Barbara McClintock comes largely from Evelyn Fox Keller's McClintock biography (Keller 1983), from McClintock's Nobel Lecture, from conversations with some of her friends and colleagues, and from a conversation I had with her in the early 1980s.
3. I draw my information about Franklin from Brenda Maddox's recent biography *Rosalind Franklin: The Dark Lady of DNA* (2002); from Anne Sayre's *Rosalind Franklin and DNA* (1975), which Sayre wrote as a much-needed corrective to James D. Watson's *The Double Helix* (1968); from Watson's book itself; and from the historian of science Robert Olby's *The Path to the Double Helix* (1974). I have also consulted some of Franklin's own publications and articles colleagues and friends have written about her and have spoken with some of her friends, including Sayre.
4. Maddox 2002, 132–33.
5. Maddox 2002, 304–5.

REFERENCES

Culver, John C., and John Hyde. 2000. *American Dreamer: The Life and Times of Henry A. Wallace*. New York: W.W. Norton.

Hubbard, Ruth. 1990. *The Politics of Women's Biology*. New Brunswick, N.J.: Rutgers University Press.

Keller, Evelyn Fox. 1983. *A Feeling for the Organism: The Life and Work of Barbara McClintock*. San Francisco: W. H. Freeman.

Maddox, Brenda. 2002. *Rosalind Franklin: The Dark Lady of DNA*. New York: HarperCollins.

Olby, Robert. 1974. *The Path to the Double Helix*. London: Macmillan. Sayre, Anne. 1975. *Rosalind Franklin and DNA*. New York: Norton. Watson, James D. 1968. *The Double Helix*. New York: Atheneum.

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