Nobel Prize Women in Science

Their Lives, Struggles, and Momentous Discoveries

SECOND EDITION

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Barbara McClintock

June 16, 1902–September 2, 1992

GENETICIST

Nobel Prize in Physiology or Medicine 1983

WHEN A MISS BARBARA MCCLINTOCK of St. Louis announced her 1936 engagement in the newspapers, the chairman of the University of Missouri's botany department was horrified. Mistaking his new thirty-four-year-old assistant professor for the woman in the newspaper, he summoned Dr. Barbara McClintock to his office. Then he threatened her, "If you get married, you'll be fired."

The University of Missouri was "awful, awful, awful," McClintock complained years later. "The situation for women was unbelievable, it was so bad."

Eventually, she marched into the dean's office and asked pointblank whether she would ever get on the university's permanent staff. He shook his head no. In fact, he confided, when her mentor left she would probably be fired.

McClintock retorted that she was taking an immediate leave of absence without pay and that she would never return. Then she packed her Model A Ford with all her belongings and drove off, without a job or even any prospect of a job. Toying with the idea of becoming a weather forecaster, she finally decided that she never wanted a job of any kind again. It was years before she changed her mind.

McClintock was at the top of American science when she quit it. She had revolutionized maize genetics; one of her early experiments still ranks among the twentieth century's most important biological experiments. She was the vice president of the Genetics Society of America and was about to become its president. She had not yet done her Nobel Prize–winning project, but she had already received an honorary doctorate from a well-known university and would

Barbara McClintock at a press conference when her Nobel Prize was announced in October 1983.

Barbara McClintock at Cornell in 1929, with (from left to right) Charles Burnham, Marcus Rhoades, and Rollins Emerson. Kneeling, George Beadle.

Barbara McClintock at the far right of the first row in her first grade class, P.S. 139 in Brooklyn, N.Y. Her name is on the blackboard on the right with four other girls who made the honor roll.

Barbara McClintock at her parents' home in Brooklyn while she was attending Cornell University.

soon be elected to the National Academy of Sciences, then the nation's highest scientific honor.

But McClintock was a woman who wanted to do research full-time—and she was a feisty woman at that. So, despite friends in high places, she had no permanent job. Universities were the chief sponsors of scientific research in the United States, and they reserved their research positions for men. Thus, McClintock's decision to leave academia meant giving up the passion of her life—genetics.

McClintock had wanted to be free and independent all her life. Born in Hartford, Connecticut, on June 16, 1902, she was the youngest of the three daughters of Dr. Thomas Henry McClintock and the former Sara Handy. "My parents were wonderful," McClintock recalled. "I didn't belong to that family, but I'm glad I was in it. I was an odd member."

Dr. and Mrs. McClintock had hoped for a boy and had chosen his name: Benjamin. "My mother took the blame because it was her fault she didn't deliver the right thing," McClintock noted dryly. Mrs. McClintock and Barbara could not conceal their feelings from each other: Barbara knew that her mother was disappointed, and Mrs. McClintock knew that Barbara knew.

The two maintained a wary, arm's-length relationship. When Barbara was an infant, her mother often put her on a pillow on the floor and gave her a toy; Barbara played happily alone. Within four months of McClintock's birth, her parents decided that her name—Eleanor—was far too sweet and gentle. So, as McClintock enjoyed explaining, they changed Eleanor to Barbara because it sounded harsher.

When Barbara was two years old, the long-awaited boy was born. Barbara's mother was overwhelmed with caring for four small children. A Mayflower descendant and a Daughter of the American Revolution, she had lived in affluence until she defied her father to marry a homeopathic physician. To devote more time to her son and to relieve the strain between herself and Barbara, she periodically sent her daughter to stay with an aunt and uncle in rural Massachusetts. The uncle sold fish from a horse-drawn wagon, and Barbara enjoyed accompanying him on his rounds. From him, she learned to repair machinery and to love nature. Back home, she continued to rebuff her mother's hugs and kisses. "I didn't get approval, but I didn't get harsh treatment from her," McClintock admitted.

Barbara's father raised her as a boy, free from the conventional restraints placed on girls. When she was four years old, he gave her boxing gloves. "I didn't play with girls because they didn't play the way I did," McClintock said. "I liked athletics, ice skating, roller skating, and bicycling, just to throw a ball and enjoy the rhythm of pitch and catch; it has a very wonderful rhythm."

"My parents supported everything I wanted to do, even if it went against the mores of the women on the block. They wouldn't let anybody interfere," McClintock explained. When a neighbor tried to teach Barbara "womanly" things, Mrs. McClintock sternly told the housewife to mind her own affairs. When Barbara decided that her teacher was "emotionally ugly," her father let his daughter stay home from school.

Playing baseball with the boys on her block, however, did not make her one of the boys. Once her team members were so embarrassed to have a girl catcher that they refused to let her play an away game. Luckily, the other team did not care and invited her to join its side. On the way home, her neighborhood buddies accused her of being a traitor. "So you couldn't win," Barbara realized, concluding reasonably enough that "you had to be alone. You couldn't be in a society you didn't belong to. You were only *tolerated* by the boys.... I knew I couldn't win—and that's a dreadful feeling as a child." As a result, some of Barbara's happiest childhood moments were spent reading or just thinking about things.

Far from being unhappy, Barbara felt a great sense of freedom and opportunity as she grew up. When she was eight years old, the McClintocks moved to Flatbush, a rural neighborhood in Brooklyn, New York. With telephones and Morse code speeding the latest world news into the little community, "You felt as if you were branching out," McClintock said. "There was change. Everything was changing." Barbara was ready to take on the world. When she learned that the Statue of Liberty was 152 feet high, she announced with confidence, "That's no problem! I can shinny up!"

"When I reached adolescence, my mother panicked." Barbara wanted to attend Cornell University, but Mrs. McClintock thought that higher education would make her daughters "strange" and unmarriageable. She had convinced Barbara's older sister to reject a scholarship to Vassar College. "My father was an M.D. though. He sensed from the beginning that I would be going into graduate work. He didn't want me to be an M.D. He thought I would be treated so badly. Women got such nasty treatment. But he *warned* me; he didn't coerce me. He was very supportive with me. He had great faith I'd come out all right."

Unfortunately, when Barbara graduated from high school during World War I, Dr. McClintock was in France in the army medical corps. Acting on her own, Barbara's mother flatly vetoed her daughter's Cornell plans. Instead, Barbara found a job as an employment agency interviewer and spent her evenings and weekends studying frantically in the public library.

When her father returned from France in 1919, he supported Barbara immediately. Within days, she was enrolled in Cornell's College of Agriculture, where the tuition was free. McClintock remained grateful to her father for the rest of her life, emphasizing, "I just knew what I wanted to do. It was easy because it was so clear and because I had the support of my father, the complete support. My mother—if she could have done it without raising trouble—she'd have stopped it." After her children were grown, Mrs. McClintock took summer courses in art and writing at Cornell and finally understood what education had meant to Barbara. The revelation came too late; Barbara was the only McClintock child to attend college.

Cornell thrilled McClintock from beginning to end. Sometimes she was so immersed in her work that she could not remember her own name. A shade over five feet tall and wiry slim at ninety pounds, McClintock had a belly laugh like a child and loved jokes. Years later a photographer took so long setting up a picture of her in her laboratory that, just as he pressed the button, she popped a microscope cover over her head, and that is the picture he took. Sometimes her dreams seemed so funny that she woke up laughing. She was president of the freshmen women and played tenor banjo in a jazz group around town until she decided that late hours interfered with her work.

McClintock was a modern woman who smoked, bobbed her hair, and wore golf knickers—plus fours—for field work. Although she relished scandalizing Cornell with her haircut and pants, she may not have succeeded. Bobbed hair was de rigueur for fashionable young women from 1921 on, and knickers were standard wear for both men and women throughout the twenties, much like blue jeans today. Her choice of friends was *avant-garde* though. The social gap between Jews and Gentiles was enormous at Cornell, but most of the women in McClintock's circle were Jews. She studied Yiddish, and when her friends were not invited to join sororities, she rejected her own bids.

McClintock's vigor, intensity, and enthusiasm marked her as special, and by the time she graduated in 1923, she was already deep in graduate work. So were many other young American women. Between 30 and 40 percent of all graduate students in the United States during the 1920s were women. In fact, women accounted for approximately 12 percent of the science and engineering Ph.D.'s awarded in the United States—a proportion they would not reach again until the 1970s. Most studied biology, and almost one in five was a botanist. A goodly number of them specialized in genetics. Most of the rest were in zoology and psychology, which required little mathematics.

Getting a good science education, however, was much easier than getting a research job. Industry, government, and most colleges and universities refused to hire women. Most women scientists taught in women's colleges, where teaching loads were heavy and research time short. Only four percent of women scientists in the United States were employed by coeducational colleges and universities, and they were concentrated in home economics and physical education and in low-ranking positions as assistants, instructors, and assistant professors.

Genetics, however, was a wide-open field. McClintock and genetics were born and raised together. Gregor Mendel's studies of heredity in garden peas were rediscovered in 1900, just two years before McClintock's birth. By the 1920s, genetics was America's first world-class science and biology's most abstract specialty. When McClintock entered graduate school in 1923, many biologists still did not accept Mendelian genetics. The word *gene* had been coined but it had no clear definition or physical reality. It was just an abstract concept and controversial theory describing the way inherited traits are passed from one generation to another. As Thomas Hunt Morgan put it, geneticists assumed "there is something in the egg that is responsible for every detail of character that later develops out of the egg."

Chromosomes were known to carry hereditary elements inside the nucleus of the cell. Before a cell divides, its chromosomes double in number. Then half move to one end of the cell and half to the opposite end. As the cell stretches out, it divides into two halves, each the exact duplicate of the other and each containing the same amount of chromosomal matter. Geneticists also knew that each species has a characteristic number of chromosomes, ninety-four for goldfish, forty-six for human beings, ten for corn, and so on. The discovery that DNA is the chemical basis of genes was decades in the future.

As McClintock began her career, fruit flies and corn were vying as genetics' leading research tool. Morgan, who was studying fruit flies at Columbia University, had shown that many of the fly's physical traits are inherited as a package deal, like red hair and freckles in human beings. He correlated their visible characteristics—long and short wings, gray and black bodies, and so on—with changes in their chromosomes. Traits that are "linked" or inherited together correspond to genes residing on the same chromosome. In fact, the probability of those traits being inherited together increases the closer they are together on the chromosome. According to how often the traits were inherited together or separately, Morgan and his followers mapped the relative locations of the fruit fly's genes on its chromosomes.

Cornell geneticists worked with corn, however. Scientifically known as *Zea mays,* corn is an economically important crop. It was an ideal research tool, too. The variegated colors of its kernels functioned like a technicolor spread sheet of genetic data; genetic changes were as plain as the kernels on the cob. Furthermore, maize could be self-fertilized, inbred to produce tightly controlled extremes of genetic behavior. Each maize plant produces both male and female flowers: female flowers borne on the ear contain egg cells; male flowers produced in the tassel at the top of the stalk contain sperm cells, known as pollen.

When spring-planted corn reached sexual maturity in July, Cornell's geneticists began working from dawn to dark seven days a week to control the mating. Normally, wind wafts pollen from the tassel of one plant to the silk of another. There a pollen grain germinates, growing a long phallic tube down through a silk to carry the sperm to the egg at the bottom of the cob. Sperm and egg cells fuse, starting the next generation's seed, a kernel on the cob. Each fertilization produces one kernel.

To prevent random promiscuity, geneticists cover the ears and tassels with paper bags and transfer the pollen to the silk by hand. To self-fertilize a plant and inbreed exotic strains, they fertilize the silk of one plant with its own pollen.

Despite the attractions of maize as a research tool, Cornell's ge-

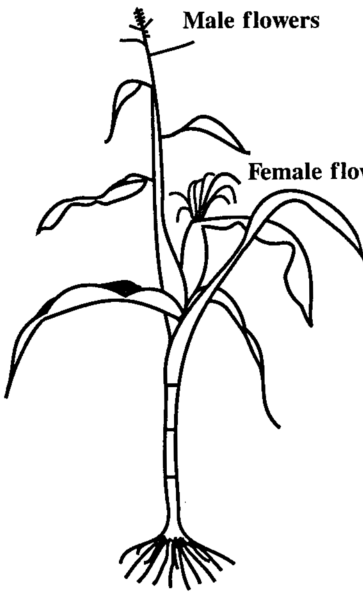

Fig 7.1. Corn plant.
A corn plant produces both male and female flowers.

neticists had not studied its chromosomes. They had no way to identify which chromosomes carried which inherited traits. Working in the botany department because Cornell's plant breeders refused to have women in their department, McClintock devised a system.

Using new staining techniques, she discovered that each of the ten chromosomes in maize could be distinguished under a microscope by their tiny knobs, extensions, and constrictions. Then she went on to identify each chromosome with a group of visible traits that are generally inherited together. By plotting the probability of these traits appearing together, she mapped the position of the genes on the chromosomes, just as Morgan had done with the fruit fly.

At first, none of her Cornell colleagues understood her project. Then Marcus Rhoades, who had earned his Ph.D. with Morgan, came to Cornell. Rhoades immediately realized how good McClintock was. "Hell," he said, "It was so damn obvious. She was something special." Immediately, he asked McClintock, "Can I join you?" Then Rhoades—her champion, interpreter, and soul mate for decades to come—explained the importance of McClintock's work to Cornell.

From then on, McClintock was the enthusiastic leader of a little band of professors and young men who already had their Ph.D.'s. "It was quite a remarkable thing that this woman who hadn't gotten her Ph.D. yet, or probably even her master's, had these postdocs trailing around after her, just lapping up the stimulation that she provided," recalled Ernest Abbe, later a University of Minnesota professor. "Lester G. Sharp was a prominent geneticist, but she was telling him what the answers were. It was very cute," Abbe laughed. McClintock even interviewed prospective graduate students for faculty members because she noticed so much more than anyone else. Later, during the late 1920s and early 1930s, Sharp propagated McClintock's research to the genetics community at large in his authoritative textbook *An Introduction to Cytology*. "His textbook was very important in getting her recognition early on," Abbe emphasized.

As she later recalled, McClintock and her little band "did very powerful work with chromosomes. It began to put cytogenetics, working with chromosomes, on the map in the late 1920s–early 1930s.... It was just a little group of young people. The older people couldn't join; they just didn't understand. The young people were the ones who really got the subject going because they worked intensely with each other. It was group activity because they discussed everything and were constantly thinking about what they could do to show this, that, or the other thing." Two members of the group, McClintock and George Beadle, would later win Nobel Prizes, Beadle for his "one gene, one enzyme" hypothesis. Following McClintock's lead, the Cornell maize group entered its golden age.

McClintock's enthusiasm and intensity swept her ahead of the others. To solve a problem, she worked in spurts, night and day for weeks. During a long drought, she saved her corn by laying water pipes up to her hilltop patch; standing in the hot sun, she watered her plants as tears of fatigue coursed down her cheeks. During a late-night flood, she replanted her washed-out corn by the light of car headlights. To Beadle's dismay, McClintock could interpret his experimental data faster than he. He complained to the department chair, the eminent geneticist Rollins A. Emerson. "Emerson told him that he should be grateful there was someone around who could explain it," McClintock commented dryly. "The fun was solving problems, like a game. It was entertaining."

McClintock earned her Ph.D. degree in 1927 at age twenty-five and stayed on as botany instructor. Over the next few years, she published nine papers on maize chromosomes. Rhoades considered each one a milestone in genetics and thought that she already deserved a Nobel Prize.

In the meantime, McClintock's mother still hoped her daughter would quit work and get married. "Every time I went home at vacation time, she'd try to persuade me to let somebody go up and get my things and not go back. It was a real fear on her part that I'd be a professor." But McClintock finally decided that she was too independent for close, emotional relationships. She had a faithful beau, her undergraduate chemistry instructor Arthur Sherburne, but she concluded that "marriage would have been a disaster. Men weren't strong enough...and I knew I was a dominant person. I *knew* they would want to lean against you.... They're not decisive. They may be very sweet and gentle, and I knew that I'd become very intolerant, that I'd make their lives miserable." Eventually, she told Sherburne "not to stay in touch with me."

Instead of marrying, she managed her life with "a fastidious spareness, an aesthetic of order and functionality," as her biographer Evelyn Fox Keller expressed it. Highly organized, McClintock arranged her data on cards, the cobs neatly tagged and cross-referenced to tables. She scheduled her time so that she could play a fast tennis game each day at five o'clock and still drive to her friend Dr. Esther Parker's cottage for supper before dark. Dr. Parker, a physician, had been an ambulance driver during World War I for the American Friends Service Committee. Her house was McClintock's home away from home.

Late in the summer of 1929, Harriet Creighton came to Cornell as a botany graduate student from Wellesley College. Within minutes of meeting, McClintock had organized Creighton's academic career, steering her to the right courses and advisers. Technically, instructors were too low-level to advise graduate students, but practically speaking, McClintock was in charge. McClintock gave Creighton her best research project as a thesis topic. In the late 1920s, there was circumstantial evidence, but no hard proof, that chromosomes carried and exchanged genetic information to produce new combinations of physical traits. McClintock wanted the proof.

She had bred a special strain of corn with an easily identifiable ninth chromosome that usually produced waxy, purple kernels. Under her microscope, she could see an elongated tip on one end of the ninth chromosome and a knob that readily absorbed stain at the other end. According to her mathematical analysis, the elongated tip was located near the region of the chromosome that determined whether the plant would produce waxy kernels. She suspected that the region near the knob was responsible for supplying purple pigment.

That spring, Creighton and McClintock planted waxy, purple kernels from the strain. In July, they fertilized the silks with pollen from a plant of the same strain whose kernels were exactly opposite types, that is, they were neither waxy nor purple.

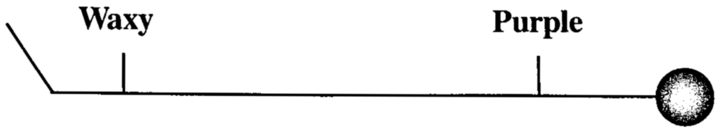

Fig 7.2. Crossing over.
Step One. Barbara McClintock specially bred corn to produce many waxy, purple kernels. The chromosome responsible had an elongated tip on one end and a knob at the other.

That fall, when McClintock and Creighton harvested the ears, some of them had the usual waxy, purple kernels and some kernels were the opposite, neither waxy nor purple. But some ears were different: they had inherited one trait—but not both. Thus, they were either waxy or purple, but not both. When McClintock and Creighton examined the chromosomes of these new kernels under their microscopes, they could see that their structure had changed markedly. Physical bits of the ninth chromosome—either the knob or the elongated tip—had actually exchanged places. Whereas every elongated chromosome in the parent plants had a knob, they now found a mix: elongated chromosomes without knobs and knobby chromosomes without tips.

McClintock and Creighton had proved that genes for physical traits are carried on the chromosomes. They had produced the first physical proof that exchanging chromosomal parts helps create the amazing variety of forms present in the biological universe.

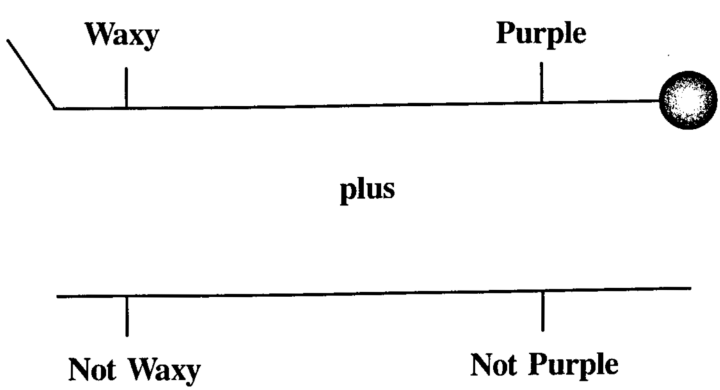

Fig 7.3. Crossing over.
Step Two. Barbara McClintock fertilized a plant with waxy, purple kernels using pollen from a plant with kernels that were neither waxy nor purple.

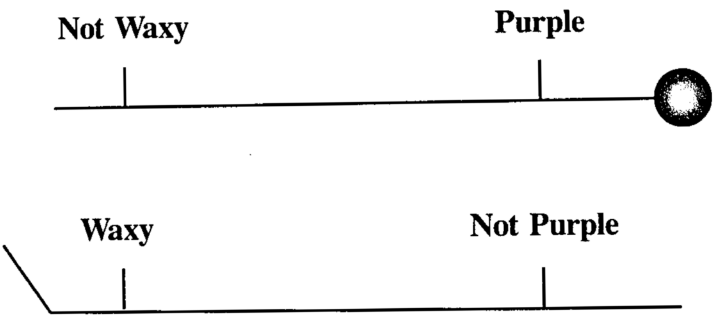

Fig 7.4. Crossing over.
Step Three. Some of the kernels produced had mixed characteristics, and McClintock could see through a microscope that bits of the responsible chromosome had exchanged places.

Normally, McClintock liked to publish enormous amounts of supporting data in her papers; today each one of her reports would make several separate articles. So she was waiting for a second crop before publishing the data. Luckily, Thomas Hunt Morgan visited Cornell and heard about the experiment. He urged them to publish immediately. In his excitement, he wrote a journal editor that an important article would arrive in two weeks. Thanks to Morgan, McClintock's article was published in August 1931. A few months later, a German geneticist, Curt Stern, published parallel data on fruit flies. Had McClintock waited for another crop, Stern would have been first.

The paper made McClintock's reputation. "Beyond any question, this is one of the truly great experiments of modern biology," Mordecai L. Gabriel and Seymour Fogel declared in their book *Great Experiments in Biology.* James A. Peters, editor of *Classic Papers in Genetics,* wrote, "This paper has been called a landmark in experimental genetics. It is more than that—it is a cornerstone." Then he warned, "It is not an easy paper to follow, for the items that require retention throughout the analysis are many and it is fatal to one's understanding to lose track of any of them. Mastery of this paper, however, can give one the strong feeling of being able to master almost anything else he might have to wrestle with in biology." James Shapiro, a University of Chicago microbiologist, told *New Scientist* magazine that the experiment should have won a Nobel Prize by itself.

When Marcus Rhoades asked McClintock how she learned so much from a microscope, she replied, "Well, you know, when I look at a cell, I get down in that cell and look around." Explaining the remark later, she said, "You're not conscious of anything else.... You are so absorbed that even small things get big.... Nothing else matters. You're noticing more and more things that most people couldn't see because they didn't go intently over each part, slowly but with great intensity.... It's the intensity of your absorption. I'm sure painters have the same thing happen right along."

"When you're doing something like this, the depth of your thinking is very penetrating. You can feel the intensity of it," she added. Many scientists believe that the thrill of discovery is unique to science. But McClintock contended that engineers, historians, and writers—"anyone who must think intensely and integrate vast amounts of information to solve a problem"—must feel it too. "The thrill comes from being intensely absorbed in the material."

By this time, McClintock knew she would have to leave Cornell. Emerson, the department chairman, was one of her greatest fans but he could not override the faculty, which was strongly opposed to giving permanent faculty positions to women.

For the next five years, from 1931 to 1936, McClintock crisscrossed the country in her beloved Model A Ford. At the top of her profession, she was at the bottom of the career ladder. While her friends worked frantically to find her a permanent job, she won a series of short-term fellowships to do research at various universities. The fellowships were highly prestigious stepping-stones for men on the way to professorships. For the few women who received them, however, they were stopgaps intended to tide them over. Nevertheless, McClintock was happy to use grants from the National Research Council, the Rockefeller Foundation, and the John Simon Guggenheim Memorial Foundation to work at Cornell, the California Institute of Technology, and the University of Missouri. As she confessed, "I couldn't wait to get to the laboratory in the morning, and I just hated sleeping."

Years later, McClintock explained in a speech to the American Association of University Women what those fellowships meant to her: "For the young person, fellowships are of the greatest importance. The freedom they allow for concentrated study and research cannot be duplicated by any other known method. They come at a time when one's energies are greatest and when one's courage and capacity to enter new fields and utilize new techniques are at their height."

Of all the advances in genetics during the 1920s, one of the greatest was the discovery that X rays enormously speed up the rate of mutations, fifteen-hundred-fold in fruit flies, for example. Instead of waiting for spontaneous mutations, scientists now could produce them at will. Lewis Stadler had a Rockefeller grant to build a genetics center at the University of Missouri to study X-ray-induced mutations. Stadler planted a field with kernels from X-ray-irradiated pollen and asked McClintock to figure out how the mutations had occurred.

Studying Stadler's fields, McClintock discovered that X rays actually break a plant's chromosomes and leave them with damaged, frayed ends. Then, she was surprised to see the chromosomes mend themselves: their frayed ends fuse with the frayed ends of other damaged chromosomes. She even found that some damaged chromosomes fuse together in rings. Often, two fragments fuse in such a way that the ends of the repaired chromosome pull in opposite directions during cell division and make the chromosome break *again.* As a chromosome breaks, repairs itself, and rebreaks, its ends lose more and more genetic material. She called the entire process the breakage-fusion-bridge cycle.

Many scientists would have been content to have discovered ring chromosomes, but McClintock was always interested in maize for the clues it offered to nature as a whole. She constantly tried to integrate her specialized studies with broad questions regarding heredity in other species. Thus, when she discovered ring chromosomes, she immediately asked how the frayed ends of the damaged chromosomes find each other and repair themselves. If the genetic process includes emergency repairs, it must be able to recognize and process information. As she pointed out, "The conclusion seems inescapable that cells are able to sense the presence in their nuclei of ruptured ends of chromosomes and then to activate a mechanism that will bring together and then unite these ends, one with another.... The ability of a cell to sense these broken ends, to direct them toward each other, and then to unite them so that the union of two DNA strands is correctly oriented is a particularly revealing example of the sensitivity of cells to all that is going on within them."

McClintock's insight came a good fifteen years before other scientists like Evelyn Witkin began work on DNA repair processes in the 1950s. McClintock was already poking holes in the standard picture of the chromosome as a rigid string of stable genes, arranged like pearls along a necklace chromosome. She was starting to think of the genetic process as responsive to signals, processing information, and receiving and interpreting signals from inside and outside the cell. She was looking at nature afresh, free of the conceptual constraints that most scientists work within, observed Witkin, who, until her retirement, was the Barbara McClintock Professor of Genetics at Rutgers University. Eventually, McClintock's unbiased approach would meet head-on with those who still believed in the stable chromosome.

When McClintock and her Model A Ford moved on to Caltech in 1931, she was the first woman postdoctoral fellow to work at the men's school. Although McClintock was paying her own way with her fellowship, Caltech's board of trustees had to give its approval before she could come. Her first day there, a colleague took her to lunch at Caltech's elegant faculty club. As she walked the length of the dining room to an empty table, everyone stopped eating and stared at the tiny thirty-year-old woman with her boyish figure, tousled hair, and practical clothes. To Warren Weaver of the Rockefeller Foundation, she seemed "more boy than girl."

Alarmed at the stares, McClintock demanded, "What's wrong with me?"

"Oh, everyone's heard about the trustees' meeting, and they're looking you over," her host replied cheerily.

Caltech's practice was to make visiting researchers with fellowships automatic members of the faculty club, but McClintock was never allowed in the building again. Nor did she visit any labs other than her own and that of Linus Pauling, the politically liberal chemist who later won two Nobel Prizes. Scientifically, however, her visits to Caltech were productive. Two summers later, she discovered the nucleolar organizer there. The nucleolar organizer region of the chromosome helps form the nucleolus, the cell's factory for synthesizing ribosomes. Although Caltech would not hire her full-time, she did not mind helping men who were hired there. When Charles Burnham, one of her old gang at Cornell, asked her what he should teach in his cytology techniques class at Caltech, she laid the course out for him. It was 1971 before Caltech hired its first woman professor, Olga Taussky Todd, a protégé of Emmy Noether.

Using her Guggenheim fellowship, McClintock visited Germany in 1933, the traumatic year in which Hitler became chancellor and fired the Jews from German universities. Science laboratories were in chaos, and her student residence was empty except for herself and a Chinese gentleman, who dined in silence. Loneliness, the politicizing of genetics, and the persecution of Jews appalled her. In December, she fled back to Cornell.

She returned at a bad time. The Depression was worsening and universities were cutting back. Few could afford a pure researcher. As Warren Weaver observed at Cornell, "The Dept. of Botany does not wish to reappoint her, chiefly because they realize that her interest is entirely in research and that she will leave Ithaca as soon as she can obtain suitable employment elsewhere; and partly because she is not entirely successful as a teacher of undergraduate work. The Botany Dept. obviously prefers a less gifted person who will be content to accept a large amount of routine duty."

Friends interceded with the Rockefeller Foundation, however, and arranged $1,800 a year for McClintock to spend two more years at Cornell. Morgan wrote the foundation that "she is highly specialized, her genius being restricted to the cytology of maize genetics, but she is definitely the best person in the world in this narrow category." The $1,800 was the largest income McClintock had ever earned.

Testifying on her behalf, Morgan also confided that "she is sore at the world because of her conviction that she would have a much freer scientific opportunity if she were a man." But McClintock denies that she was ever bitter. Realistic at recognizing prejudice, yes, but never bitter. "If you want to do something, you have to pay the price and never take it seriously. I never worried. I couldn't compete with men, so I didn't try."

When McClintock left Cornell for good, Cornell's golden age of maize genetics ended. After years of trying to get her a permanent position, friends had finally found her a job with Lewis Stadler at the University of Missouri starting in 1936. She would be only an assistant professor—far below the rank and pay of a man with comparable attainments—but it was her first faculty position. Her wandering years were over. Or so she thought.

For several years, McClintock worked in Columbia, Missouri, during the winter and raised her corn plants at Cornell during the summer. She grew only a few thousand plants each year, but they were highly selected, so she had no waste. "I wanted to know each plant well, so I carefully organized what I was going to need and why, and how many samples I needed in each case. I was highly organized...so that it was manageable. It had to be manageable. The recording was equally foolproof. I didn't want to have anything come up that seemed irrational and not right, and if I did it myself I would know, because my memory would tell me where to look...and how to find the error."

Helen Crouse, who had read McClintock's nucleolus paper as an undergraduate at Goucher College, visited Ithaca the summer of 1938. When she asked a timid young man how to find McClintock's lab, he replied, "Oh, well, she's up under the roof, and she doesn't want to see anybody." But he took Crouse up anyway. McClintock came to the door with a green, opaque visor over her eyes and a cigarette in a long filter holder in her hand. "What do you want?" she demanded. Crouse turned around, but her companion had vanished. After Crouse introduced herself, McClintock answered, "I heard you were coming. I was expecting you. Let's go home for lunch."

Home was Dr. Parker's house. When they got to the porch, McClintock sprayed their ankles well with flea repellent because Parker kept three large Irish setters. "We had a great lunch with Dr. Parker, who never knew whether her dress was right- or wrong-side out and didn't care. She was a wonderful vigorous sort of person. And I must have stayed a week," Crouse said. A few weeks later, McClintock invited Crouse to the Genetics Society meeting in Woods Hole, Massachusetts. "I didn't have fifty cents; but she said she'd pay all my expenses to go, that she'd like to have someone to go with her," Crouse said. "I had a glorious time."

After Crouse's sun-filled visits in Cornell and Woods Hole, she started graduate studies at the University of Missouri. There she was surprised to discover McClintock's position was not only clouded over but downright stormy. As a teacher, McClintock was intense, inspiring, and so full of ideas and fast talk that it was hard to keep up. She had insisted on proper equipment, and the university bought her new microscopes for a lab course. She installed them late one Friday night, putting a slide in each and delicately adjusting their lights and lenses to highlight the important feature in each demonstration. The next morning, the students gave a passing glance to the demonstrations on their way to pollinate their fields. McClintock was crushed. On the way to lunch with Crouse, she burst into tears—because the "corn boys" had skipped some of the slides. "She took it all so intensely," Crouse realized.

As usual, McClintock was way ahead of everyone else. Taking a quick look through Crouse's microscope one day, she discovered more than Crouse had found in her own material. Crouse had not adjusted her microscope's light and lens properly, and McClintock stalked out of the lab, slamming the door behind her. "You had to have a pretty sturdy constitution to survive," Crouse decided. McClintock was not about to waste her time on inept students, especially when jobs were scarce for even the best.

McClintock reigned over a spacious third-floor lab like "the Queen Bee. Everyone was scared of her," according to Crouse. Technically, Crouse was not McClintock's graduate student, so there was little tension between them. But McClintock's sharp tongue so terrified one of her official graduate students that he fled by the back greenhouse door whenever she entered the front. Another young man escaped to Berkeley.

Although the Rockefeller Foundation regarded Stadler and McClintock as the leaders of the genetics center at Missouri, university administrators thought that McClintock was a troublemaker and hoped she would leave. While everyone wore knickers for field research, McClintock wore pants *all* the time. She even let her students work in the lab past the eleven P.M. campus curfew. Then one Sunday she forgot her keys, climbed into her lab through a groundfloor window, and totally scandalized the locals. The culture shock was reciprocal. Crouse was appalled that agriculture students practiced their hog calling on campus. She was even more upset to learn that wildlife students hunted at night by blinding animals with their car headlights before they shot them.

Whatever the reason, McClintock was in a no-win situation. Excluded from faculty meetings, she was not part of the department. The authorities would not accommodate her research needs; she arranged for substitute lecturers each fall so that she could harvest her plants in Cornell, but the administration disapproved. At the same time, she could not get another job. She was expected to recommend male colleagues for the likes of Yale, Harvard, and elsewhere—"jobs that would have been just right for me, with my experience"—but she was never considered for those jobs herself.

"Missouri was very conventional, and there was no hope. And also, you get tired of being always the lowest one on the ladder," she said. Crouse thought she was "absolutely furious that no one paid her any attention."

McClintock had a wry sense of humor. When the University of Rochester gave her an honorary degree, for example, she called it "getting my shirt stuffed." But the bite of her wit grew sharper at Missouri. She and some of her students ate supper at Mrs. Pyles's boardinghouse, which was extensively decorated with religious objects. One day Mrs. Pyles rearranged her pictures, and McClintock joked about "creeping Jesus." Bible Belt Missouri was unamused. Crouse had a professor who could not remember her name, until a friend pointed out that Crouse rhymes with "mouse." McClintock laughed and took to calling Crouse "Miss Louse." But when Crouse retaliated and called McClintock "Babs," McClintock was irritated.

"I hadn't known she was such a tiger," Crouse conceded. But then, Crouse realized, women who succeeded in science were "the ones with the strength to abide in a world where they weren't wanted. They had to have stamina and brains and nerve and gall to survive. You're not going to find any weeping willow making it." As for McClintock, she claimed that when she was nervous or upset, she talked too much. Then she would blow off verbally and afterward not remember why. "I don't remember bad things."

McClintock was searching for ways out of the trap. On the way to lunch at Jack's Latch cafeteria, she often stopped in the post office to chat with the federal meteorologists. She was trying to teach them new forecasting methods, and as the University of Missouri became more intolerable, she toyed with the idea of becoming a weather forecaster, too. Finally, in 1941, she asked Missouri's dean if she would ever get promoted to a permanent position. "If Stadler leaves," the dean answered, "you'll probably be fired."

"I want a leave of absence—and I won't be back," McClintock snapped back.

"I thought you were going to say that" was his only response.

"There was no use staying there," McClintock thought. "Though it was good for the work, it was bad for the morale and too hard to take.... I didn't want a job. I just didn't want one anymore, and I decided I'd never go back to a university. That was out."

"I just quit the whole business," McClintock declared. She had no job, no means of support, no place to work, and no prospects.

She did not care about her career, but she did care about her corn. Writing Marcus Rhoades, then at Columbia University, she inquired where he grew his plants. "Cold Spring Harbor" was the reply.

Cold Spring Harbor had been founded on rural Long Island in 1890 as a summer center for the study of Darwin's evolution theory. In 1941, a handful of researchers worked there year-round, financed by the Carnegie Institution of Washington. In summertime, as many as sixty geneticists, including Harriet Creighton, Marcus Rhoades, Max Delbrück, and Salvador Luria, flocked there. Today, Cold Spring Harbor is a large, private research center for basic biological research that is financed by federal and private grants.

McClintock wangled an invitation to plant her corn at Cold Spring Harbor that summer. In the fall, she stayed on in a summer house until the weather turned cold and Marcus Rhoades lent her a spare room in his New York apartment. Finally, a friend, Milislav Demerec, became genetics director at the lab and offered her a temporary position.

Before she could get permanent status from the Carnegie Institution, she had to go to Washington, D.C., to be interviewed by its president, Vannevar Bush. Demerec nagged McClintock to go, but she kept postponing the trip. Finally, he ordered her to take a plane.

Not caring whether she was hired or fired, McClintock went to see Bush "with complete freedom from any nervousness. And, as a consequence, we had a very good time talking, because I simply didn't care what his opinion would be. It took three or four years before I realized that I could stay in a job, that this was more like no job at all. I had complete freedom.... I could do what I wanted to do, and there were no comments. It was simply perfect. You couldn't mention a better job. It was really no job at all."

The decade that had started so disastrously in Missouri ended gloriously at Cold Spring Harbor. It was Barbara McClintock's kind of place. Everyone wore blue jeans, worked seventy to eighty hours a week, and loved biological research. Teaching was not required, and there were no restrictions on research. Thanks to support from the Carnegie Institution, McClintock was free and independent of any changing administrations at Cold Spring Harbor.

McClintock settled into a routine undisturbed by passing decades. She alternated quiet winters analyzing data with busy summers filled with visitors and corn growing. For exercise, she ran, swam, and played tennis. Loaded with field guides, she took long nature walks, gathering black walnuts for brownies or checking the spots on ladybug beetles.

In addition to her cornfield, she had a spacious laboratory within a stone's throw of Long Island Sound. Seven days a week she worked from early morning until late evening on a long surface made of several desks pushed together. In a small side room she stored boxes of dried corncobs, each carefully tagged and cross-referenced so that when colleagues asked for seed of a particular strain she could explain its lineage. When she entertained friends, they met in the lab.

Across the road she kept an unheated, two-room pied-à-terre in a converted garage. Her real home was her lab, so she kept no telephone in the apartment; lab employees relayed night-time emergency messages. The apartment was as meticulously organized as her work. All the hangers in her closets faced the same direction and none touched another. Each sheet in her linen closet was enclosed in a plastic bag and tagged for size. "She was totally dedicated to efficiency," Crouse observed on visits.

McClintock enjoyed quality equipment. Although she ate most meals in the lab dining room, she bought a spectacular electric range with purple, green, and red lights and a complete set of copper-bottomed Revereware pots. She cared for her cars and, until she was eighty, changed their tires. She stripped and reassembled her microscopes. When she found a piece of machinery she liked—an electric fan or a tabletop vacuum cleaner to remove corn chaff—she often bought three of each.

Life at Cold Spring Harbor became both McClintock's strength and her weakness. Thanks to the support of the Carnegie Institution, she could work without interruption, even on unpopular projects. But isolation also left her without colleagues to popularize her research to the scientific community at large. For the first time in her career, McClintock would have to explain her own work.

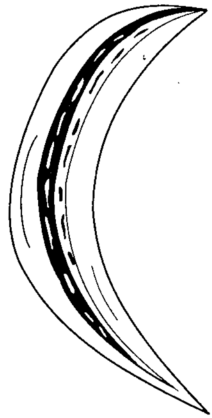

Fig 7.5. Breaking.
A plant with a long history of inbreeding and self-fertilization produced leaves with bizarrely colored twin splotches.

She began reaping the benefits of her international reputation during her early years at Cold Spring Harbor. In 1944, she was elected the first woman president of the Genetics Society of America. That same year, she was named to the prestigious National Academy of Sciences, which had admitted only two other women in eighty-one years. Surprisingly, when McClintock heard about the honor, she burst into bitter tears. Had she been a man, she said, she would have been delighted by the honor. But as a woman, she felt trapped. She wanted to be free to walk out on genetics if she ever got bored. Now she would never be able to leave it. "It was awful because of the responsibility to women," she explained. "I couldn't let them down." As she wrote a friend, "Jews, women, and Negroes are accustomed to discrimination and don't expect much. I am not a feminist, but I am always gratified when illogical barriers are broken—for Jews, women, Negroes, etc. It helps all of us."

World War II had put women to work in unprecedented numbers. In its wake, McClintock felt buoyant and self-confident enough in 1947 to declare, "Opportunities for women have never been greater than they are at the present time. There is no question in my mind that these opportunities will become increasingly better and at a very rapid rate. The restrictions in opportunity...are being steadily removed."

Challenging her maize plants with broken chromosome problems at Cold Spring Harbor, McClintock was fascinated by their response. During the winter of 1944–1945, she planted a greenhouse with self-pollinated kernels. Each was the heir to a long traumatic history of inbreeding and self-fertilization that had resulted in broken arms at the end of their ninth chromosome. When the seedlings sprouted, she was astounded. The leaves had broken out with quirky patches of curiously colored patterns. Moreover, the bizarre patches occurred in pairs. The leaf of one plant, for example, had two albino splotches of similar size side by side: one patch contained many fine green streaks while its complementary twin patch contained only a few green streaks. The results, McClintock thought, were startlingly conspicuous and totally unexpected. Generations of breaking, healing, and rebreaking the chromosomes had created a crisis in the plant's genetic system. Every time a cell divided, chromosomes broke and some genes were lost.

Because the complementary patches sat side by side, McClintock immediately realized that some bizarre event had struck the plant's cells as they had divided. "One cell had gained something that the other cell had lost," she told herself. "I set about to find out what it was." Eventually she realized that when a chromosome that has broken and re-fused breaks in two again, one of its parts may gain some genetic material while the other part may lose some.

McClintock was fascinated by everything around her, including her own mind, and she described its functions as objectively and precisely as she did her plants. Hence, she described her reaction to the strangely spotted plants by saying, "My mind went straight on it and worked quite hard on thinking about it, and it seemed all logical that we'd just missed the idea. So I had a pretty good feeling for it, and I had a pretty good feeling."

From the beginning, she knew she had discovered a basic genetic phenomenon, not just an event unique to maize. Long before scientists knew that genes are made of DNA, she asked the next question: how are genes controlled?

Comparing chromosomes of both the plants and their parents under her microscope, she deduced that parts of their chromosomes had changed positions. Six years of painstaking research later, she would be able to prove that a gene need not have a fixed position on a chromosome. She would conclude that genes are not stable pearls laid out along a chromosome string. Instead, they can move around and turn on and off at various times during a cell's development.

Eventually, McClintock described and characterized two new kinds of genetic elements: the first is a controlling element, a switch to turn on and off the genes that express physical characteristics like color or size. The second type is an activator that can make the on-and-off switch jump around from one part of a chromosome to another. Today, McClintock's discovery is called genetic transposition, and the moving chromosome parts are called transposable elements, transposons, or "jumping" genes.

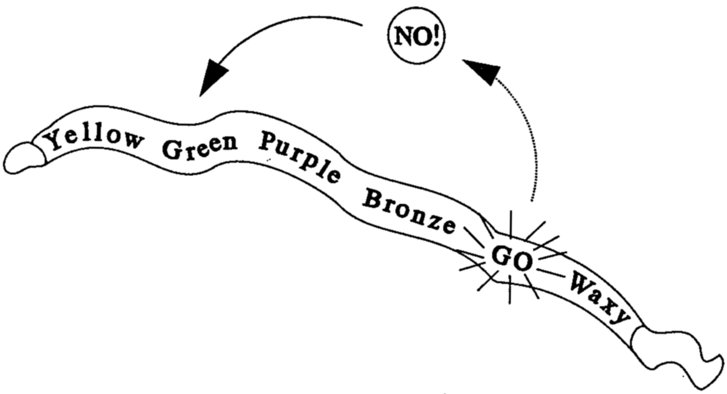

Fig 7.6. Jumping genes.
The genetic activator makes the switching gene move from one part of the chromosome to another to turn genes on and off.

Thus, an activator gene can cause the off-switch gene to jump next to a pigment gene and turn off the color. If the off-switch turns off the pigment gene early in a plant's development, a large region of the plant gets no pigment. If the pigment gene is turned off partway through development, parts of the plant are streaked or spotted with color. When the activator makes the off-switch turn back on, the pigment gene resumes work.

As a result, not only are genes unstable, but their mutation effects are too. Geneticists had assumed that a mutated gene was dead and could not be reactivated. But McClintock showed that environmental conditions could reverse some mutations and turn the genes back on. Her experiments provided a radically fluid picture of genetics, in contrast to the old view of stable mutations and immovable genes.

The implications of transposable elements fascinated McClintock even more than the discovery itself. She saw immediately that transposons are a fundamental phenomenon that helps explain the incredible variety of organisms produced by nature. In 1951 she noted, "The same mechanisms may well be responsible for the origins of many of the observed mutations in plants and animals." In a famous 1955 statement, McClintock prophesied that it "would be surprising indeed if controlling elements were not found in other organisms."

For six years, McClintock collected evidence, stuffing cards, tables, filing cabinets, and shelves with data. She was so excited that she often called Evelyn Witkin down from her lab to see the latest wonder. "It was a great thing to see. She was getting such really intense joy out of it," Witkin remembered. "She was so very sure of what she was seeing, and her evidence was absolutely convincing."

While McClintock was studying transposons, the world of genetics was changing. Chemists and physicists had joined the hunt for the physical basis of hereditary. Trained in Cold Spring Harbor summer schools, they applied the principles of physics to biological problems. In their excitement, these new molecular biologists ignored previous work by crystallographers, biochemists, bacterial experts, chemists, and geneticists, including McClintock. The molecular biologists' softball games became a symbol of their disregard. As the codiscoverer of DNA's structure James Watson told the story, the softball "all too often" wound up in McClintock's cornfield.

In an hour-long talk at a major Cold Spring Harbor symposium in 1951, McClintock summarized her findings before a group of leading scientists. The report was long, complicated, and dense with statistics and proofs. When she finished, there was dead silence, Witkin remembered. "It fell like a lead balloon," recalled Harriet Creighton. McClintock felt as if she had "collided with the stable chromosome."

Scientists scrambling to learn molecular biology wanted it simple; they did not like a genetic system that was fluid, moving, changing, and intricately regulated. They reacted with puzzlement, frustration, even hostility. "I don't want to hear a thing about what you're doing. It may be interesting, but I understand it's kind of mad," a biologist told her. A leading molecular biologist called her "just an old bag who'd been hanging around Cold Spring Harbor for years."

Understandably, McClintock was upset and disappointed. She summarized her work in a longer article published in 1953. Maize geneticists understood and accepted the data, but she wanted the science community at large to realize the wider significance of her work. Only three scientists outside her field, however, requested copies of the article. McClintock concluded that publishing was a waste of time. From then on, she wrote up her work in large notebooks, all tabulated, documented, and analyzed, and filed the notebooks on a shelf. She submitted only brief summaries of her work for publication in the annual reports of the Carnegie Institution of Washington—which only a few libraries purchased. "I don't know of any other scientist who would have had the discipline or self-confidence to do that," observed a friend of her later years, molecular biologist Bruce Alberts, then at the University of California at San Francisco. She stopped giving seminars at Cold Spring Harbor, too. Twenty years ahead of her time, McClintock went into "internal exile" at the lab, waiting for the scientific community to catch up with her.

McClintock so enjoyed ideas and thinking that the pain of being ignored soon slipped away. "I was startled when I found they didn't understand it, didn't take it seriously," she explained. "But it didn't bother me. I just knew I was right. People get the idea that your ego gets in the way a lot of time—ego in the sense of wanting returns. But you don't care about those returns. You have the enormous pleasure of working on it. The returns are not what you're after."

Being ignored gave McClintock more time to work and learn about other fields of biology. She was one of the few nonmolecular specialists who kept up with molecular biology. "Despite her age and her coming from a very specialized area of biology, she's on top of everything," as Alberts noted while McClintock was still alive. She devoured nonfiction—from biographies to monographs on offbeat biological subjects. Keeping an open mind about anything she could not understand, she viewed nature's oddities as windows onto fundamental phenomena in nature. She read up on stick insects, animal mimicry, plant galls, midwife toads, extrasensory perception, and the methods by which Tibetan Buddhists control their body temperature. She regularly scanned twenty biological journals of widely differing specialties; one year she spent a month reading all the literature on insect evolution.

Finding transposable elements everywhere in nature, McClintock photographed them for her own pleasure and for teaching her friends. Driving past a field of Queen Anne's lace, she would stop her car to walk through the field. Each flower of Queen Anne's lace consists of a cluster of florets, each formed from the progeny of a single cell. Normally, the white florets on the outside rim of the blossom open first and the center floret opens last to reveal a spot of pink, green, or purple pigment. But on closer examination, McClintock found blossoms where the colored floret was not confined to the center. The activator gene had turned the pigment gene on too soon. "It was the right pattern in the wrong place at the wrong time," she realized. Her face lighting up at the memory, she insisted, "You can see the pleasure. The pleasure is very great.... I love the springs, summers, and falls for all they can entertain you with."

As legend has it, McClintock was ignored because she was a woman and because scientists thought her "crazy" and "mad." But this is incorrect; most geneticists did not think she was crazy. McClintock had been famous and highly respected for years, Witkin emphasized. "Most geneticists didn't think she was crazy. It was just extremely difficult both to understand her experiments and to reconcile her conclusions on transposable elements with the prevailing belief in the stability of genes on the chromosomes." Asked about McClintock's work in 1951, the great geneticist Alfred H. Sturtevant replied, "I didn't understand one word she said, but if she says it is so, it must be so!"

Corn and fruit fly geneticists quickly incorporated her ideas into their graduate courses and conducted follow-up experiments. Her work was included during the 1950s and 1960s in authoritative books like James A. Peters's *Classic Papers in Genetics* (1959) and L. C. Dunn's influential *Short History of Genetics* (1965). Nobel Prize–winning biologist David Baltimore said, "I remember growing up as a student in the sixties; one of the things all of us tried to read were Barbara McClintock's papers in the Cold Spring Harbor symposia from the 1950s. But a lot of us gave up." Her results were complex and possibly irrelevant to molecular biology in other organisms.

Nevertheless, the fact remains that the scientific community at large ignored transposable elements for years. "Transposable elements are an example of how new ideas are accepted coldly by the scientific community," a much younger geneticist, James Shapiro, declared. "If she says something has happened, she has seen it in dozens and hundreds of cases. One reason that people don't read her papers is because the documentation is so dense. So first they said she's crazy; then they said it's peculiar to maize; then they said it's everywhere but has no significance; and then finally they woke up to its significance."

McClintock became discouraged enough to write Marcus Rhoades and Helen Crouse during the 1960s and 1970s to ask about jobs elsewhere. For two winters in the late 1950s, she even suspended her research entirely and trained Latin American cytologists to identify maize strains for the National Academy of Sciences. The adoption of modern seed was destroying indigenous species. Studying the geographic distribution of particular chromosomes, McClintock realized that they revealed ancient migration and trade routes. Corn seeds are so tightly enclosed in their husks that the plants cannot travel without people. Her insights led to a major study of ancient migrations based on the chromosomes of present-day maize plants. Thanks to her Latin American visits, McClintock mastered the Spanish language, which she kept up by watching Spanish television stations.

During the 1960s, when McClintock could have considered retirement, she collected awards from Cornell University, the National Academy of Sciences, and the National Science Foundation. None of these honors was given for her transposable element work. Nevertheless, a parade of pilgrims began to line up outside her door to learn from her. Many remained her friends. As always, to save time for activities she loved, she concentrated on her family and on close friends who interested her; she ignored casual acquaintances who bored her.

With friends, she was warm, charming, and open—far from the recluse that the media made her out to be. In fact, she studied human nature the way she studied corn—carefully, precisely, and with absorbing interest. An enthusiastic teacher one-on-one, she moved instinctively to the age and intellectual level of the person she was talking to, Guenter Albrecht-Buhler discovered. Speaking before McClintock's death he said, "She's far ahead of her time and tries not to startle you with it. I think it's a defense mechanism from the time when it was important for women not to be brighter than others.... She enjoys making things clearer. She's a passionate teacher. The passion of her existence is removing the fog...."

Often, the highlight of a visit with McClintock was a nature walk, during which she showed these professional biologists things they had never seen before. For example, "I'm *very* interested in galls. When an insect injects a chemical into a plant, the plant grows an elaborate, highly specific home that fits that particular kind of insect perfectly. And one grape plant may have many different types of galls. This tells me that organisms have all the necessary machinery, the potential, to make any kind of organism. All around you, there is so much pleasure, if you think about it."

Molecular biology finally caught up with McClintock during the late 1960s when James Shapiro and others discovered transposable elements in bacteria. Suddenly, molecular biologists started finding mobile genetic elements in all kinds of organisms, including people. Transposable elements are used in much of today's genetic engineering. They are responsible for many mutations and play an important role in evolution, inherited birth defects, resistance to antibiotics, and perhaps the incidence of cancer. The movement of genes and gene segments on chromosomes helps to explain how cells produce antibodies to combat a host of different viral and bacterial threats, how bacteria retaliate by acquiring immunities to human defenses, and how certain cancer cells develop. These genetic elements, cloned by recombinant DNA techniques, are used to carry desired genes to new hosts. Scientists today make mutations with transposable elements, instead of with chemicals and X rays. Watching the discoveries multiply, McClintock wrote a friend, "All the surprises...revealed recently give so much fun. I am thoroughly enjoying the stimulus they provide."

Contemporary scientists regard the inheritance process as a fluid information-processing system, much like a computer. "We now think of a dynamic storage system subject to constant monitoring, correction, and change by dedicated biochemical complexes," Shapiro explained in an article in *Genetica.* "We can now think about integrated, multigenic systems that can be turned on and off in a coordinated fashion according to the needs of the organism."

By the late 1970s, McClintock's honors were piling up in glorious profusion, this time for transposable elements. In 1980–1981, she received eight major awards, three of them in one week: the Albert Lasker Basic Medical Research Award, the $100,000 Wolf Prize in Medicine from the Wolf Foundation in Israel, and the MacArthur Foundation Fellowship, $60,000 a year tax-free for life. As McClintock noted, she made her money late in life.

Her reaction? "Rather upset. I'm not a person who likes to accumulate things," she explained, squirming miserably in her chair during a press conference. "I don't like publicity at all.... It's too much at once." Her biographer, Evelyn Fox Keller, conducted five interviews before McClintock broke off discussions. Keller wrote about McClintock as a brilliant recluse, a mystic whose "passion is for the individual, for the difference," not in broad fundamental issues common to all of biology. When *A Feeling for the Organism* was published in 1983, McClintock announced tersely, "I want nothing to do with a book about me. I do not like publicity." She never read the book. She even refused to autograph it for a colleague.

McClintock's friends reacted to the book in a variety of ways. But virtually all stressed that McClintock was neither a recluse nor a mystic. And they argued that she had always been interested in maize as a window on fundamental biological phenomena and not just as a study in and for itself. McClintock herself denied that she was a mystic, if being a mystic meant believing in something she knew little about. She said she did not dismiss phenomena that she did not understand, but she did not believe in them either. "You just don't know," she declared flatly.

Early in the morning of October 10, 1983, McClintock was listening to her apartment radio when she learned that she had been awarded the Nobel Prize for Physiology or Medicine. The Nobel Committee called her work "one of the two great discoveries of our times in genetics," the other being the structure of DNA. The prize was remarkable in many respects. Only once before had the Nobel Committee waited so long to award a researcher. She shared the award with no one; in the past several decades, all but a handful of the medical and physiology prizes have been shared by two or three winners. She was the seventh woman to receive a science Nobel. And finally, the prize, which is generally given for medical or animal biology, had never been awarded for studies of higher plants.

McClintock won only after it was clear that her work had implications beyond botany.

Overwhelmed at the news, McClintock took a walk in the institute woods, collecting black walnuts and her thoughts. "I knew I was going to be in for something," she explained. "I had to psych myself up. I had to think of the significance of it all; to react. I had to know what approach I would take."

Then she told the lab's administrative director, "I will do what I have to do." She issued a press release noting how unfair it seemed "to reward a person for having so much pleasure, over the years, asking the maize plant to solve specific problems and then watching its responses." Then she held a press conference, sitting on a stool in her carefully pressed dungarees and shirt, whispering courteously. At eighty-three, her brown hair was graying, her skin was sun-wrinkled, and her eyes were bright.

"I don't even know what the award brings in," she admitted.

"It's approximately $190,000," a reporter replied.

"Oh, it is," she whispered. The reporters laughed. Then, with characteristic objectivity, she spelled out how her mind was working. "No, I didn't know, and I'll just have to get to one side and think about this."

Thanking the Carnegie Institution of Washington, she said, "I don't think there could be a finer institution for allowing you to do what you want to do. Now, if I had been at some other place, I'm sure that I would have been fired for what I was doing, because nobody was accepting it, but the Carnegie Institution never once told me that I shouldn't be doing it. They never once said I should publish when I wasn't publishing."

Asked if she was bitter at having to wait so long for recognition, she took pains to explain, "No, no, no. You're having a good time. You don't need public recognition, and I mean this quite seriously. You don't need it. You need the respect of your colleagues.... When you know you're right, you don't care. You can't be hurt. You just know, sooner or later, it will come out in the wash, but you may have to wait some time. But...anybody who had had that evidence thrown at them with such abandon couldn't help but come to the conclusions I did about it."

Furthermore, she reiterated, "It's such a pleasure to carry out an experiment when you think of something—carry it out and watch it go—it's a great, great pleasure. It couldn't be nicer.... I just have been so interested in what I was doing, and it's been such a pleasure, such a deep pleasure, that I never thought of stopping.... I've had such a good time, I can't imagine having a better one.... I've had a very, very satisfying and interesting life."

The announcement that Barbara McClintock had won the Nobel Prize electrified the scientific community like no other recent prize—as much for the beauty of her motivation and dedication as for her scientific tour de force. When McClintock accepted her award from King Carl Gustaf in Stockholm, the ovation from the normally reserved and formal audience was so loud that it made the concert hall floor vibrate. Her solitary excellence, her quiet thoughtfulness, and her perseverance in the face of male prejudice and scientific rejection had captured their imaginations. Talking briefly with a Carnegie trustee afterward, McClintock parted with the words, "We women have to stick together."

The Nobel Prize with its competition, publicity, fawning hangers-on, and name-droppers was a burden for McClintock. "You put up with it," she remarked tersely. "It's a good thing that it happened so late in life," she told a friend. Otherwise, it would have interfered with her work. Overall, she said, "It's been very, very difficult on a person. It hasn't been easy or pleasant."

Despite the Nobel, McClintock continued with her research. In her eighties, she switched her exercise program from running to aerobic dancing. She ate a chocolate a day, traveled twice yearly to South America where much of today's maize research is conducted, and worked twelve-hour days. Her reading was as encyclopedic as ever. Her work table was covered with neat piles of reading material carefully underlined with a ruler with coded red, blue, and green ink. She read thoroughly and in an organized manner on multiple levels. Pencil notes filled the margins: "imp" beside each important point and "exp" for possible experiments. She spent much of her time helping molecular scientists analyze her material.

The tiger in McClintock mellowed, and there were fewer blasts of impatience. As McClintock neared ninety, she began to slow down to an eight- or nine-hour work day. Minor health problems irritated her. "I'm almost ninety," she told a caller. "And in my family ninety is the end, and I'm beginning to feel it."

She still passionately resisted anything that bored or distracted her from the main joys of life. As she protested, "I want to be free."

On September 2, 1992, Barbara McClintock died. At age ninety, she was free.

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