A Feeling for the Organism: The Life and Work of Barbara McClintock Study Guide

A Feeling for the Organism: The Life and Work of Barbara McClintock by Evelyn Fox Keller

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Plot Summary

A Feeling for the Organism is the story of the rise, marginalization and rediscovery of Barbara McClintock and her crucially important work in cytology and genetics, which ultimately led to a revolution in the understanding of the human genome. The author of the book, Evelyn Keller, is a geneticist herself who learned of McClintock's pivotal work as she passed through graduate school. She decided to explore the life of this unusual woman and scientist, telling McClintock's story in her own words and the words of those who knew her.

The book begins with a historical overview of the culture of the genetics community and related sciences from the 1920s through the 1980s, the vast stretch of time over which McClintock's work took place. We discover that early in the 1920s, genetics was a kind of standalone science. It was only rediscovered after Mendel in 1900, two years before McClintock was born. She entered Cornell in 1919, studying the chromosomes of the Drosophila fruit fly and corn, the only two species whose chromosomes were regularly studied at the time. During the 1920s and '30s the world of genetics was focused on the chromosome. At the time, genes were only theoretical entities postulated due to theory; they had not been directly observed. McClintock's work at the chromosomal level would reveal mechanisms of replication and informational exchange that could not be reduced to the gene or molecular level of nature. And when the revolution of molecular biology took place in the 1950s, her work was marginalized due to the widespread belief that all of life could be explained purely at the genetic level. In the '60s and '70s, it became clear that molecular biology had to postulate the process McClintock discovered decades before - transposition - in order to make sense of various observed phenomena. This discovery rocketed McClintock back to prominence and made it clear that McClintock was pivotal in helping the world understand that our genetic structures are not static entities, but dynamic systems in a state of equilibrium.

The story, however, does not merely focus on these scientific details. It is largely structured around McClintock's biography, her personality, her eccentricities, and her philosophies of science, creativity and life. McClintock was a notorious recluse and had trouble getting along with others. She often had a chip on her shoulder because of the great amount of sexism she had to struggle with early in her career. But she had an extraordinary ability to concentrate and an intuitive approach to science, which she called "getting a feel for the organism" that she believed led to her discoveries. McClintock believed that science does not merely proceed according to explicit, rational argumentation but includes an intuitive, subconscious element, an element she tapped into and many others have missed. The author is fascinated by this approach and the personality that embodied it and thus it becomes the focus of the book.

Chapter 1, A Historical Overview

Chapter 1, A Historical Overview Summary and Analysis

Genetics was a young science when Barbara McClintock became involved in it. Gregor Mendel's work had been rediscovered in 1900, two years before she was born. When McClintock enrolled at Cornell in 1919, genetics was only just beginning to come into its own, given the famed genetics studies of the genes of the fruit fly Drosophila and other works during the 1910s. McClintock earned her PhD in botany from Cornell's College of Agriculture, but the fruit fly related excitement had not yet spread there. Cornell's geneticists studied mostly corn, which matures slowly, whereas fruit flies generate new generations within ten days, allowing for detailed experimentation. McClintock came to believe that both fruit flies and corn could be studied at the genetic level by examining chromosomes at the microscopic level, not merely through breeding. In 1931, Harriet Creighton (McClintock's student) and McClintock published a paper cataloging the sizes and shapes of chromosomes and that sex cells exchanged chromosomes during fertilization. With this paper, McClintock firmly and permanently established the link between chromosomes and genetics. Throughout the 1930s, McClintock continued her work, rising to vice-president of the Genetics Society of America in 1939 and member of the National Academy of Sciences in 1944. In 1945, she became President of the Genetics Society.

1944 proved to be one of the most important in McClintock's career. That same year, a paper was published showing that DNA provided the information for inheritance. In the 1950s, molecular biology was born, putting genetics on a deep scientific footing. But many thought molecular biology solved the problem of life, making McClintock's work seem irrelevant. The method of molecular biology began to give genetics a mechanical feel in its explanations. But McClintock stepped away from the molecular level, continuing to study higher animals. In the 1960s, it became clear that molecular biologists had been too optimistic about explaining the structure of life, and new discoveries continued to complicate their field. One dogma that broke down was Crick's view that once genetic information passed was encoded in proteins, it could never get out. Information in DNA was never modified. McClintock's study of corn was one of the first steps in undermining this dogma, despite her work being published in a time where the dogma seemed to be strengthening. She believed that she had shown that genetic information was modified within maize genes. The stable loci of chromosomes moved, something she called transposition. But her colleagues thought this was a bizarre idea. She was marginalized in the 1960s, but in the early-1970s other scientists began to discover the same phenomenon. In the 1980s, McClintock continues to study transposition in Cold Spring Harbor, where she worked since 1941, but her research continues largely in seclusion. McClintock prefers things this way, but her new fame threatens her privacy. The next chapters will explain McClintock's perception of her unfolding research project; the reader will also hear from others involved in her work.

Chapter 2, The Capacity to Be Alone

Chapter 2, The Capacity to Be Alone Summary and Analysis

McClintock's work began at the Long Island Biological Laboratories in the town of Cold Spring Harbor, forty miles east of Manhattan. In the winters, scientists can study their alone. The author, Evelyn Keller, travelled there in 1978 to interview McClintock. As a graduate student at the same laboratory, Evelyn often saw McClintock, but never spoke with her. When Evelyn finally meets McClintock, she is star struck and surprised to see that McClintock more or less lived in the lab. Contrary to what Evelyn had heard, she found McClintock warm and approachable. They would speak for five hours, talking about women, science, her life, but she resisted being interviewed, unable to see how her life could be of interest because her life was so eccentric. McClintock lived most of her life alone, but seems totally fulfilled.

McClintock was born to be a pioneer, and was descended from mavericks herself. Her mother and father were high-spirited, energetic and eccentric people. McClintock had three siblings, Marjorie born in 1898, Mignon in 1900, and Malcolm Rider "Tom" in 1903. Barbara was born on June 16th, 1902. McClintock believed her 'capacity to be alone' began in infancy; her mother would leave her alone, and she would never mind. Barbara's sister Majorie said that her mother was under great stress when Barbara was born, in part due to the difficulties of Dr. McClintock, Barbara's father, founding his own medical practice. When Barbara went to school, she enjoyed herself immensely, often being away from family. She went to live with her aunt and uncle, and grew more distant from her mother. The family would later move to Brooklyn in 1908, and things somewhat improved, but Barbara still valued her solitary moments more than any others. She also displayed an intensity of study as a child, particularly in her piano lessons, an intensity her mother found unhealthy. Barbara continued to exhibit a strong individuality as she grew up. And in adolescence she became increasingly attracted to activities girls 'were not supposed to do.' She loved to know things.

During World War I, McClintock's father was called to war, and her mother had to work harder. Her older sisters were married off; Tom ran off to see in his teens. McClintock's mother was afraid that McClintock would become a college professor. Barbara new it would be difficult, but she was determined and had no trouble being different. Barbara's parents didn't support her interests in science but they respected her self-determination. In 1919, she made her way to Cornell; however, women had been going to Cornell for some time by the early-'20s. Cornell had often been open to women scientists, or women in any area. When her father returned from war, he supported her interests.

Cornell made Barbara extremely happy; her tuition was free, but money was still sometimes a problem. Nonetheless, Barbara pursued her studies. She was particularly drawn to spend time with Jewish girls, which was unusual during those days. Barbara somewhat blossomed socially during this time. She even dated somewhat. Her dates were usually artists, however; the attachments didn't last; her feelings were not strong enough. Despite this, she was not particularly focused on a career, just enjoying herself. Nonetheless, she found herself on the path towards becoming a professional scientist. She "just knew [she] had to go on." As a result, she registered as a graduate student in botany, focusing in cytology (work on chromosomes). McClintock grew up independent and remained that way for her entire life. She often felt detached from her body, which she thought 'was something you dragged around.' She preferred the world of ideas.

Chapter 3, Becoming a Scientist

Chapter 3, Becoming a Scientist Summary and Analysis

Most of McClintock's teachers supported her, despite the fact that she was female. They would often talk outside of class and left her free to study as she pleased. By her second year of graduate school, she knew what she wanted to study - chromosomes. She picked up some new techniques for chromosomal analysis for studying chromosomes under the microscope.

Evelyn explains that chromosomes are found in the nucleus of the cell; she describes the process of mitosis and meiosis. McClintock apparently found this fascinating. These processes of chromosomal reproduction made it clear by the 1920s that they both carried genes and had something to do with inheritance. One limitation of genetics at the time was that geneticists studying mostly fruit flies and corn. McClintock learned the shape, size and other traits of all ten corn chromosomes. She enabled a detailed cytogenetic analysis of corn which would have been impossible for any other organism.

In 1927, McClintock turned twenty-five and received her PhD. She wanted to stay at Cornell and decided to do her best to stay. But this was difficult because she wanted to combine the two types of geneticist - the breeder and the cytologist - into one. Many of her colleagues found this bizarre. But McClintock maintained that this combination was essential for understanding the physical aspect of inheritance. McClintock also opened up studying corn as seriously as studying fruit flies. A new graduate student helped her ideas to gain acceptance, a man named Marcus Rhoades. They began a lifelong friendship. She also came into contact with George Beatle, who would achieve fame along with McClintock and Rhoades. He shared the 1958 Nobel Prize in Physiology. All three were maize geneticists, studying with Rollins Emerson, the greatest maize geneticist of his day. While he was the most prominent, McClintock's work was opening up new areas of study, and many began to join their research group.

Evelyn also interviewed Rhodes and Beadle. They recognized how good McClintock was early on, better than they were, but they never resented her. However, many of her colleagues found her difficult because she couldn't tolerate 'fools'. And many didn't understand why her work was important. Beadle, however, lost track of McClintock's work early on, but always admired her enthusiasm. He only later on began to understand the importance of her work. McClintock was apparently very happy in this stage of her life, and also very productive, publishing nine papers between 1929 and 1931. While Rhodes and Beadle knew they had bright futures, McClintock's was less certain due to her sex. However, in 1929, a twenty-year-old Wellesley graduate student, Harriet Creighton, arrived and studied with McClintock; they both achieved fame through one of their publications. Evelyn interviewed her as well; she was delighted to talk about McClintock, who she greatly admired. McClintock advised her on many matters; they did not work well together only because they were women either. They spent most of their time learning and practicing the science, and Creighton often found McClintock hard to follow. They began to focus on the possibility of transposition in corn chromosomes, engaging in hard research together. The work they produced was very important; they had scooped a man named Curt Stern, who still later greatly admired them. Many of the young geneticists had a chance to meet at the Sixth International Congress of Genetics in Ithaca, New York in 1931. Many important papers were given in that year. A friend was able to inform her parents on a transatlantic steamship of her accomplishments; their concern with her oddity gave way to pride.

Chapter 4, A Career for Women

Chapter 4, A Career for Women Summary and Analysis

In 1931, McClintock decided it was time to leave Cornell; she simply could not receive a faculty appointment there due to her gender. She won a fellowship, however, and divided her time between the University of Missouri and Caltech, continuing the use Cornell as her home base. Ithaca was something of a second home to her. She collaborated with a variety of scientists during this time and during the 1930s she and others found that X-Rays could be used to study chromosomal structures. McClintock was able to place genes on chromosomes as a result. And she could also identify a process of transposition within the replication of 'ring' chromosomes.

McClintock would also make one of her great discoveries in this time, which began in 1931. She found a small body normally visible at the end of chromosome six. This small body 'held the key' to an important discovery. The body turned out to be a 'nucleolar organizer' which takes genetic material out of a replication process and brings it back after the process is complete to have it reused. McClintock discovered this process three decades before molecular biologists could give an explanation of it. She called the body the 'nucleolar organizer region' or NOR, which is required for a proper nucleolus to be formed. Even in the 80s, when A Feeling for the Organism was written, McClintock still believed that the ramifications of her discovery were not fully appreciated. She believes this is partly her fault, due to the article's poor writing. When her fellowship ended, she bought a Model A Ford, driving back and forth between her research labs, and still had no thought of a career. In 1933, however, she received a Guggenheim Fellowship to go to Germany, but this was a grim time to visit. McClintock was unprepared for what she discovered; she was alone and unable to understand the cruelty Hitler perpetrated on the Jewish people, who she had grown to love. She was depressed and returned to Cornell to pick up her work. But her experience in the Nazi regime had sent her reeling into a Depression. She had run out of fellowships, having no regular position, and refusing to take up a research position. McClintock had, what she mockingly called, a 'career for women.' T.H. Morgan secured her a fellowship from the Rockefeller Foundation, however; he found her bitter because she knew how much better her life would be had she been a man pursuing the same research. From 1934-35 she was on fellowship, but he lack of appointment continued. Some wanted to appoint her at Iowa State, but the director of the department would not appoint a woman.

McClintock, however, never wished she was a man; instead she wished to 'transcend gender altogether', and to some extent she succeeded in the minds of her colleagues. McClintock suffered because she refused to accept a 'woman's place' for her. One could not be a 'lady scientist' in those days. And she began to develop resentment at her stead in life. However, during this time she continued successful research, but in 1935, when her fellowship ended, the Golden Age of maize genetics at Cornell ended as well.

Chapter 5, 1936-1941: University of Missouri

Chapter 5, 1936-1941: University of Missouri Summary and Analysis

Lewis Stadler found McClintock a position at the University of Missouri in Columbia, pushing hard for her appointment. The Rockefeller Foundation was building a genetics center at Missouri and wanted McClintock as a colleague and the salary was a significant improvement. She was happy to accept. She wanted to blaze a trail. Her next research project involved studying how broken chromosomes 'reanneal' or come back together. Using X-Rays, she was able to split various chromosomes and see how they recombined. She began to report her work, displaying mutations new seen before, in 1938. For whatever reason, her research did not take off with her colleagues and she lost the position at Missouri. She was an outsider with the department. They did not even notify her of job inquiries concerning her. Evelyn found it hard to determine why she was not encouraged to stay. She took a leave of absence in June 1941 and never returned. Apparently, some of her behaviors made it difficult to keep her on; for instance, one day she locked herself out of her building; figuring that there was only one sensible thing to do, she scaled the wall and let herself in the window. Other similar events occurred as well. Being a woman and a maverick at once made her too much to handle. She was also much too blunt. When the dean found out that she was going to be initiated into the National Academy of Sciences, he tried to woo her back, but she rejected the offer, wanting to stay out of the university. Those years of rejection were difficult for her but gave her a sense of personal affirmation and strengthened her commitment to her work.

Chapter 6, Interlude: A Sketch of the Terrain

Chapter 6, Interlude: A Sketch of the Terrain Summary and Analysis

Genetics in many ways had a 'climactic' period during the 1940s. At this time, genes were considered mere theoretical entities, whereas chromosomes were the 'real' entities. This idea continued even into the sixties. Genetics was also not integrated well with biology or evolutionary sciences during that period; this marginalization helps the reader to understand McClintock's work, because she was simply not on the map of biological science. She did not hew close to any institutional school. The 1940s and '50s further marginalized her work. New research paradigms split developmental theory and gene transmission, leaving McClintock in a world of her own. Embryology and genetics were also not closely tied either. Genetics was an outsider vis-à-vis several related sciences that would only much later become integrated. For some time, to give a further example, Darwinian Theory was focused on small-scale evolutionary change and the role of selection in the production of new species. Many geneticists resisted the idea that natural selection could produce genuine genetic change, leading to further schism. However, population genetics eventually united the two fields, solving many of the relevant disagreements.

As a result of the new unity, the domain of genetics was extended. Classical genetics advanced, but philosophers and historians of science remain baffled by the methodological flux during these periods of time, and how McClintock, in particular, remained almost wholly unaffected by many of these sociological changes in the scientific community. She was, for instance, skeptical of population genetics; and she found the 'numerical' methods of population genetics unable to accurately represent radical new changes that so much of her work was built upon. And in fact, some held her concerns, particularly a German scientist, Goldschmidt, who left Germany during Hitler's rule. He dispensed with the idea of genes as separable developmental units, a view akin to McClintock's. Goldschmidt, however, was an iconoclast, whereas McClintock's heterodoxy had a fine subtlety to it. McClintock was unique in her great attention to detail and her tenacity of hunting down chromosomal modifications. Many saw her research as narrow, but she was in fact coming to an understanding of the whole organism. She thought that the study of genetics involved getting a "feeling for the organism," hence the title of the book. Evelyn then describes some of the details of how McClintock acquired this 'feeling.' She often proceeded intuitively, believing her mind a computer that ran much of its processing unconsciously; she would often search to check for mistakes in her work and could usually explain the few that occurred. In fact, she believed that she 'never made a mistake.' She felt like she 'understood' the phenotype of the plant - she integrated it at a deep level of her neurological processing.

She came to this through carrying out the most laborious parts of her work all on her own. She believed her insights all developed subconsciously.

Chapter 7, Cold Spring Harbor

Chapter 7, Cold Spring Harbor Summary and Analysis

When the United States entered WWII, McClintock was struggling being unemployed. She spent time with her good friend Marcus Rhodes. He was going to Cold Spring Harbor to plant corn to study and McClintock decided to follow him. It was easy to acquire an invitation for her. Milislav Demerec, a geneticist there, was a friend of McClintock's. Eventually Demerec became director of the genetics department at the Carnegie Institution of Washington at Cold Spring Harbor. He offered McClintock a one-year position and then tried to make the appointment permanent. She resisted losing her freedom, but eventually agreed. Evelyn does not know exactly why McClintock resisted such a wonderful offer. Perhaps she would have felt too protected.

The laboratories at Cold Spring Harbor were world class, exceeding many other prominent labs in its accomplishments. In winter, however, McClintock had few colleagues. She was the only maize geneticist there. But the benefits to her work and morale were significant. WWII hardly interrupted her research. Her work contributed to geneticists' understanding of inheritance, and in a close lab, some geneticists discovered the DNA carried hereditary characteristics. McClintock published regularly. In 1944, Beadle asks her to visit Stanford; he was working on a genetic analysis of a red mold on bread, Neurospora, and wanted McClintock's help. She was also elected to the National Academy of the Sciences at this time. With her election, she was not a dignitary and immediately acquired prominence. Yet her experience at Stanford shook her confidence in her abilities. Neurospora presented various challenges, particularly in its meiotic cycle. However, eventually she was able to reorient herself. She recounts an experience under some eucalyptus trees where she figured out how to solve the problem. In that moment, she described her insight as the evaporation of her self-consciousness. True knowing came from the loss of self. In this way, she could be free of the body, if even for a moment. At forty-two in 1944, McClintock was finally gaining deserved recognition.

Chapter 8, Transposition

Chapter 8, Transposition Summary and Analysis

McClintock continues her experimentation on plants at Cold Spring Harbor. She has developed some unusual mutations in plants with a high degree of genetic instability. The maize she grew had varied colors, each splotch of which represented division from a single mutated cell. The number of patches of a particular size indicated the frequency of mutation during the seed's development. The appearance of the corn allowed McClintock to generate a history of the seed's development. She found that if a plant exhibited a high rate of mutation early in its development, that it would maintain this rate of mutation throughout its life - this held for high and low levels of mutation. McClintock knew then that something was regulating the mutation rate. She was one of the first to discover this phenomenon, and became obsessed with understanding the mechanism of control. This led her to look for 'determination events' or events that would fix a regulatory practice within an organism, such as its rate of mutation. She worked over two years to understand the idea of a determination event. She had her first full glimpse of transposition after this period, finding that information was leaving cells and reentering it.

The next section describes the stages of her discovery, which include much technical jargon, and will not be useful to reproduce at length. Nonetheless, to put it briefly, the process of transposition has two stages - a chromosomal element is released and then inserted somewhat else. McClintock discovered how this process occurred through self-pollination of her maize plants. She was able to use genetic markers to map the relevant stages of development and tracks the transposition of genetic information. What she discovered was the different parts of a chromosome would respond different to the chromosomal elements attempting to insert themselves. In this way, the insertion process came to fix mutation rate and other regulatory elements in the life of the organism. She further discovered that the insert piece of the chromosome - Ac - had an internal feedback regulatory mechanism, which contained the ability to produce these determination events.

After six years, McClintock had reams of data, so much it was difficult to manage it all. She could prove that the process of transposition occurred, something nonsensical to geneticists of her day. Evelyn interviews one of the geneticists McClintock influenced, Evelyn Witkin; she recounted that McClintock amazed her and taught her many things. She made the process of study 'real.' While Witkin was impressed, others could not grasp what was going on and didn't pay much attention to her work. In 1950 she published her first article detailing her work on transposition but she had many presentations to give and not enough time to organize her findings properly for her colleagues who didn't share her methods.

Chapter 9, A Different Language

Chapter 9, A Different Language Summary and Analysis

In 1951, McClintock gave her talk at the Cold Harbor Symposium; no one understood her. Some complained and others snickered. She tried again, but she was stunned by her failure to explain herself to her colleagues. Even five years later, after the mechanisms she discovered proved to be far more complex than she initially thought, she had trouble explaining herself. Such rejection would be hard for any scholar to endure, but McClintock's conviction that she was right helped her through. She believes that in the long-run it was good for her; she had to readjust. Many were dismissive, but not everyone; she had a few die-hard supporters. These allies, however, could not protect her from overwhelming rejection. She had made a lot of progress towards being at the forefront of her field, but this set her back; and she began to withdraw into her work. McClintock reports to Evelyn that she was happy with the rejection, but at the time she considered leaving the lab. Evelyn does not understand why her colleagues so quickly rejected her work. Often in science resistance to new ideas is sociological, not logical. Scientific language is not as precise as many from the outside believe; and communication among scientists is often difficult given their different methods. This was another reason that McClintock struggled to gain recognition. Evelyn recounts other examples of such rejections, such as Freeman Dyson's difficulties gaining recognition. McClintock had built a whole new world that was hard for her colleagues to enter. As her inability to communicate continued, she retreated further from the profession; this lasted throughout most of the 1950s.

Chapter 10, Molecular Biology

Chapter 10, Molecular Biology Summary and Analysis

The 1950s brought about the revolution of molecular biology; but this produced a crisis in classical genetics, opening the door to another revolution. Many were concerned about the concept of a gene. Chromosomal studies flourished in the '40s, and many were convinced that genes were real, but the '50s brought the very concept into question. Geneticists did not even understand what a mutation was. During this conflict, McClintock's work on transposition was welcome. The '50s brought a re-examination of McClintock's work. Geneticists began to focus on bacterial DNA; the gene became less mysterious over time, understood as a genuine molecular object. Many sciences converged to bring this about - biochemistry, microbiology, X-ray crystallography and physics. This led to the creation of molecular biology, which began with enormous enthusiasm, with the prospect of 'explaining life' seemingly at its fingertips.

A student of Niels Bohr, Max Delbruck, organized a group that more or less created the science. This team's collaboration has been described as the 'romantic' period of molecular biology. Watson and Crick, the famous mappers of the DNA molecule, developed out of this group. The team was set up at Cold Spring Harbor and often interacted with McClintock. They held her in high-regard, but saw her as a member of a previous generation of research. The team aimed to explain all of life by explaining the physical basis of the gene. The idea of working to understand organisms from the chromosome-down, as McClintock did, seemed backward. But not all shared Delbruck and his team's prejudices. The author mentions of view of these individuals. It was during this time, in 1953 specifically, that Watson and Crick unlocked DNA. Due to this unlocking and the revolution it brought about, many believed the problems of classical genetics had been solved. However, this was a premature conclusion. McClintock's work showed that not all genetic effects were 'local' but instead interactions at more 'global' levels of nature had mechanisms that were not reducible to the more 'local' levels.

Chapter 11, Transposition Rediscovered

Chapter 11, Transposition Rediscovered Summary and Analysis

Molecular biology saved the gene, but only by bringing about an excessive reductionism within genetics. Many began to focus on the question of how genes copied themselves. No one yet knew how cells deriving from a single egg differentiated despite having the same DNA.

McClintock spent time in the 1950s listening to all of these new findings, but she maintained a certain distance. She denied the central dogma of that day, that DNA would explain everything. Her Ds-Ac system of regulation and control could not be fully explained at DNA's level of nature. She argued that the transposition she found in corn could be found elsewhere in nature. The geneticist community had reached an apparent consensus that excluded McClintock's ideas but this was not so in Russia where Lysenko aimed to resurrect Lamarckian evolutionary theory, a contrast to Darwin's view. During this time, the idea of 'Soviet' and 'bourgeois' sciences emerged. As a result, science often became politicized and competitive. In response, many in the West defended the autonomy of science from these political matters. A man named Jacques Monod, a biochemical geneticist, with Francois Jacob, revived transposition in 1960 in response to this competitive atmosphere. They proposed that genetic structured possessed the same regulatory mechanisms that McClintock had postulated but they also provided a molecular model. McClintock was overjoyed when she heard about their work; they had found transposition elsewhere in nature.

Her work would be revived and she wrote a paper on parallels between her work and the work of Monod and Jacob. She gave a seminar at Cold Spring Harbor trying to demonstrate the ubiquity of transposition in nature. Many continued to find the idea transposition heretical, nonetheless. She believed that her colleagues possessed 'tacit assumptions' that caused them to see transposition as an illogical mechanism. But young scientists lacked these assumptions and were fascinated by her work. McClintock saw that earlier molecular biologists had no feel for cell development and so could not understand the holistic process she was uncovering. Her 1960 seminar was her last attempt to explain herself; she believed that she had tried hard enough. She now encountered a new isolation due to molecular biology, for molecular biology had given biology a new kind of order which froze out her research. She briefly took a trip to Central and South American to collect data when the National Academy of the Sciences gave her the opportunity.

Ironically, transposition was revived through molecular biology, which mixed the conceptions of 'transduction' and 'transposition.' Transduction was a similar process to transposition, but the points of insertion for transduction were more clearly defined. As molecular biologists explored this phenomenon, they discovered versions of it that looked just like transposition. By the 1970s, this process was becoming increasingly understood.

The author gives a brief explanation here of the relevant similarities of the two processes. Apparently, genes would 'jump' chromosomes, as McClintock's work implied. Looking back on McClintock's work, some began to see that her understanding of the relevant mechanism was subtler than their own. The differences in focus between McClintock and these molecular biologists were still significant enough to prevent harmonization, however. A molecular biologist, Gerald Fink, developed a theory of a significantly similar process to McClintock's and James Shapiro, another molecular biologist, came to believe that McClintock's studies should form 'the essential background' for understanding the new data derived from DNA sequencing methods. McClintock became increasingly outspoken in the 1970s and in '78 presented a paper where she presented an even more radical proposal where she argued that control mechanisms may come in more varieties and perform more functions than she had previously imagined. These mechanisms would help to explain how evolution occurred. McClintock may have overstepped but her original research from the 1920s, '30s and '40s had been vindicated. Now all acknowledge what McClintock argued - that the genome 'is not a static entity, but a complex structure in a state of dynamic equilibrium." Transposition occurs in simple and complex organisms alike. And transposition can help to explain rapid evolution. It also opens up a whole new level of complexity into genetics. McClintock's vision of evolution would be neither random nor purposive but the result of the progress of regulative mechanisms at the genetic level.

Chapter 12, A Feeling for the Organism

Chapter 12, A Feeling for the Organism Summary and Analysis

McClintock's story illustrates the fallibility of science, and its reliance on ordinary, flawed humanity. But it shows that science can overcome the weaknesses of its members over time. It can adjust and adapt. Evelyn asks what enabled McClintock to break out of 'the box' before others did. She believed that you had to be patient, to "hear what the material has to say to you." You must proceed partly intuitively and acquire "a feeling for the organism." One must come to know an organism like one knows one's own home or body, intuitively, non-propositionally, intimately. Her method isolated her, but it nonetheless produced good science. McClintock not only embraced reason but processes partly beyond it. She is always pleased by scientific surprises. McClintock had a kind of 'reverence' for nature, a union with it that contrasts with the standard stereotype of science as a merely rational enterprise. Later in life she became fascinated by the ability of Buddhist monks to focus for extremely long periods of time and seems to have unintentionally acquired some of their abilities to focus. She began to teach herself these methods of control and came to the ability to, like Buddhist monks, control her blood flow and internal temperature. She could not share this view with others at the time, however. McClintock was one of the first to foresee that the development of science would partly overlap with some of the main questions of Eastern religion - about the relationship between spectators and actors in science, for instance. McClintock's success, the author argues, is that she draws on multiple methods of knowing, believing the ultimately unified. The author cites a psychoanalyst who believes that genius grows out of child development where children develop a "love affair with the world." McClintock had this very affair, which describes her youth.

The author ends by describing the changes of science towards busier and more collaborative models. Scientists rarely have the time any more to get a 'feel for the organism' and the pace of research seems to preclude McClintock's contemplative approach. However, some biologists still retain this ability. McClintock is excited about the future of science; she believes that scientists will come to integrate these methods of knowing, becoming less rigid, and is optimistic about the direction of her field.

Characters

Barbara McClintock

Barbara McClintock was born in 1902, the third of four children. From an early age, she possessed a preference for being alone and the extraordinary ability to not only not mind solitude but actively enjoy it. Partly due to her mother's emotional distance and partly due to her personality, McClintock did not naturally gravitate to the activities and interests of girls in her time and area. Instead, she became interested in science and plants. Despite her mother and father's concerns, she went to Cornell and studied botany, focusing on cytology, the study of chromosomes. She eventually went to graduate school to study chromosomes as her career. McClintock was a notoriously eccentric woman, preferring to keep to herself, often overly blunt in conversation and unable to pick up on social cues. She was also often discriminated against due to her gender, despite her incredible skills as a scientist. McClintock's solitary work on the chromosomes of maize led to her discovery of the process of transposition, or the dynamic exchange of information between the chromosomes of a single cell. This discovery was ridiculed and misunderstood by many of her colleagues in the 1940s and '50s, which pushed her further into her natural state of seclusion. In the 1970s, however, dominant research paradigms forced scientists to return to her work, vindicating her life's research.

The Cornell Group

McClintock lived near Cornell in Ithaca, New York, so when she decided to go to college, Cornell was a natural choice. She loved her time as an undergraduate, and studied botany, becoming increasingly interested in cytology, the study of chromosomes. By the time she went to graduate school, her talents became increasingly obvious to all those around her. During the period of her research other graduate students and faculty came to Cornell interested in similar subjects. Some studied Drosophila fruit flies, while many, perhaps most, studied the chromosomes of corn, as McClintock did. This was a 'golden age' of chromosomal studies for genetics, laying the groundwork for much important research in the future. The Cornell group included many important figures, including two of her fellow graduate students who she knew her whole life, Marcus Rhoades and George Beadle. Their faculty advisor was the most renowned cytologist of his time, Rollins Emerson. Later, many others joined them, including Charles Burnham, Harold Perry, H.W. Lee and another woman, Harriet Creighton, who published an article with McClintock that still ranks among the classical papers in genetics. From 1928 to 1935 the Cornell Group worked together fabulously, but eventually Rhoads, Beadle and many others graduated, going off to wonderful careers. McClintock wanted to stay, and had trouble finding a job elsewhere due to her gender. She often looked back on her days with the Cornell Group fondly.

McClintock's Parents

McClintock's parents were initially skeptical of her interest in going to school and studying cytology, but eventually became proud of her accomplishments. McClintock attributes her ability to be solitary partly to her mother's emotional distance.

Evelyn Witkin

One of McClintock's early allies and defenders, who stood up for her research on transposition when it was ridiculed.

Evelyn Keller

The author of the book, she attempts to interview McClintock, but McClintock refuses. Instead, they have several conversations that allow Keller to gather the information she needed for her book.

George Beadle

One of McClintock's colleagues at Cornell and lifelong friends, Beadle was a fellow maize cytologist who defended her work and helped her to find a position later on.

Marcus Rhoades

Another maize cytologist who helped McClintock integrate socially into the Cornell Group.

Rollins Emerson

Chairman of the Plant Breeding Department at Cornell and Dean of the Graduate School. He also led the Cornell Group.

Rockefeller Foundation

The Rockefeller Foundation supported McClintock's work when no one else would, providing her crucial fellowships when she could not find permanent positions.

Harriet Creigton

A graduate student at Cornell who studied with McClintock, the two women authored one of the most important papers in genetics together.

Molecular Biologists

Molecular biology became the dominant research paradigm in genetics in the 1950s, which led to the marginalization of McClintock's work. However, the research paradigm was later forced to reinvent McClintock's ideas.

Max Delbruck

A student of Niels Bohr and one of the founders of molecular biology who led a research group at another facility in Cold Springs Harbor.

Objects/Places

Cold Spring Harbor, New York

The location of the Long Island Biological Laboratories, where McClintock worked for forty years. Cold Springs had long, cold winters during which McClintock would do much of her solitary research.

Long Island Biological Laboratories

The laboratory facilities where McClintock worked for forty years.

Ithaca, New York

The location of Cornell University, where McClintock went to college and graduate school.

Cornell University

The college where McClintock went to college and graduate school.

The University of Missouri in Columbia

A university in Missouri where McClintock had a professorship for several years before having to leave due to various tensions with the department.

CalTech

The Pasadena technical institute where McClintock held a visiting research positions for several years.

McClintock's Laboratory

Located in Cold Spring Harbor within the Long Island Biological Laboratories, McClintock spent years largely alone doing her research there. She more or less lived out of her lab.

Maize

Corn, and an early object of study for cytologists. It had a relatively simple ten chromosome genome that was amenable to study.

Drosophila

A fruit fly that produced new generations in ten days, making it an ideal object of study for geneticists.

Transposition

The process of the exchange of information between chromosomes, a process thought impossible for decades until McClintock showed that it occurred in maize. She would later be proven correct when she suggested that transposition was ubiquitous across nature.

Chromosomes

The container of all genes within a cell and McClintock's main structure of study.

Genes

The building blocks of chromosomes. During McClintock's time they had not been directly observed and were only considered 'theoretical' entities that may not turn out to exist.

Molecular Biology

Introduced as a science through the combination of others, it took the genetics world by storm in the 1950s, marginalizing McClintock's less reductionist approach.

DNA

Deoxyribonucleic Acid, and the chemical structure that contains all the information for producing life. DNA was the focus of most of genetic research for some time, but McClintock's work focused on a higher level of nature at the chromosomal level, and on processes that could not be reduced to the level of DNA.

Ds-Ac System

The system of information replication that distinguished transposition from other biological processes, and the system entirely constructed by McClintock.

Determination Event

An event in cell replication where various rates of mutation, growth, etc. are fixed for the life of the cell.

Themes

The Capacity to Be Alone

Barbara McClintock was a loner from birth, at least this was what she believed. Her sister Majorie reported that as a child, when McClintock was left alone, she never raised a fuss. And as she grew up, she found little need to interact with others. This was partly due to her mother's emotional distance due to stress but partly due to her natural constitution. McClintock notes that her happiest times in life were when she was alone. As she became a scientist, she worked alone. While she enjoyed sharing her work with her colleagues, she found most people difficult to interact with and had poor social skills. Her lab at Cold Springs Harbor was her lab alone and almost all of her important work was done alone; many researchers have their students do their heavy lifting, taking on the most laborious aspects of research. However, McClintock did all of this work herself.

McClintock's capacity to be alone helped her to survive rejection by her colleagues on at least two occasions. Early in the 1930s, when she graduated from graduate school, she had trouble finding work due to her gender. While she had some male allies, many deans refused to hire a female scientist. As a result, McClintock had to subsist entirely on the generosity of foundations which offered her fellowships until she garnered an appointment at the University of Missouri in Columbia. However, she lost this job as well, partly (not wholly) due to her gender. Her capacity to be alone also helped her to survive her colleagues wide rejection of her work on transposition and their inability to understand her work. She gradually retreated into her research, and became hardened to rejection. Without this capacity to be alone, her experiences of rejection may have crushed her spirits.

A Feeling for the Organism

The title of the book is "A Feeling for the Organism," so one might guess that this idea is the main theme of the story. "A Feeling for the Organism" is McClintock's phrase, which describes, in a nutshell, her unique methodology and philosophy of science. To explain it, we can contrast it with a more familiar approach, that of molecular biology. Molecular biology originated partly among physicists. It was a reductive science which attempted to explain higher-order phenomena like chromosomal changes, through interactions at lower levels of nature, particular at the level of genes. The paradigm proceeded very mechanically and was thought to lead straightforwardly from discovery to discovery. It became a systematic research program and was team-oriented.

McClintock's methodology was, in contrast, holistic. She rejected the view that all important phenomena at the chromosomal level could be explained at the level of the gene. She also believed that the process of discovery could not be routinized or converted into a decision procedure, a connect-the-dots manual of discovery. She believed that most of her insights were deliverances of her subconscious and that they arose from getting a 'feel for the organism.' McClintock studied her specimens with great intensity, coming to know all the ins and out of the entire creature. She did all of the laborious cataloging work herself and came to know her specimens so well that she knew them like the rooms in her own home. Thus, she had a kind of intuitive grasp of her organism and believed that out of this intuitive grasp or 'feel' she could generate holistic explanations, avoid being trapped by scientific dogma, and avoid mechanical modes of thought and retaining an art and mystery to the scientific enterprise.

Scientific Dogma

McClintock was always a very independent thinker. Coupled with her capacity to be alone, her penchant for intense research and intuitive approaches to her science led her to develop unique methods of research. Chapter 9, "A Different Language," focuses in detail on this difficulty. McClintock's research on transposition was ahead of its time, but when she presented her work in the 1940s, a new research paradigm within genetics was developing. Molecular biology was in its infancy but many believed that within a decade or so the central problems of genetics would be solved. Their approach was very reductionist. They focused on the gene itself, not on the chromosome, largely believing that they could reduce all important genetic phenomena to this level of nature. McClintock was, however, one of the few dissenters, believing that a more holistic approach to genetics and cytology was appropriate. When she presented her work, many not only could not understand her, but actively questioned her mental stability. McClintock believed that her colleagues' minds were frozen with presuppositions that made it difficult if not impossible for them to comprehend her findings. The grip of scientific dogma was responsible for her long marginalization. Luckily, the dogma broke down in the 1970s, and she received due recognition. Keller later argues that McClintock's unique approach prevented her from many of the negative effects of group think and dogma.

Style

Perspective

The author of A Feeling for the Organism is Evelyn Fox Keller, a female geneticist whose career began two generations after McClintock's. She wrote the book in the early-1980s, when McClintock was finally earning her well-deserved reputation as a revolutionary within the field of genetics due to her early and prescient work on the process of transposition. When Keller was in graduate school, McClintock was something of a legend. Her reclusiveness and solitary research method only added to her status. When Keller decided to write the book, she was unsure whether she would be able to convince McClintock to give her an interview. And sure enough, McClintock refused. However, she did speak to Keller for over five hours, much to Keller's delight. Keller describes being star struck when she met McClintock.

Keller's perspective, therefore, is one of deep admiration for the uniqueness, perseverance and genius of Barbara McClintock. As a scientist, she was fascinated by McClintock's ability to do her research by herself, pay great attention to detail and continually produce creative work. She was also fascinated by McClintock's struggle as an early female scientist, something the feminist movement had made easier during Keller's education. Finally, she was impressed by McClintock's pluralistic scientific method, which focused not merely on rational precision but also on letting one's intuitive sense for the organism generate creative insights. The title of the book 'a feel for the organism' describes McClintock's philosophy of science - coupling intuition and reason, something Keller deeply admires. Thus, if there is any bias in Keller's perspective, it is in favor of McClintock, but she is often even handed, and points out McClintock's eccentricities and difficulties interacting with others when it is appropriate.

Tone

The tone of A Feel for the Organism is multi-faceted. It has three general styles, narrative, informative, and philosophical. The first style, narrative, comprises most of the book. Keller speaks in the ordinary tone of a narrator of a powerful story. She writes with compelling prose, engaging in detailed character development, all the while interweaving genuine scientific information at appropriate points. Keller's tone is light, accurate and simultaneously optimistic and somber, depending on the stage of McClintock's life that she is describing. The next tone is informative. From time to time, Keller believes that it is important to explain in detail McClintock's scientific accomplishments. Thus, she spends pages and pages explaining not only the phenomenon of chromosomal transposition but McClintock's particular theory of informational exchange which explained how transposition worked. She sometimes warns her reader that she will use technical jargon, and indeed the tone shifts in line with the introduction of technical terms. The tone has a dryer feel, despite the fact that Keller makes a sincere effort to make McClintock's findings compelling; this somewhat comes through in her prose. Keller's tone indicates somewhat intent on communicating complex concepts to her reader, while maintaining a close connection to the scientific details. Finally, the tone is sometimes philosophical. This arises in particular towards the end of the book, but elsewhere in the book as well. She is often very impressed with McClintock's unique scientific methodology and the philosophy of science and discovery that accompanies it. In these parts of the book her tone is one of excitement, energy, admiration and fascination; it is clear that Keller largely (if not entirely) agrees with McClintock's approach.

Structure

The structure of A Feeling for the Organism is a mixture between a work of popular science and a biography; it interweaves scientific ideas with narrative story-telling and analysis about a single individual, Barbara McClintock. The book contains twelve chapters. The first is a historical overview not only of McClintock's life but of the scientific developments during her time. The chapter, however, focuses mostly on scientific developments so that the reader has a sense of the important developments within genetics during McClintock's life. In many ways, this chapter gives the scientific set for McClintock's life and work. Chapter 2 covers McClintock's childhood, analyzing her unique "capacity to be alone." Chapter 3 discusses her college years, her experience in graduate school and her decision to become a scientist, while Chapter 4 describes her difficulties landing a professorship due to her gender. Chapter 5 discusses her difficulties at the University of Missouri, her first academic appointment. These chapters cover many of the book's main themes, but Chapter 6 is an interlude, which covers various scientific information and developments relevant to the book. In Chapter 7, we are introduced to the lab in which McClintock spent forty years of her life and Chapter 8 explains her discovery of transposition, not only discussing the personal aspects, but giving a detailed scientific explanation of the phenomenon of transposition and McClintock's explanation for it; Chapter 9 discusses the rejection of McClintock's work by her colleagues. Chapter 10 details how the new molecular biology paradigm further marginalized her work, while Chapter 11 explains how she was ultimately vindicated by the same paradigm that marginalized her. In Chapter 12, the narrative is largely complete and the reader is introduced to McClintock's unique philosophy of science and philosophy of life.

Quotes

"With this work, which had been referred to as 'one of the truly great experiments of modern biology,' the chromosomal basis of genetics was finally, and incontrovertibly, secured." (4)

"I don't like publicity at all. All I want to do is retire to a quiet place in the laboratory." (13)

"Barbs was simply Barbs." (24)

"Whatever the consequences, I had to go in that direction." (28)

"He understood what I was trying to do when the others did not." (47)

"I don't know why, but I was sure it had the key." (68)

"Everything she did would turn into something big!" (80)

"It was her conviction that the closer her focus, the greater her attention to individual detail, to the unique characteristics of a single plant, of a single kernel, of a single chromosome, the more she could learn about the general principles by which the maize plant as a whole was organized, the better her 'feeling for the organism'." (101)

"It was both thoughtful and generous of you to write me as you did concerning the National Academy. I must admit I was stunned. 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." (114)

"The idea of control was not even thought of." (122)

"McClintock was right to be apprehensive. Her talk at the Cold Spring Harbor Symposium that summer was met with stony silence. With one or two exceptions, no one understood." (139)

"By God, that woman is either crazy or a genius." (142)

"But science and art alike make tougher demands on intersubjectivity: both are crucially dependent on internal visions, committed to conveying what the everyday eye cannot see." (150)

"It is expected that such a basic mechanism of control of gene action will be operative in all organisms." (177)

"The beauty of science is that, notwithstanding all our tacit assumptions, these surprises can get through." (183)

"The genome is not a static entity, but a complex structure in a state of dynamic equilibrium." (193)

"These are two equally dangerous extremes - to shut reason out, and to let nothing else in." (197)

Topics for Discussion

How do you think McClintock developed her capacity to be alone?

To what extent do you believe that sexism prevented McClintock from gaining more prominence? To what extent do you believe her poor social skills prevented her from doing the same?

How do McClintock's methodology of science differ from that of molecular biology?

List and explain two main factors that led to the marginalization of McClintock's work.

Explain the process of transposition and its significance in the history of genetics.

How we McClintock's work eventually rediscovered?

What do McClintock mean when she speaks of "A Feeling for the Organism?" Explain this in detail and give your own assessment of her view.