

Barbara McClintock's Transposon Experiments in Maize (1931-1951)

Barbara McClintock conducted experiments on corn (*Zea mays*) in the United States in the mid-twentieth century to study the structure and function of the chromosomes in the cells. McClintock researched how genes combined in corn and proposed mechanisms for how those interactions are regulated. McClintock received the Nobel Prize in Physiology or Medicine in 1983, the first woman to win the prize without sharing it. McClintock won the award for her introduction of the concept of transposons, also called jumping genes. McClintock conceptualized some genetic material as not static in structure and order, but as subject to re-arrangement and may be altered during development.

McClintock began her research into transposons by examining how genes combined in a process called crossing over. Prior to McClintock's research, scientists had studied crossing-over. Crossing over is the process by which homologous chromosomes align side by side during meiosis and physically exchange genetic material. In 1909 Frans Alfons Janssens in Belgium described the phenomenon of chromosomal re-arrangement as chiasmotypie, a process in which chromosomes arrange in the shape of an X, the center of which became called the chiasma after chi in the Greek alphabet. Then in 1916 Thomas Hunt Morgan working on genetics in his fly lab at Columbia University in New York City, New York, hypothesized that chromosomes go through a crossing-over process during development. In 1931, McClintock built on that research using corn plants to provide a description of the physical basis of chromosomal crossing-over.

McClintock began her work on genetic recombination and transposition with doctoral student Harriet Baldwin Creighton in 1931 at Cornell's College of Agriculture in Ithaca, New York. Together they examined maize chromosomes and published their results in the 1931 paper "A Correlation of Cytological and Genetical Crossing-Over in *Zea Mays*." In that paper, they described the physical basis for the exchange of genetic material between homologous chromosomes, called crossing-over. McClintock continued her research solo, and in 1944 at Cold Spring Harbor Laboratory in Laurel Hollow, New York, she began her experiments to test the existence of some genetic elements on the chromosome that are capable of movement. She labeled those elements as transposable elements or transposons, and she published on the findings in 1950's "The Origin and Behavior of Mutable Loci in Maize". The discovery of transposons provided a causal explanation for unusual phenotypic features in maize after breeding and helped to identify the mobile elements on chromosomes.

McClintock's study of transposable elements on chromosomes attempted to clarify Rollins Adams Emerson's 1910 research about the occurrence of purple or brown spots on white kernels in maize, called colorless. Emerson had hypothesized that the spots occurred due to unstable mutations on chromosomes. Yet, Emerson had not provide evidence for that explanation of the phenomenon. McClintock instead suggested that the occurrence of unexpected purple- and brown-colored kernels was due to genetic transposition.

To test that claim, McClintock bred maize plants to vary in the color of the kernels. McClintock took cell samples from the corn, dyed the samples, looked at them under the microscope by using staining techniques to enhance the contrast in the microscopic images, and observed the chromosomes. McClintock bred maize plants carrying chromosomes that resulted in a recessive brown phenotype (called *bz*) with maize plants with chromosomes that coded for a dominant white phenotype (called colorless or *C'*). Given normal theories of inheritance, the offspring should have been maize plants displaying white kernels, but instead those kernels were white with some brown spots. McClintock attributed the unexpected variation to a chromosomal breakage in which a chromosome lost one

allele. McClintock called that phenomenon dissociation, which occurred at a chromosomal locus she called Ds. She hypothesized that the kernels carrying three alleles must have lost both their dominant colorless allele and their dominant purple allele due to breakage, and the losses resulted in the occurrence of some recessive brown kernels among the expected colorless kernels. McClintock called the chromosomal site where that breakage supposedly occurred, dissociation (Ds). Additionally, she argued that such a breakage took place due to a factor called activator (Ac). The amount of brown spots on the creamy background depended on the timing of breakage during development.

When McClintock presented her findings at a Cold Spring Harbor Symposium in 1951, the audience at the conference considered her results to be obscure and difficult to understand. McClintock's research did not fit with then current theories of genetic phenomena, as genetic material was conceived as a static entity before the 1960s. Thus, scientists paid little attention to McClintock's experiments before François Jacob and Jacques Monod described similar phenomena in bacteria in 1960.

Decades later in 1983, McClintock received the Nobel Prize in Physiology or Medicine for her experiments detailing the evidence for transposons. McClintock's work did not receive widespread recognition among scientists until the 1980s, which provoked a debate. According to Evelyn Fox Keller, an historian of biology, McClintock was awarded the Nobel Prize more than thirty years after the publication of her results due to gender inequalities in science. Contrary to Fox Keller's interpretation, historian of science Nathaniel Comfort argued that McClintock had to wait so long before receiving scientific acclaim because some aspects of genetics were still unclear until the early 1980s, and therefore McClintock's research required a more comprehensive framework to validate her results.

In the 1950s, McClintock could not test her hypothesis about controlling elements, like Ds and Ac, because the structure of the DNA molecule had not yet been discovered at the time of her research, so it was difficult to locate those elements. Additionally, the genetic techniques at the time when McClintock conducted her research could not identify or intervene in specific parts of the genome. The existence of transposable elements was finally tested in the early 1980s, when Nina Fedoroff and her team isolated and cloned the elements.

McClintock's experiments on maize plants highlighted the instability of genetic material and stated the existence of transposable elements in the genome.

Sources

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