

LEARNING ACTIVITY

Observing Your World: Barbara McClintock



AMERICAN
PHILOSOPHICAL
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OBSERVING YOUR WORLD: BARBARA MCCLINTOCK

Introduction

Pair this learning activity with the short educational film
“Barbara McClintock: Scientific Persistence Pays Off.”

Learn about Barbara McClintock and what can be
gained by looking at the whole picture of something
rather than just one part.

LEARNING ACTIVITY CONTENTS

INQUIRY DESIGN
MODEL 4

INSTRUCTIONS/TASKS 5

MCCLINTOCK
LEVELS OF CORN
ACTIVITY CARDS 6

ORIGINAL
DOCUMENTS 13

TRANSCRIPTION
OF ORIGINAL
DOCUMENT 19

HISTORICAL
CONTEXT 21

IMAGE CREDITS 23

Inquiry Design Model (IDM)

Compelling question:
How does knowing many parts of something lead to scientific discovery?

PA State Aligned System standards:

See reverse.

Staging the Question: How does learning about the different parts of something help us understand the whole? What is something that students own and they know how it fully works? Why is that important?

Supporting question #1:	Supporting question #2:	Supporting question #3:
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What did McClintock discover through her research with corn?	What can we learn from investigating things on both small and large scales?	How does persistence in science help in the discovery of new things?
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Formative performance task:	Formative performance task:	Formative performance task:
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<ul style="list-style-type: none"> Watch “Barbara McClintock: Scientific Persistence Pays Off.” Read McClintock levels of corn activity cards. Discuss how they connect to one another. 	<ul style="list-style-type: none"> Place the cards from smallest scale to largest. Discuss why you put them in that order and how the different levels relate to one another. 	<ul style="list-style-type: none"> Read the draft of McClintock’s 1989 Nobel Prize speech. Discuss ways in which McClintock persisted.
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Featured sources:	Featured sources:	Featured sources:
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McClintock Levels of Corn Activity Cards	McClintock Levels of Corn Activity Cards	Notes for speech at Nobel Prize banquet, Barbara McClintock, 1983.
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Summative performance task	Construct an argument that addresses the compelling question, “How does knowing many parts of something lead to scientific discovery?” using specific claims and relevant evidence from sources.
	Extension: Reflect about something you know from its smallest part to its largest one. How does that help you understand it overall?

PA State Aligned System standards:

5.6-8CC: Students who demonstrate understanding can consider historical factors that have contributed to the development of technologies & human progress. **CC.3.5.6-8.B:** Determine the central ideas or conclusions of a text; provide an accurate summary of the text distinct from prior knowledge or opinions. **CC.3.5.6-8.F:** Analyze the author's purpose in providing an explanation, describing a procedure or discussing an experiment in a text. **CC.8.5.6-8.B:** Determine the central ideas or information of a primary or secondary source, provide an accurate summary of the source distinct from prior knowledge of opinions. **CC.8.5.6-8.D:** Determine the meaning of words & phrases as they are used in a text, including vocabulary specific to domains related to history/social studies. **CC.3.5.9-10.A:** Cite specific textual evidence to support analysis and technical texts, attending to precise details of explanations or descriptions. **CC.3.5.9-10.B:** Determine the central ideas or conclusions of a text; trace the text's explanation or depiction of a complex process, phenomenon or concept; provide an accurate summary of the text. **CC.3.5.9-10.D:** Determine the meaning of symbols, key terms, and other domain-specific words and phrases as they are used in a specific scientific or technical context relevant to grades 9-10 texts and topics. **CC.8.5.9-10.A:** Cite Specific textual evidence to support the analysis of primary and secondary sources, attending to such features as the date and origin of the information. **3.1.9-12.P:** Students who demonstrate understanding can ask questions to clarify relationships about the role of DNA & chromosomes in coding the instructions for characteristic traits passed from parents to offspring.



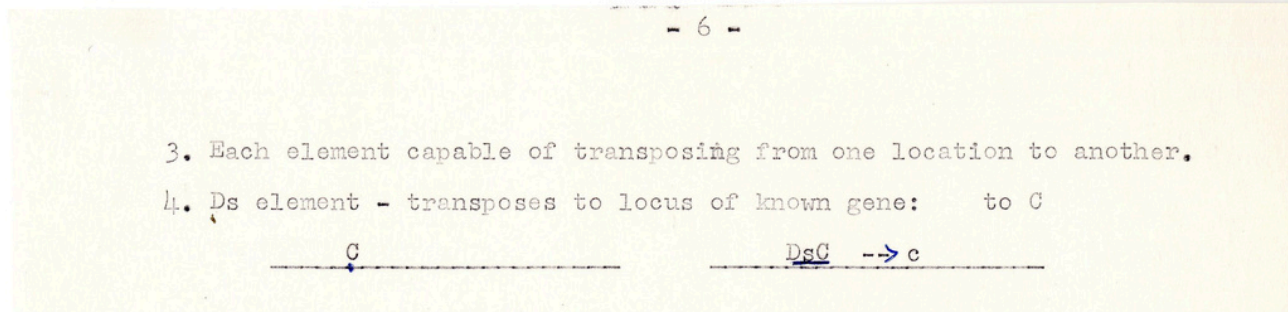
INSTRUCTIONS

- What did McClintock discover through her research with corn?
 - Watch the educational film “Barbara McClintock: Scientific Persistence Pays Off.”
 - Read through the McClintock levels of corn cards. If printing these, make sure to print them double-sided.
 - Discuss how they connect to one another.
- What can we learn from investigating things on both small and large scales?
 - Place the cards from smallest scale to largest.
 - Discuss why you put them in that order and how the different levels relate to one another.
- How does persistence in science help in the discovery of new things?
 - Read the draft of McClintock’s 1989 Nobel Prize speech.
 - Discuss ways in which McClintock said she moved forward even though many colleagues didn’t agree with her findings.
- Reflect together on the question: How does knowing many parts of something lead to scientific discovery?



<https://youtu.be/v4k-4B3q1GA?si=nrNsMGUjhmZySZ77>

Activity Cards



“Chromosomal Elements Controlling Gene Action -
Lecture at Harvard University”, Barbara McClintock,
February 14, 1958. APS. Gift of the estate of Barbara
McClintock, 1992.

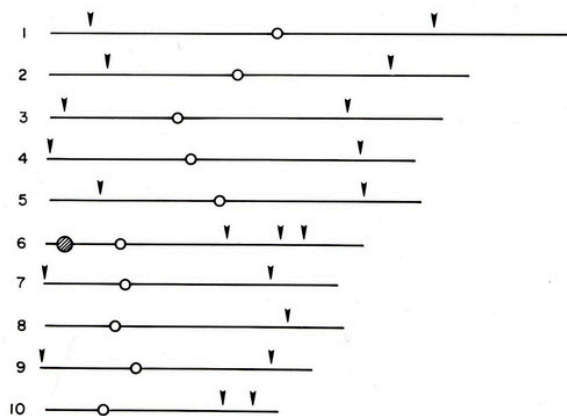


FIGURE 1. Diagram illustrating the relative size of the ten chromosomes of the maize complement. Open circles locate the centromeres. The large hatched circle in chromosome 6 represents the nucleolus organizer. Arrowheads point to locations within each chromosome where knobs may be formed.

“Mechanisms That Rapidly Reorganize the Genome”, Barbara McClintock, 1978. APS. Gift of the estate of Barbara McClintock, 1992.

Transposons

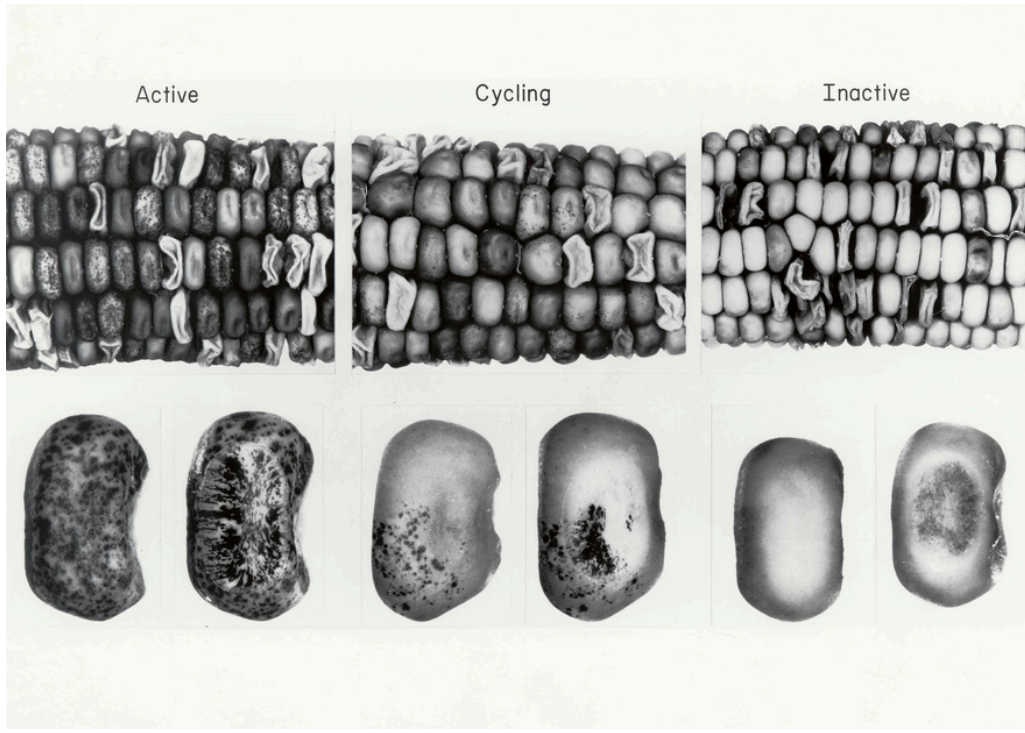
Barbara McClintock worked her whole life to understand the genetics of maize (can also be called corn). She discovered that DNA sequences are not always fixed on chromosomes. They can “jump” to different positions on a chromosome and can change how an organism functions or looks. These “jumping genes” are often referred to as transposons.

Chromosomes

Corn has 10 pairs of chromosomes. As part of her work, McClintock studied corn chromosomes under the microscope.

Chromosomes are described as thread-like strands that contain genes. Genes determine physical traits, like the color of corn kernel.

Activity Cards



Inactivation of the Maize Transposable Element Activator (Ac) is associated with its DNA Modification, P S Chomet, S Wessler, S L Dellaporta, 1983. APS. Gift of the estate of Barbara McClintock, 1992.



McClintock, Barbara, March 26, 1947. APS. Gift of the estate of Barbara McClintock, 1992.

Kernel

Corn was an ideal experimental organism for genetics since researchers could link genetic changes (mutations) in chromosomes to specific colors and patterns in the kernels.

Corn

Individual corn kernels on a single ear of corn can have different genetic make-up.

Activity Cards



*Barbara McClintock in cornfield,
postcard. APS. Gift of the estate of
Barbara McClintock, 1992.*

Answer Sheet:

From smallest to largest: Transposons,
Chromosomes, Kernel, Corn, Corn Field

Corn Field

McClintock had a research cornfield in Cold Spring Harbor, New York. Here, she investigated her corn population. She covered the tassels of corn with brown paper lunch bags to control the population.

Answer Sheet:

From smallest to largest: Transposons, Chromosomes, Kernel, Corn, Corn Field

ORIGINAL DOCUMENT

"Chromosomal Elements Controlling Gene Action - Lecture at Harvard University",
Barbara McClintock, February 14, 1958. APS. Gift of the estate of Barbara
McClintock, 1992.

- 6 -

3. Each element capable of transposing from one location to another.
4. Ds element - transposes to locus of known gene: to C

$\frac{C}{\quad} \quad \quad \quad \frac{DsC}{\quad} \rightarrow c$

C -- color in aleurone; c, no color in aleurone.

5. Action of DsC -- will be recessive c as long as Ac not in nucleus.
6. When Ac in nucleus, changes occur to Ds element -- some allow C to again act -- but, alleles formed.

Example: $\frac{(X^C)}{c} / c (DsC)$ no Ac x $c (XC) / c (XC)$; 1 Ac

✓ One half of progeny will get Ac! low half = w Ac = all colorless.

one of these -- XC = not change in gene action as + does not respond to Ac.
othe half of these DsC -- mutations will occur. as do respond to Ac.

Thus: one quarter of kernels on ear will show mutations. Slide 1

Mutations to various different alleles.

Emphasis = - Complete stability of recessive in absence of Ac:
Exactly comparable to case of a_1 , described earlier.

7. Transpositions of Ds to various known gene loci -- set up experiments to find this:

Chromosome 1 -- Bz₂
Chromosome 3 - A₁ locus -- two cases examined
Chromosome 5 - A₂ " -- one case studied
Chromosome 9 -
C - four cases
Sh -
Bz - several cases
Wx - five cases.

Slides: characters:

Slide 2 C, Sh, Bz, and recessives - characters involved

Slide 3 Mutable bz.

8. From studies -- able to obtain a very large number of new alleles at each of these different loci. The mode of origin and the mechanism responsible for control of action of gene and changes in this action are known. Depend on action of separate ^{transposits} elements, carried in chromosomes, control action of gene and subsequent changes in action. Time of occurrence of change in action also understood.

ORIGINAL DOCUMENT

“Mechanisms That Rapidly Reorganize the Genome”, Barbara McClintock, 1978.
APS. Gift of the estate of Barbara McClintock, 1992.

GENOME REORGANIZATION

for the *Ds-Ac* (Dissociation-Activator) transposable gene-control system (McCLINTOCK, 1951) and for rearrangements instigated by the B-type chromosome (RHOADES and DEMPSEY, 1973, 1975, 1977), supporting evidence based on illustrative examples of chromosome modifications induced by innate systems was not given. I am pleased to have this opportunity to provide a few illustrative examples in support of these statements.

UNORTHODOX TYPES OF CHROMOSOMAL REARRANGEMENTS INDUCED BY THE BREAKAGE-FUSION-BRIDGE CYCLE

In maize both the chromatid and chromosome types of breakage-fusion-bridge cycle (BFB) (McCLINTOCK 1938, 1941, 1942, DOERSCHUG 1973) have exposed innate mechanisms that initiate various grades of genome reorganization. The full extent of their effects was not appreciated until the summer of 1944 and thereafter. For purposes not related to the subject of this report, 677 maize kernels were placed in germinating chambers during the spring of 1944. Each kernel had received a newly broken end of the short arm of chromosome 9 from both the pollen and egg parent. (See Figure 1 for the relative size of the 10 chromosomes of the maize set as well as the potential locations of knobs in each chromosome.) The break was induced by mechanical rupture of a chromatid bridge in the anaphase preceding gamete formation. Following zygote formation, the broken ends fused with each other to form a dicentric chromosome (McCLINTOCK 1942, 1944, 1951). The chromosome type of BFB cycle was then initiated.

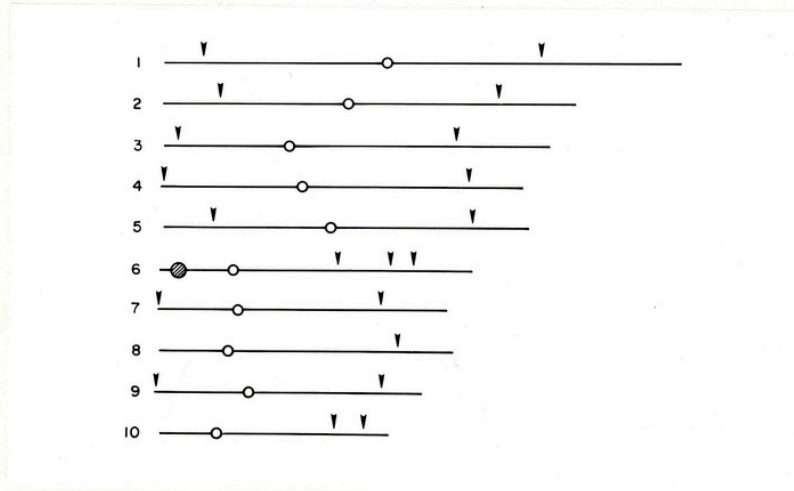


FIGURE 1. Diagram illustrating the relative size of the ten chromosomes of the maize complement. Open circles locate the centromeres. The large hatched circle in chromosome 6 represents the nucleolus organizer. Arrowheads point to locations within each chromosome where knobs may be formed.

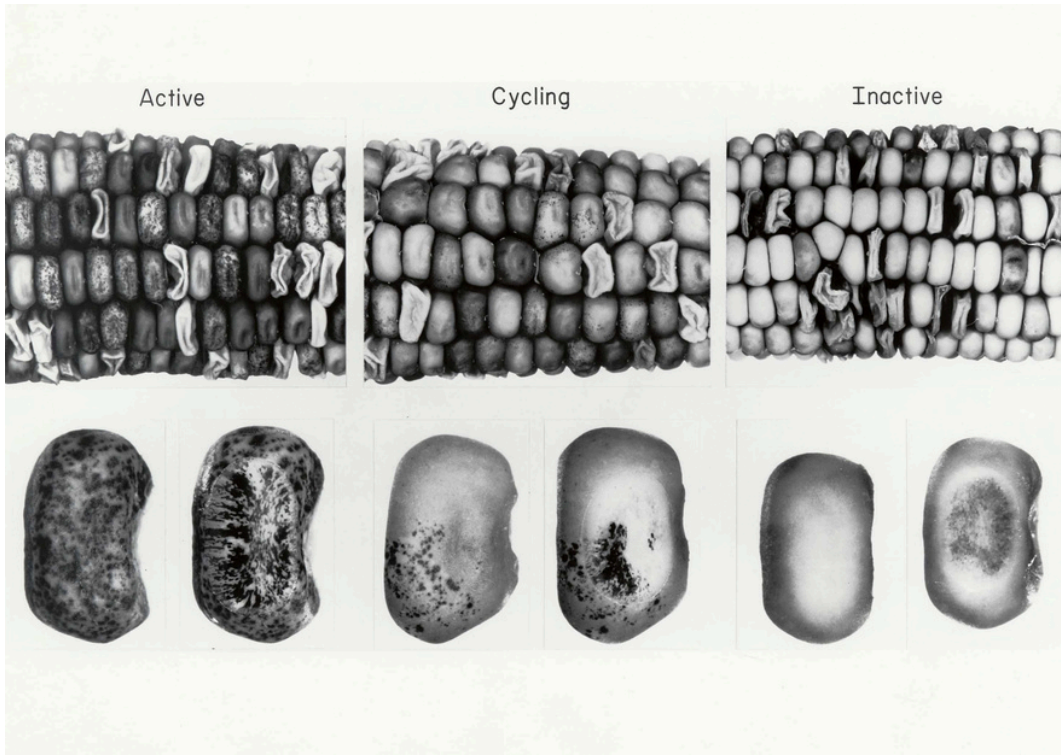
ORIGINAL DOCUMENT

McClintock, Barbara, March 26, 1947. APS.
Gift of the estate of Barbara McClintock, 1992.



ORIGINAL DOCUMENT

Photograph of maize samples, labeled “Active,” “Cycling,” and “Inactive”, 1983. APS. Gift of the estate of Barbara McClintock, 1992.



Barbara McClintock in cornfield, postcard. APS. Gift of the estate of Barbara McClintock, 1992.



ORIGINAL DOCUMENT

Notes for speech at Nobel Prize banquet, Barbara McClintock, 1983.
Barbara McClintock Papers, APS, gift of the estate of Barbara McClintock,
1992.

- much later
8. Another person, ~~whom I had known for his stay at C.S.H.~~ ^{well} ~~visited~~ ^{visited} ~~me at my lab.~~
An animal physiologist ~~came to my lab~~ ^{came to my lab} ~~and we~~ ^{and we} ~~discussed~~ ^{discussed} ~~the~~ ^{the} ~~subject.~~
Before we ~~got~~ ^{started} a serious discussion he said:
"Now, I understand you are working on something
quite strange. And I don't want to hear anything
about it." That made me laugh -- truly.
9. Those years were a ~~free~~ ^{bleeding} ~~bleeding~~ ^{bleeding} ~~time~~ ^{time} ~~for~~ ^{for} ~~me~~ ^{me} ~~to~~ ^{to} ~~learn~~ ^{learn} ~~much~~ ^{much} ~~from~~ ^{from} ~~visitors~~ ^{visitors} ~~who~~ ^{who} ~~talked~~ ^{talked} ~~about~~ ^{about} ~~their~~ ^{their} ~~own~~ ^{own} ~~studies~~ ^{studies}. I learned much
without having to contribute anything
also, I enjoyed the freedom of not ~~having~~ ^{being} ~~to~~ ^{to} ~~be~~ ^{be} ~~imprisoned~~ ^{imprisoned} ~~by~~ ^{by} ~~the~~ ^{the} ~~need~~ ^{need} ~~to~~ ^{to} ~~defend~~ ^{defend} ~~an~~ ^{an} ~~unpopular,~~ ^{unpopular,} ~~unorthodox~~ ^{unorthodox} ~~view~~ ^{view} ~~of~~ ^{of} ~~genetic~~ ^{genetic} ~~phenomena.~~ ^{phenomena.}

was inhibited and given honestly that probably reflected
the views of many.

TRANSCRIPTION

Text

Page 1:

GRAND HOTEL

Stockholm-Sweden

1. My life in genetics began in 1921. By the the mid-1940's I was well enough known to be invited to give lectures at universities or science meetings.
2. after that time, however, invitation stopped, [they?] did not appear again until many years later.
3. This was because I had quite accidentally discovered a phenomenon that was so radical it could not be accommodated into the genetic **dogma** of the times- even though several other persons started working with the same materials and subject. We were outcasts.
4. During the 1950s and 1960s-our institution at C.S.H. had numerous visitors throughout the year. Out of courtesy or friendship they would visit me. And this is where the fun began.
5. At first I was naïve enough to believe they might be interested in learning of my radical finding. And viewing the plant materials here--with [are pleasing] to ever spectacular in their pattern, like many spectacular flower patterns.
- #6. I was soon disillusioned—almost immediately. A few visitors were truly interested and enjoyed viewing the [metup] with the exception of most visitors, [hush] turned glassy-eyed. One person accurately fell asleep while I was attempting to discuss the subject. I [will meant our school responses], I don't want you to think that I was disturbed by them. Truly I was amused

Commentary

Dogma: ideas established by an authority that is believed to be true without question

TRANSCRIPTION

Text

**7 In 1951, a geneticist working with the same plant visits my lab. Almost before greeting me he burst out saying—" if Marcus Rhoades had not told me what you doing was all right I wouldn't believe a word you said."

8.

Page 2:

8. ^not much later another person - An **Animal physiologist** visited me at my lab. Before we started a serious discussion he said "[now] & understand you are working on [something] quite strange. And I don't want to hear anything about it." That made me laugh - truly.

9. Those years were a blessing - Visitors called about their own studies - I learned much without [having] to [contribute] anything. Also, I enjoyed the freedom of not being distracted by the need to defend an unpopular [unattractive] view of genetic phenomena.

An [] and give honestly, that probably reflected the views of many.

Commentary

Animal physiologist:

A scientist who studies how animals function from the cellular level to the whole organism.

Did you notice the [] in the transcription?

Those are not in the original document. They were added by the transcriber. They mean that the transcriber is unsure what word was written.

HISTORICAL CONTEXT

■ Who was Barbara McClintock?



- Barbara McClintock was born on June 16th, 1902 in Hartford, Connecticut. She was the third of four children to Sara Hand McClintock, a pianist, and Thomas Henry McClintock, a physician.
- McClintock would enroll in Cornell University as an undergraduate student. It was here that she took a class in genetics that sparked her love for that field of science. She would go on to get her bachelors degree at Cornell University in 1923 in botany, her masters in 1925, and finally her PhD in 1927. She would focus on maize (or corn) cytogenetics, or the study of maize plants on a sub-cellular (chromosome) level.
- Genetics is the study of genes and how traits are passed down from one generation to the next. McClintock focused on the genetics of corn. Corn was an ideal experimental organism for genetics since researchers could link genetic changes (mutations) in chromosomes to specific colors and patterns in the kernels. It was said she developed “a feeling for the organism” and she could see using her microscope the smallest changes that usually others couldn’t. (1)
- In 1941 she would start her long residency at Cold Spring Harbor, a research facility on Long Island. It would be here that she discovered transposons, DNA segments that move from one chromosomal location to another. This movement can create mutations by switching genes on and off. (2)
- In 1943 she would be elected a member of the American Philosophical Society.

(1) J. Heather Cullen, *Barbara McClintock: Geneticist* (Philadelphia; Chelsea House, 2003), 49.

(2) J. Heather Cullen, *Barbara McClintock: Geneticist* (Philadelphia; Chelsea House, 2003), 81-82

HISTORICAL CONTEXT

■ Who was Barbara McClintock (continued) ?

- Barbara McClintock worked her whole life to understand the genetics of corn. She discovered that DNA sequences are not always fixed on chromosomes. They can “jump” to different chromosomal positions and can change how an organism functions or looks. These are called transposons and sometimes called “jumping genes.”
- In 1951 she presented her findings at the Annual Cold Spring Harbor Symposium and they were met with pushback. Some of her ideas challenged accepted theories in the field of genetics at the time, such as the idea that genes were generally fixed on chromosomes.
- McClintock persisted in her research on the genetics of corn and she would go on to be the winner of the Nobel Prize in 1983 in Physiology or Medicine. She would be the first woman to win unshared in the category of Physiology or Medicine.
- McClintock would go on working until near the end of her life, and her papers would be given to the American Philosophical Society.



IMAGE CREDITS



Portrait of Barbara McClintock, 1980.
APS. Gift of the estate of Barbara
McClintock, 1992.

*Barbara McClintock seated at
laboratory table, examining
maize, undated.* APS. Gift of
Mary Demerec, 1966.



AMERICAN PHILOSOPHICAL SOCIETY

The American Philosophical Society, the oldest learned society in the United States, was founded in 1743 by Benjamin Franklin for the purpose of “promoting useful knowledge.” In the 21st century we sustain this mission in three principal ways. We honor and engage leading scholars, scientists, and professionals through elected membership and opportunities for interdisciplinary, intellectual fellowship, particularly in our semi-annual Meetings. We support research and discovery through grants and fellowships, lectures, publications, prizes, exhibitions, and public education. We serve scholars through a research library of manuscripts and other collections internationally recognized for their enduring historic value. The American Philosophical Society’s current activities reflect the founder’s spirit of inquiry, provide a forum for the free exchange of ideas, and convey our conviction that intellectual inquiry and critical thought are inherently in the best interest of the public.

