The Teosinte Hypothesis

Activity
Student Handout

INTRODUCTION

In the film *Popped Secret: The Mysterious Origin of Corn*, George Beadle was the first to propose that teosinte is the wild ancestor of maize. At first, few scientists agreed with this hypothesis because there did not seem to be enough supporting evidence. Later in his career, Dr. Beadle undertook a huge genetic experiment to get the evidence needed to make a stronger case for his hypothesis.

In this activity, you will unravel the mathematics and concepts behind Dr. Beadle's research to understand just how it supported his claim that teosinte is the wild ancestor of maize.

PROCEDURE

Watch the short film *Popped Secret: The Mysterious Origin of Corn.* Read the information provided and answer the questions.

Dr. Beadle's Experiment

In the film, the narrator explains that many scientists doubted Dr. Beadle's hypothesis because teosinte and maize look like very different plants. It seemed unlikely that teosinte would give rise to maize within the 10,000 years or so that humans had been growing crops, because the process would involve changes in many genes — too many to occur in this time span.

Dr. Beadle's experiment set out to answer the question "How many genes control the differences between maize and teosinte?" If it were only a few genes, then his hypothesis would be strengthened.

To determine the answer to his question, Dr. Beadle crossed teosinte plants with maize plants to produce offspring (F_1) that contained one copy of each gene from teosinte and one from maize (Figure 1).

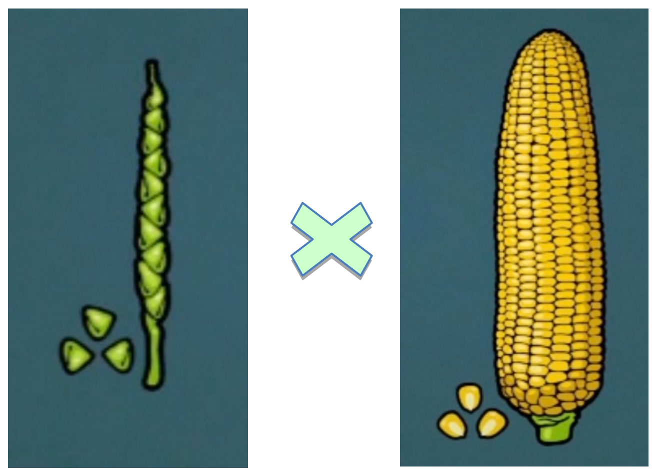

Figure 1. Cross between teosinte and maize plants.

Different versions of a gene (or any sequence of DNA) are referred to as **alleles**. So, another way to describe the F_1 plants is to say that for every gene, each plant had one teosinte allele ($gene^T$) and one maize allele ($gene^M$). Dr. Beadle then crossbred F_1 generation plants to create an F_2 generation (Figure 2).

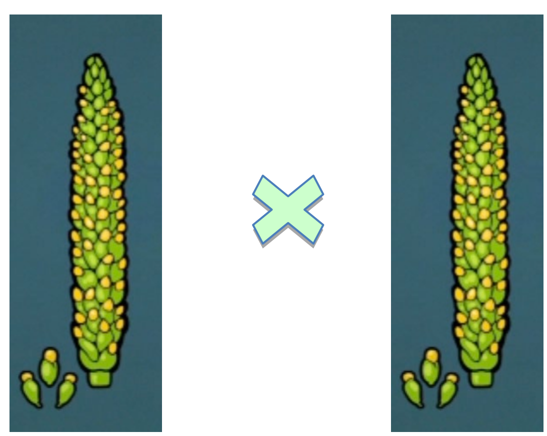

Figure 2. Cross of F_1 generation plants.

One Gene?

If a single gene, **gene *X***, with two alleles, X^T and X^M, controlled all the phenotypic differences between teosinte and maize, then Dr. Beadle would have expected the results summarized in **Figure 3**.

Note: While dominant and recessive symbols for alleles are usually in the form of capital and lowercase letters (for example, ***A*** and ***a***), different types of symbols are used when the inheritance pattern is not dominant-recessive (for example, A^1 and A^2).

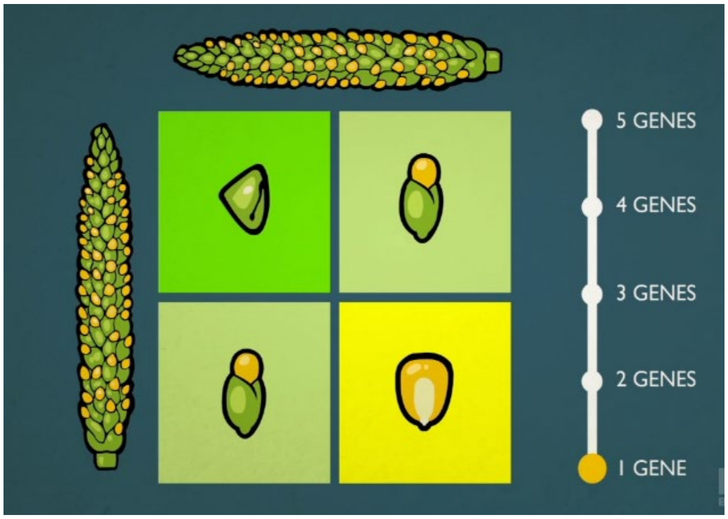

Figure 3. Expected results of the F_1 cross if one gene controlled all of the differences between teosinte and maize. The squares represent the phenotypes of the seeds in the plants in the F_2 generation. The cross predicts that if two F_1 hybrids were crossed, 1/4, or 25%, of the F_2 offspring would look just like teosinte (upper left corner); 1/4, or 25%, would look just like maize (lower right corner); and 1/2, or 50%, would look like the F_1 hybrids.

In your previous studies about genetics, you have probably been introduced to Punnett squares. Punnett squares are a tool to help predict the ratios of different phenotypes and genotypes of offspring from a genetic cross between two parents. Figure 3 uses pictures to represent the ratio of phenotypes of predicted offspring. In most cases, however, Punnett squares include the genotypes for the offspring. Use what you have learned to answer the questions below.

QUESTIONS

One Gene?

1. Using the allele symbols A^T and A^M, complete the Punnett square below by following these steps:
   - Identify the genotype of the F_1 parent plants in Figure 3.
   - Write down the alleles that each parent contributes to the cross in the spaces provided on the sides of the Punnett square (note that if one gene controls the phenotype, each parent contributes one of **two** possible alleles).
   - Determine the possible genotypes of the F_2 offspring and fill in the Punnett square.

   F_1 genotype

	______	______
_____	F_2 genotype	F_2 genotype
_____	F_2 genotype	F_2 genotype

2. If offspring homozygous for the A^T allele (A^TA^T) look just like teosinte, and offspring homozygous for the A^M allele (A^MA^M) look just like maize, identify:
   a. the ratio and percentage of offspring expected to look just like teosinte ______________ ______________
   b. the ratio and percentage of offspring expected to look just like maize ______________ ______________
   c. the ratio and percentage of offspring expected to have a combination of teosinte and maize characteristics ______________ ______________
3. Which Punnett square — the one you drew, or the one in Figure 3 — do you find more informative? Explain your answer.

Two Genes?

What if two genes, ***A*** and ***B***, determine all the differences between maize and teosinte?

4. Using allele symbols A^T/A^M and B^T/B^M, complete the Punnett square below by following these steps:
   - Identify the genotype of the F_1 parent plants in Figure 3.
   - Write down the alleles contributed by each F_1 parent in the spaces provided on the sides of the Punnett square (note that if two genes are involved, each parent contributes one of **four** possible allele combinations).
   - Determine the possible genotypes of the F_2 offspring and fill in the Punnett square.

F_1 genotype

F₁ genotype	_______	_______	_______	_______
_______	F_2 genotype	F_2 genotype	F_2 genotype	F_2 genotype
_______	F_2 genotype	F_2 genotype	F_2 genotype	F_2 genotype
_______	F_2 genotype	F_2 genotype	F_2 genotype	F_2 genotype
_______	F_2 genotype	F_2 genotype	F_2 genotype	F_2 genotype

5. How many ***different*** F_2 genotypes are there? List the genotypes and identify whether each genotype would result in a phenotype that looks just like maize (i.e., has only maize alleles), looks just like teosinte (i.e., has only teosinte alleles), or looks like a mix of the two.

6. Based on your answers to the previous questions, identify:
   a. the ratio and percentage of offspring expected to look just like teosinte ______________ ______________
   b. the ratio and percentage of offspring expected to look just like maize ______________ ______________
   c. the ratio and percentage of offspring expected to look like a mix of teosinte and maize

   ______________ ______________

Three Genes?

What if three genes, ***A***, ***B***, and ***C***, determine all the differences between maize and teosinte?

7. Using allele symbols A^T/A^M, B^T/B^M, and C^T/C^M, complete PART of the Punnett square below following these steps:
   - Identify the genotypes of the F_1 parent plants in Figure 3.
   - Write down the possible alleles contributed by each F_1 parent in the spaces provided on the sides of the Punnett square (note that if three genes are involved, each parent can contribute any of **eight** combinations of alleles).
   - Circle the genotypes from each parent that only have alleles from teosinte.
   - Fill in the F_2 genotypes of the offspring that would result from this one cross in the Punnett square.
   - Circle the genotypes from each parent that only have alleles from maize.
   - Fill in the F_2 genotypes of the offspring that would result from this one cross in the Punnett square.

F_1 genotype

	_______	_______	_______	_______	_______	_______	_______	_______
_______	F_2 genotype	F_2 genotype	F_2 genotype	F_2 genotype	F_2 genotype	F_2 genotype	F_2 genotype	F_2 genotype
_______	F_2 genotype	F_2 genotype	F_2 genotype	F_2 genotype	F_2 genotype	F_2 genotype	F_2 genotype	F_2 genotype
_______	F_2 genotype	F_2 genotype	F_2 genotype	F_2 genotype	F_2 genotype	F_2 genotype	F_2 genotype	F_2 genotype
_______	F_2 genotype	F_2 genotype	F_2 genotype	F_2 genotype	F_2 genotype	F_2 genotype	F_2 genotype	F_2 genotype
_______	F_2 genotype	F_2 genotype	F_2 genotype	F_2 genotype	F_2 genotype	F_2 genotype	F_2 genotype	F_2 genotype
_______	F_2 genotype	F_2 genotype	F_2 genotype	F_2 genotype	F_2 genotype	F_2 genotype	F_2 genotype	F_2 genotype
_______	F_2 genotype	F_2 genotype	F_2 genotype	F_2 genotype	F_2 genotype	F_2 genotype	F_2 genotype	F_2 genotype
_______	F_2 genotype	F_2 genotype	F_2 genotype	F_2 genotype	F_2 genotype	F_2 genotype	F_2 genotype	F_2 genotype

8. Identify the ratio and percentage of offspring expected to look just like teosinte by following these steps:
   a. How many F_2 genotypes did you fill in for the cross between F_1 parents with only teosinte alleles? _____
   b. Take the total number of teosinte-like F_2 individuals and divide it by the total number of F_2 possibilities in the overall Punnett square. Identify the ratio and percentage of offspring expected to look just like teosinte. _________________

A Better Way?

As you can see, Punnett squares for phenotypes that involve several genes can get complicated. If you can recognize the patterns, you can make a mathematical model to figure out how common or rare a particular genotype or phenotype would be, depending on the number of genes involved.

To do this, you begin by figuring out how many different combinations of alleles each F_1 parent could contribute to the F_2 generation. When one gene, ***A***, was involved, each parent could contribute one of **two** alleles: A^T or A^M.

When two genes, ***A*** and ***B***, were involved, each parent could contribute any one of **four** allele combinations: A^TB^T, A^MB^T, A^TB^M, or A^MB^M. When three genes were involved, each parent could contribute any one of **eight** allele combinations, and so on.

Next, determine the proportion of the F_2 offspring that you'd expect to inherit alleles only from teosinte. You have already determined this figure based on your crosses.

- When one gene was involved, 1/4 of the F_2 offspring were expected to look just like teosinte because they inherited only teosinte alleles. Note that 4 is 4^1.
- When two genes were involved, 1/16 of the F_2 offspring were expected to look just like teosinte because they inherited only teosinte alleles. Note that 16 is 4^2.
- When three genes were involved, 1/64 of the F_2 offspring were expected to look just like teosinte because they inherited only teosinte alleles. Note that 64 is 4^3.

9. Do you notice the pattern? What proportion of F_2 offspring would you expect to look just like teosinte if four genes controlled the differences between maize and teosinte? Explain your answer.

10. Write a formula in the following format to capture your model: $x = y/z^w$. Define each of the variables or replace them with constants (numerals).

11. Use your formula (and show your work) to predict the proportion of F_2 offspring expected to look exactly like teosinte if:
    - 5 genes were involved ______________________________
    - 10 genes were involved ____________________________
    - 100 genes were involved ___________________________

12. How would the probability of an offspring inheriting all its alleles from teosinte compare to the probability of an offspring inheriting all its alleles from maize? Explain your answer.

Dr. Beadle's Results

Dr. Beadle did not know for sure how many genes were involved in determining the differences between teosinte and maize, although he thought it was a relatively small number. He grew 50,000 F_2 plants to test his ideas about the number of genes involved in transforming teosinte into maize. Dr. Beadle found that about 1 in 500 F_2 plants looked identical to teosinte, and a similar number looked just like maize.

13. Use evidence from your mathematical model to support or refute Dr. Beadle's conclusion that four or five genes are involved in causing the differences between teosinte and maize.

14. A student club replicates Dr. Beadle's experiment, but on a much smaller scale. They grow 500 F_2 plants. They did not find any that looked just like teosinte. Does that mean Dr. Beadle's conclusion was wrong about the genetics of teosinte and maize? Explain why or why not.