MAPPING CHROMOSOMES

BACKGROUND INFORMATION

When Mendel first outlined the principles of genetics, he wrote about two factors for each trait that separated during gamete formation and assorted independently. It was Walter Sutton who later observed that these factors are genes and that they are located on chromosomes. In his chromosome theory of heredity, Sutton explained that each gene occupies a specific place on a chromosome. Genes that are located on separate chromsomes assort independently during meiosis. Genes that are located on the same chromosome are linked together and do not undergo independent assortment.

There are, however, exceptions to the rules of linkage groups. In order to explain these exceptions, Thomas Hunt Morgan and Alfred Sturtevant proposed that linkages could be broken some of the time. If two homologous chromosomes were positioned side by side, sections of the two chromosomes might cross, break, and reattach. This process is called crossing-over, and it occurs during the first meiotic division when homologous chromosomes are paired.

In this investigation, you will make a model that simulates crossing-over in order to determine how the frequency of crossing-over can be used to map the positions of genes on chromosomes.

PROBLEM

How can rates of crossing-over be used to map chromosomes?

MATERIALS *(per group)*

wooden stick from a frozen dessert bar
metric ruler
sheet of unlined paper
pen

PROCEDURE

1. Using a pen and a ruler, draw a vertical line 15 cm long in the center of a clean sheet of unlined paper. Make a small horizontal mark at the bottom of the line. Measuring from the bottom of the line, add horizontal marks at 1 cm, 3 cm, 6 cm, 10 cm, and 15 cm.
2. Label each horizontal mark alphabetically (A through F), starting from the bottom.
3. The vertical line on the paper represents a chromosome that has six genes on it—A, B, C, D, E, and F. This chromosome's homologous chromosome is represented by the colored edge of the wooden stick.
4. Adjust the sheet of paper so that its bottom edge is about 15 cm from the edge of your lab table or desk. Move your chair back so that the front edge of your seat is about 30 cm from the edge of your lab table or desk.

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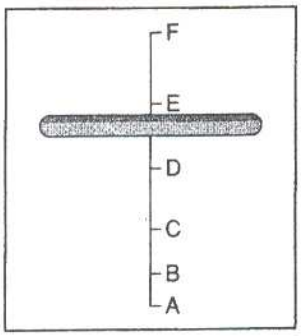
5. Toss the wooden stick, underhand, toward the vertical line until the stick lands across the line. The landing of the stick across the line represents crossing-over.
6. When crossing-over occurs, look at the colored edge of the stick to determine which genes have been separated. Make a tally mark in the appropriate place in the accompanying data table for each gene that has become separated from gene A. For example, if, as in Figure 1, the colored edge of the stick lands between D and E, make tally marks for genes E and F because they have been separated from gene A as a result of crossing-over.

Figure 1



7. Toss the stick and tally the results until crossing-over has occurred 100 times.
8. Count up the number of tally marks for each of the five genes. In the appropriate place in the data table, record the number of times each gene was separated from gene A.
9. Calculate the frequency of crossing-over by dividing the number of times each gene was separated from gene A by 100. Record the results of your calculations.
10. Calculate the location of each gene by multiplying the frequency of its crossing-over by 15 and rounding off to the nearest integer. Record the calculated gene locations.

OBSERVATIONS

Data Table

Genes Separated from Gene A	Times Separated from Gene A		Frequency of Crossing-Over	Gene Locations	
	Tallies	Number		Calculated	Measured
B					
C					
D					
E					
F					

1. Did every toss result in crossing-over? _____
2. Which genes became separated from gene A most frequently? Most infrequently?

_____

_____

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ANALYSIS AND CONCLUSIONS

1. What is the relationship between the frequency of gene separation due to crossing-over and the distance between genes?

2. Are your calculated gene locations exactly the same as the actual gene locations? If so, discuss why the experiment went as expected. If not, discuss possible sources of error.

3. How can the frequencies of crossing-over be used to map chromosomes?

CRITICAL THINKING AND APPLICATION

1. In humans, the Y chromosome contains genes that cause a human being to develop into a male. How is it possible for a normal male to have what appear to be two normal X chromosomes and 22 normal pairs of autosomes?

2. Genes A, B, and C are on the same chromosome. Most individuals who are recessive for trait A are also recessive for traits B and C. However, five percent of all those who are recessive for trait A are dominant for trait B, and one percent of all those who are recessive for trait A are dominant for trait C. Starting with gene A, what is the order of the genes on the chromosome?

3. Genes A, B, and C are on the same chromosome. Most individuals who are recessive for trait A are also recessive for traits B and C. Occasionally, individuals who are recessive for trait A are dominant for trait C or for both traits B and C. There are virtually no individuals who are recessive for both traits A and C and dominant for trait B. Explain.

4. Why do most individuals with blond hair also have blue eyes? How do exceptions come about?

5. When and how does crossing-over and recombination occur?

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