Add Up and Cross Over

Sordaria Genetics Simulation

Introduction

Crossing over occurs during meiosis I. During crossing over, homologous pairs of chromosomes exchange sections of DNA that contain the same genes. It is important to note that crossing over does not have to occur during each generation, nor does it always take place at the same point of exchange. Over time, however, crossing over leads to a greater variety of genes in a population and contributes to a diversity of characteristics and increased fitness of the population. This is reflected in the ability of the population to adapt to changes in the environment.

Concepts

- Genetic diversity
- Gene mapping
- Crossing over
- Meiosis

Background

During sexual reproduction hyphae of different haploid *S. fimicola* come into contact allowing cells in the hyphae to fuse and form a single cell with two nuclei, one from each individual. This fused cell is called a *dikaryon*. The dikaryon is not considered diploid since the two nuclei are from separate fungi and the nuclei are not fused together. The dikaryon cells undergo multiple rounds of mitosis to form a mass of cells. This mass of cells can exist for years without undergoing fusion of the nuclei. Sexual reproduction occurs when some of the dikaryon nuclei fuse. After fusion the fruiting body forms and meiosis occurs, creating the asci and ascospores, which are haploid cells.

The ascospores form inside the tight confines of the tube-like ascus. The ascospores actually line up in order based on which cell produced that particular ascospore. In 1956, a geneticist named Lindsay S. Olive (1917–1988) published an article about crossing over in *S. fimicola*. Dr. Olive used ultraviolet light to cause mutations in the genes of *S. fimicola*. After numerous trials, Dr. Olive produced a mutation in the gene that produced the pigment in the ascospore. The production of the black pigment is either greatly reduced or completely repressed in the mutated strain of *S. Fimicola*. A reduction in the amount of black pigment results in gray asco spores. An absence of black pigment results in tan ascospores. By collecting the gray or tan ascospores, Dr. Olive was able to produce true breeding fungi much like Mendel's peas.

Recall that each ascospore can be traced back to the parent chromosome. The pattern of black and tan ascospores shows whether crossing over occurred during meiosis. Observe Figure 1. Note that the diagram of the ascus indicates eight ascospores in each ascus, not the expected four cells. This is because each of the four haploid daughter cells undergoes a single mitosis after the end of meiosis II. So, each daughter cell produces a clone of itself. These clones reside next to each other within the ascus. If the cells come from parents with identical pigment genes, the ascus will contain eight spores that are the same color whether black or tan. If the cells come from parents with each pigment type, but crossing over did not occur, the spores will appear as four black, wild-type and four tan, mutant spores (4b:4t) (see Figure 1a). If crossing over of the pigment gene between a black wild-type and a tan mutant occurred during meiosis I, the four spores will have one of two possible patterns: 2:2:2:2 or 2:4:2. Each of the numbers can be either tan or black. This is written out as 2b:2t:2b:2t or 2t:2b:2t:2b and 2b:4t:2b or 2t:4b:2t. (See Figure 1b and 1 c).

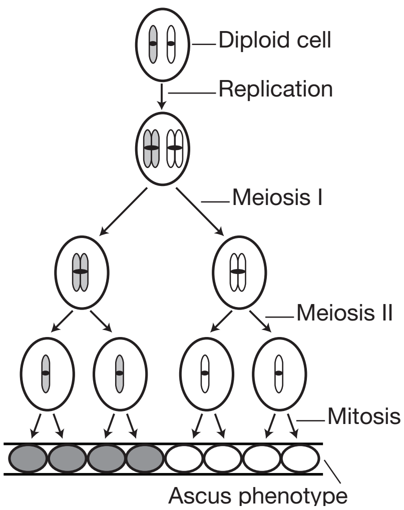


Figure 1a.
Non-crossover ascus—4b:4t

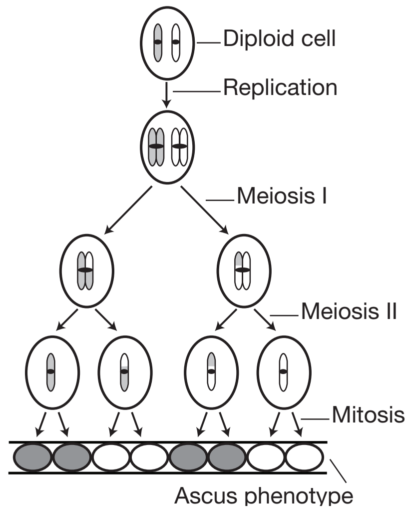


Figure 1b.
Crossover ascus—2b:2t:2b:2t

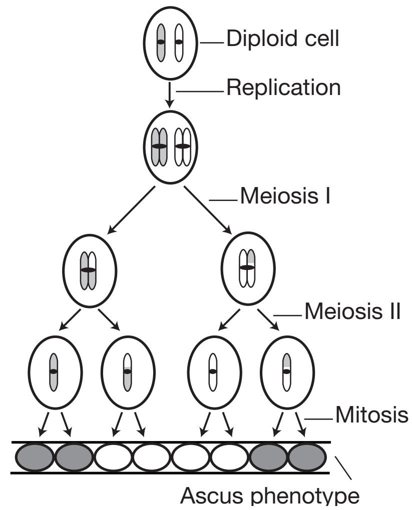


Figure 1c.
Crossover ascus—2b:4t:2b

Materials

Sordaria Cards, 5

Pencil

Safety Precautions

Although this activity is considered nonhazardous, please follow all laboratory safety guidelines.

Procedure

1. Begin with one of the five *Sordaria* cards assigned. Categorize each ascus containing both black and tan ascospore beginning at the twelve o'clock position. *Note:* Do not categorize any single-colored asci. single-colored asci are not the result of sexual reproduction between a tan mutant and a black wild type *S. fimicola* and will not be used to calculate the frequency of crossing over or the map distance.
2. Tally the results on the Counting Crossing Over Worksheet corresponding to the correct color arrangement for each ascus. *Note:* Refer to Figures 1a–1c for schematics of possible two-colored asci.
3. Categorize all of the two-colored asci on the first card.
4. Repeat steps 1–3 with the four remaining cards, compiling all the data.
5. Complete the calculations and data analysis on the Counting Crossing Over Worksheet.

AP Biology Curriculum

Enduring Understanding

Essential knowledge 3.A.3: The chromosomal basis of inheritance provides an understanding of the pattern of passage (transmission) of genes from parent to offspring.

Essential knowledge 3.C.1: Changes in genotype can result in changes in phenotype.

Essential knowledge 3.C.2: Biological systems have multiple processes that increase genetic variation.

Tips

- Published sources cite between 26 and 28 map units as the distance between the tan mutant gene and the centromere.
- Use this activity as an introduction for the Advanced Placement Biology Investigation 7 Part 5.

References

Olive, L. S. Genetics of *Sordaria fimicola; American Journal of Botany*, **1956**, 43, 97–107.

Cassell, P., Mertens, T. R., A Laboratory Exercise on the Genetics of Ascospore Color in *Sordaria fimicola*; *The American Biology Teacher*, **1968**, 30, 367–372.

The Tree of Life Web project (accessed August 2010). http://tolweb.org/Ascomycota

Biology: Lab Manual; College Entrance Examination Board: 2001.

Kits covering the same topic as *Add Up and Cross Over* are available from Flinn Scientific, Inc.

Catalog No.	Description
FB1973	Counting Crossing Over— Sordaria Genetics Student Activity Kit
FB2001	Sordaria Genetics—Student Laboratory Kit

Consult your *Flinn Scientific Catalog/Reference Manual* for current prices.

Name: ___________________________________

Add Up and Cross Over Worksheet

Data Table

Color combinations	Tally Marks	Total
Non-crossover Asci		
4b:4t		
4t:4b		
Crossover Asci		
2b:2t:2b:2t		
2t:2b:2t:2b		
2b:4t:2b		
2t:4b:2t		

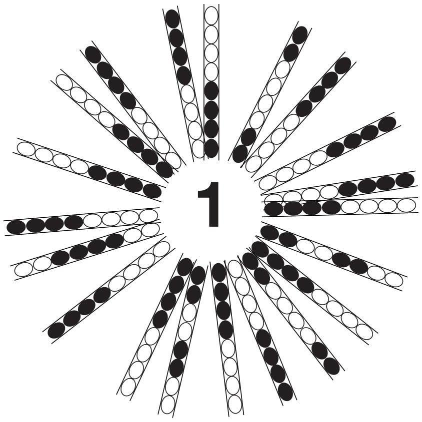
Post-Lab Questions and Calculations

1. Take the sum of the tally marks for each combination. Record each result in the *Total* column.
2. Determine the total number of non-crossover asci counted.
3. Determine the total number of crossover asci counted.
4. Determine the total number of hybrid asci counted.
5. Recall that each ascus contains eight spores because the four haploid spores underwent an additional mitosis. a correction to the totals must be performed to compensate for that extra mitotic event. Divide each of the numbers calculated in steps 3–4 by 2. Record the corrected values below.
5. Determine the map distance between the gene for spore color and the centromere using Equation 1. Report the result in map units. However, keep in mind that each ascus contains 8 spores because the four haploid spores underwent an additional mitotic event after meiosis. To account for this, the map distance found in Equation 1 needs to be halved (Equation 2).

$$\text{Map distance} = \frac{\text{corrected number of crossover asci}}{\text{corrected total number of asci counted}} \times 100 \qquad \textit{Equation 1}$$

$$\frac{\text{Map distance}}{2} \qquad \textit{Equation 2}$$

6. Was the number of each type of crossover phenotype observed relatively constant or equal? Explain why you would expect these numbers to be constant.
7. A similar technique can be used to determine the distance between two genes on a single chromosome. In this laboratory a color mutation was used as the gene of interest. What is the benefit for using a color mutant gene for learning about map units.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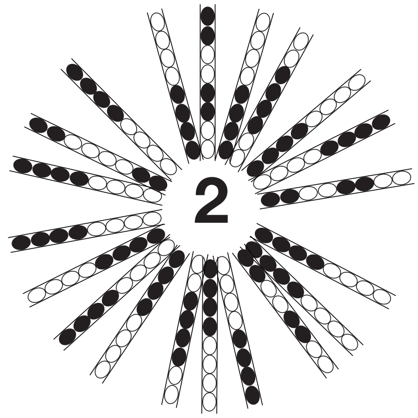
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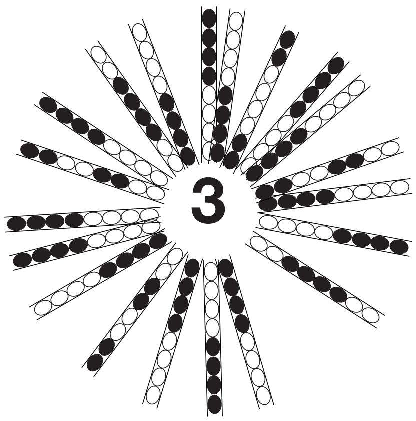
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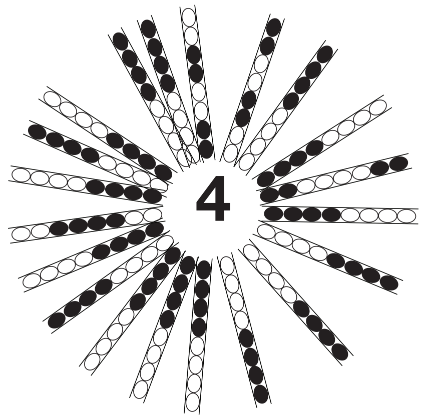
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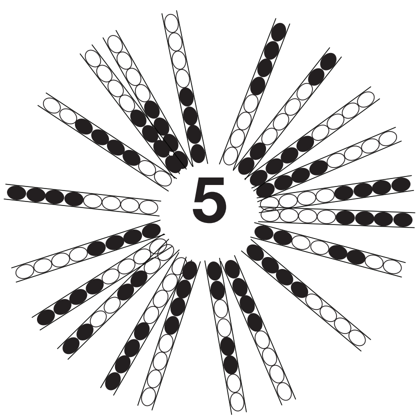
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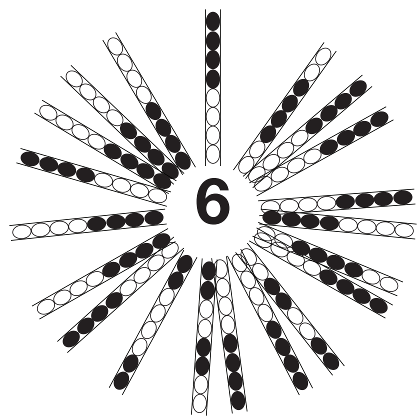
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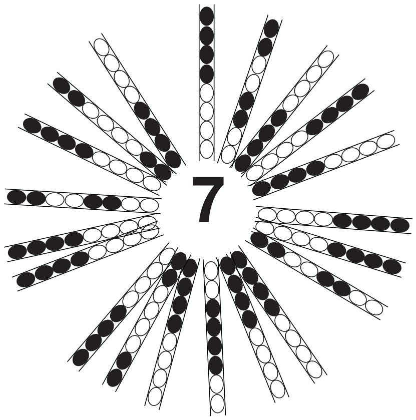
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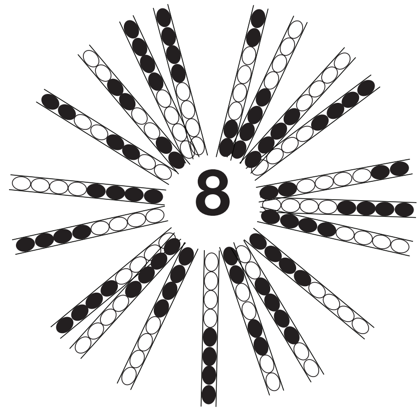
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