AP Bio FRQ Fridays

2022 #2
Crossing Over, Data Analysis, & Meiosis

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During meiosis, double-strand breaks occur in chromatids. The breaks are either repaired by the exchange of genetic material between homologous nonsister chromatids, which is the process known as crossing over (Figure 1A), or they are simply repaired without any crossing over (Figure 1B). Plant breeders developing new varieties of corn are interested in determining whether, in corn, a correlation exists between the number of meiotic double-strand chromatid breaks and the number of crossovers.

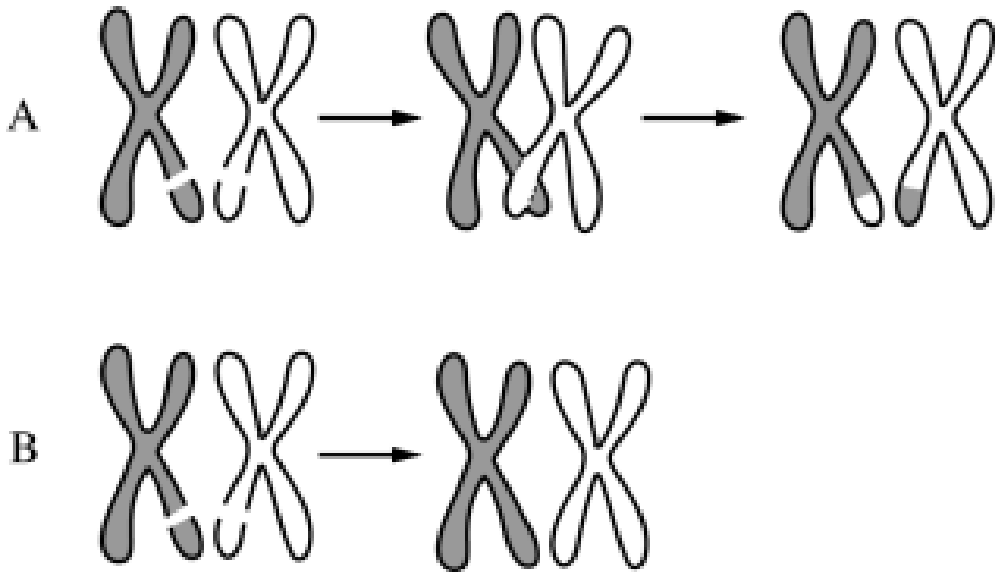

Figure 1. Double-strand breaks in chromatids are repaired with crossing over (A) or without crossing over (B).

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Using specialized staining and microscopy techniques, scientists counted the number of double-strand chromatid breaks and the number of crossovers in the same number of meiotic gamete-forming cells of six inbred strains of corn (Table 1).

TABLE 1. NUMBER OF CHROMATID DOUBLE-STRAND BREAKS AND AVERAGE NUMBER OF CROSSOVERS IN INBRED STRAINS OF CORN

Strain of Corn	Number of Double-Strand Breaks	Average Number of Crossovers ($\pm 2SE_{\bar{x}}$)
I	710	19.5 ± 0.5
II	650	18.0 ± 0.7
III	600	17.5 ± 1.0
IV	510	16.0 ± 1.0
V	425	14.0 ± 0.5
VI	325	11.0 ± 1.5

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(a) The double-strand breaks occur along the DNA backbone. **Describe** the process by which the breaks occur.

Accept one of the following:

- (Enzymatic) hydrolysis occurs between the sugars and phosphates/nucleotides.
- The covalent bonds between the sugars and phosphates/nucleotides are broken.

a) The double-strand break occurs along the DNA backbone when the covalent phosphodiester bond between the deoxyribose sugar and phosphate groups are broken. These sugar and phosphate groups are parts of different nucleotides along the backbone.

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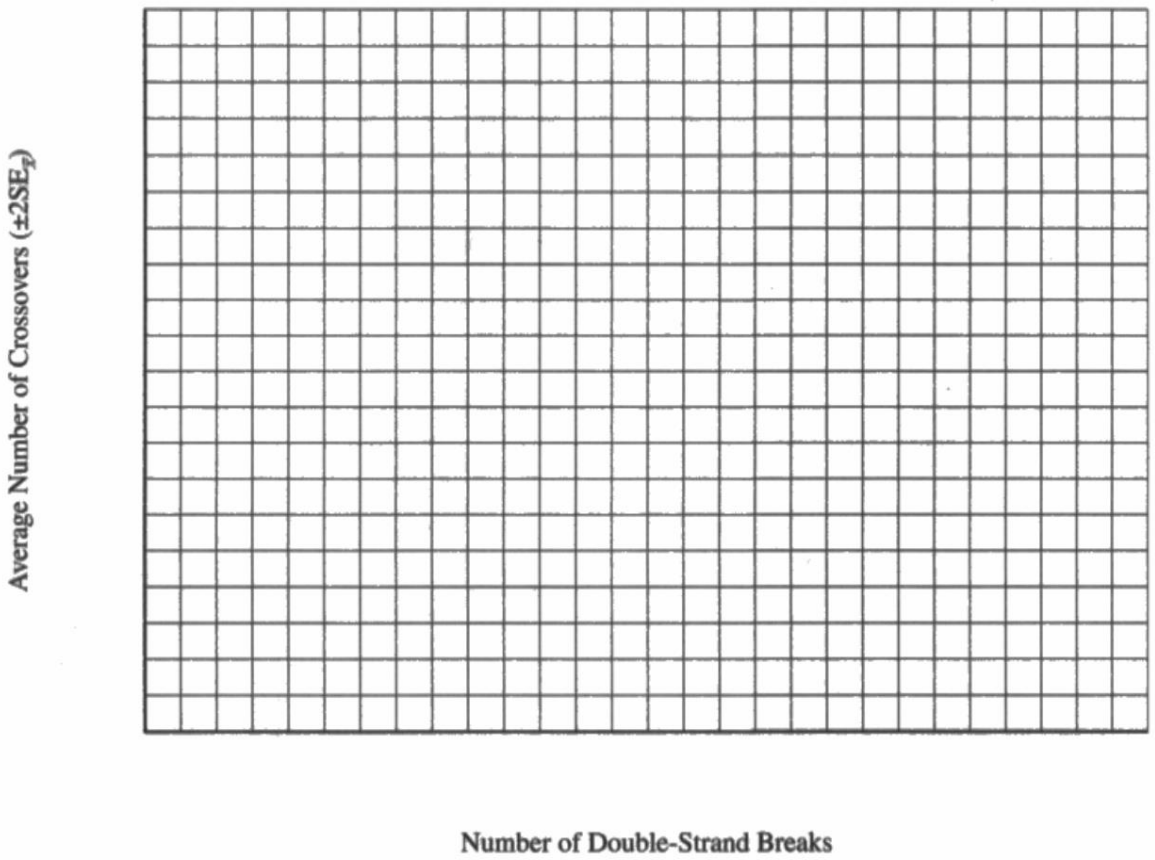
(b) Using the template in the space provided for your response, **construct** an appropriately labeled graph that represents the data in Table 1 and allows examination of a possible correlation between double-strand breaks and crossovers. Based on the data, **determine** whether corn strains I, II, and III differ in their average number of crossovers.



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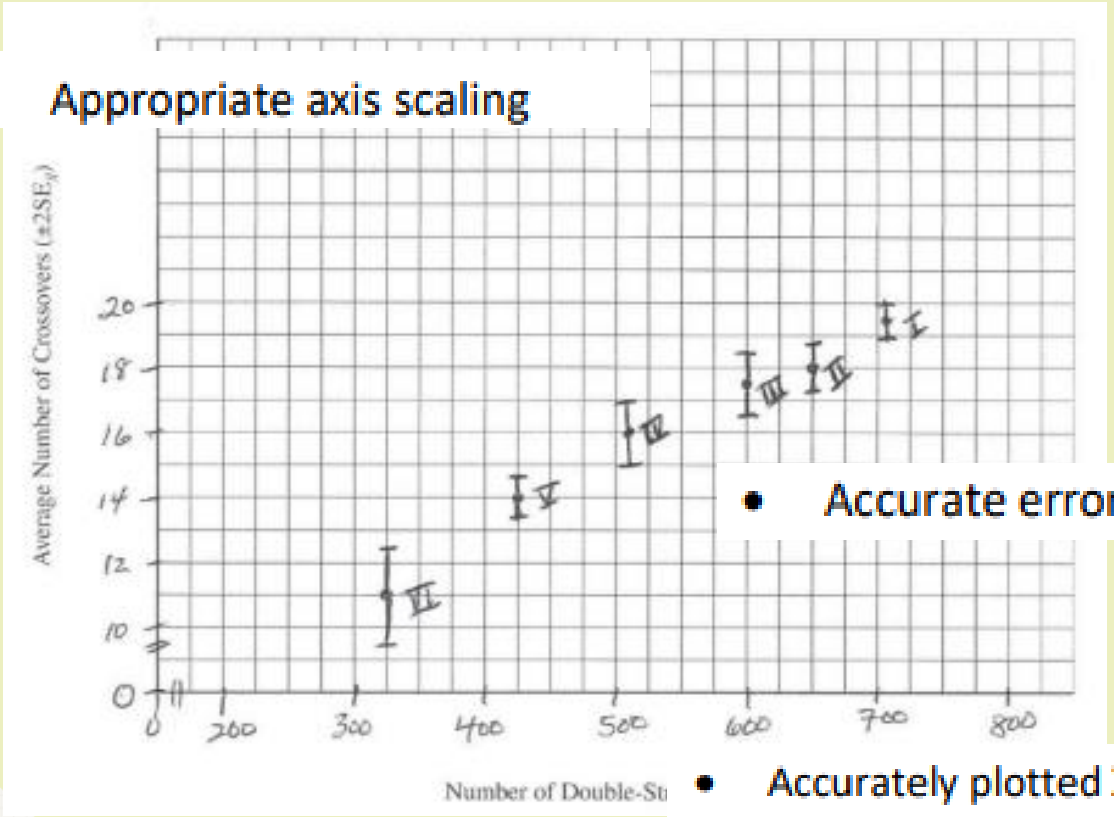

- Appropriate axis scaling
- Accurate error bars
- Accurately plotted X,Y graph with separate points for the average number of crossovers for each strain

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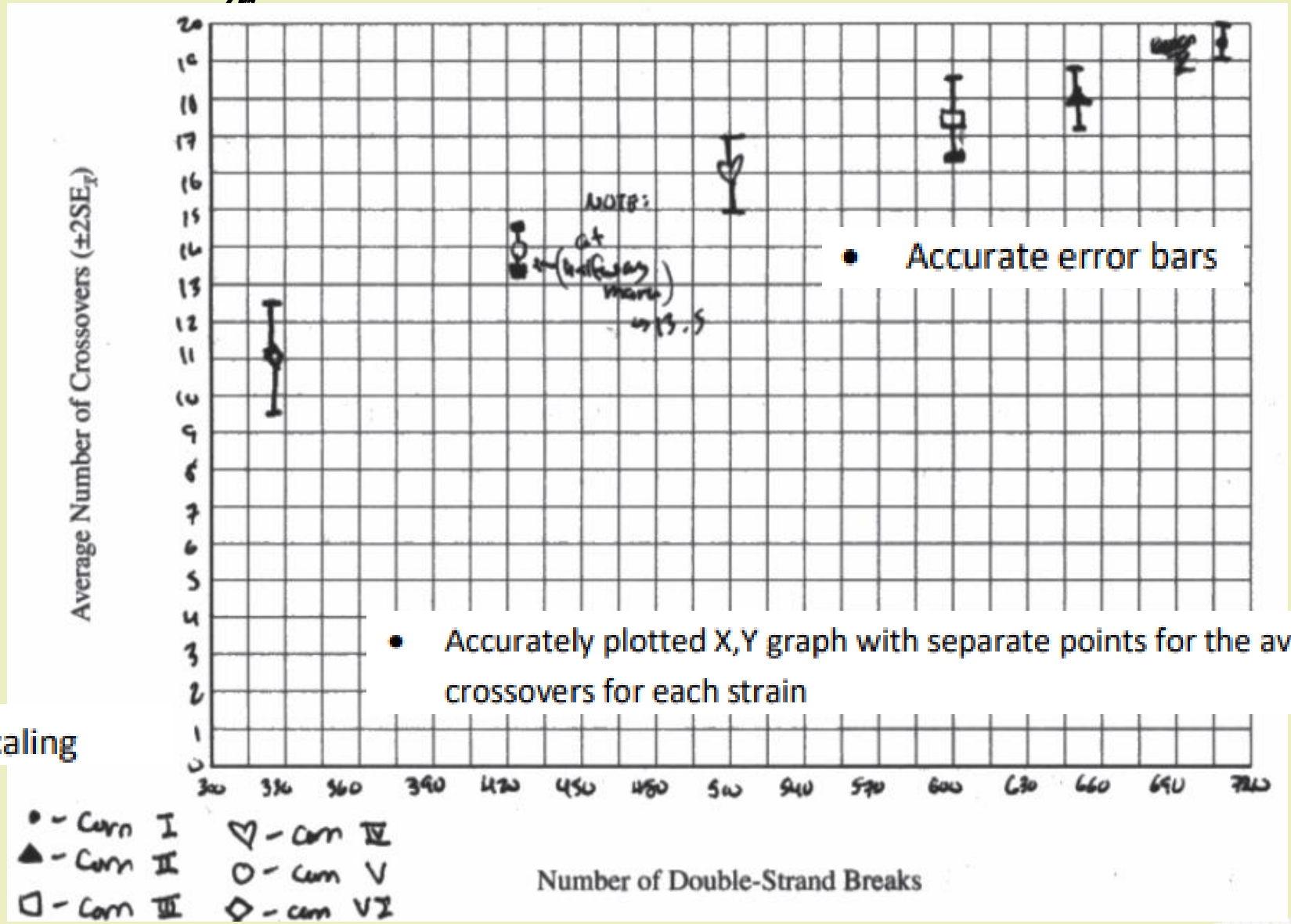

- Appropriate axis scaling

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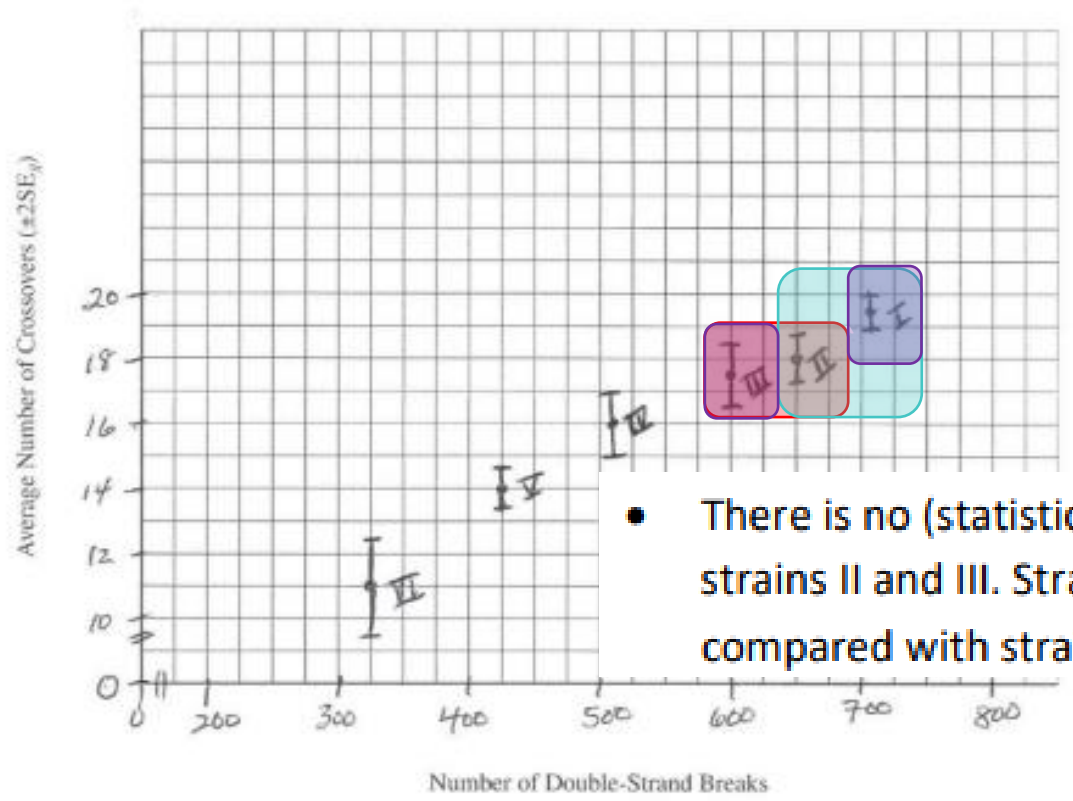

- There is no (statistical) difference (in the average number of crossovers) between strains II and III. Strain I is higher/is different (in the average number of crossovers) compared with strains II and III.

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(b) Using the template in the space provided for your response, **construct** an appropriately labeled graph that represents the data in Table 1 and allows examination of a possible correlation between double-strand breaks and crossovers. Based on the data, **determine** whether corn strains I, II, and III differ in their average number of crossovers.

b) Although corns II and III do not differ in the average number of crossovers, corn I differs from both corn II and III in the number of average crossovers.

- There is no (statistical) difference (in the average number of crossovers) between strains II and III. Strain I is higher/is different (in the average number of crossovers) compared with strains II and III.

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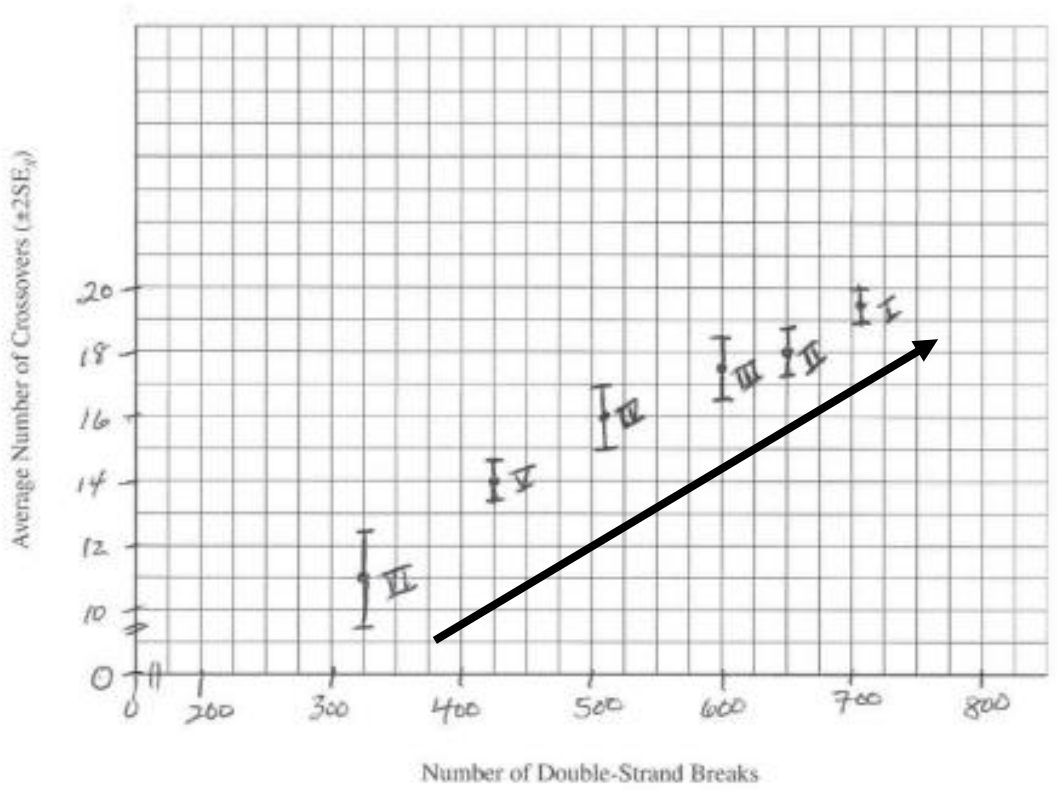
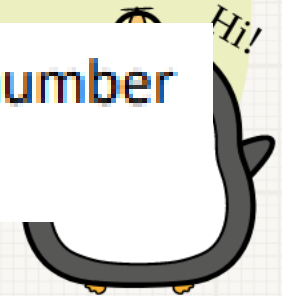
(c) Based on the data, **describe** the relationship between the average number of double-strand breaks and the average number of crossovers in the strains of corn analyzed in the experiment.



- (In general) there is a direct correlation/positive relationship (between the number of double-strand breaks and the number of chromatid crossovers).



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- (In general) there is a direct correlation/positive relationship (between the number of double-strand breaks and the number of chromatid crossovers).

c) As the average number of double-strand breaks increases, the average number of crossovers in the strains of corns analyzed in the experiment increase as well.

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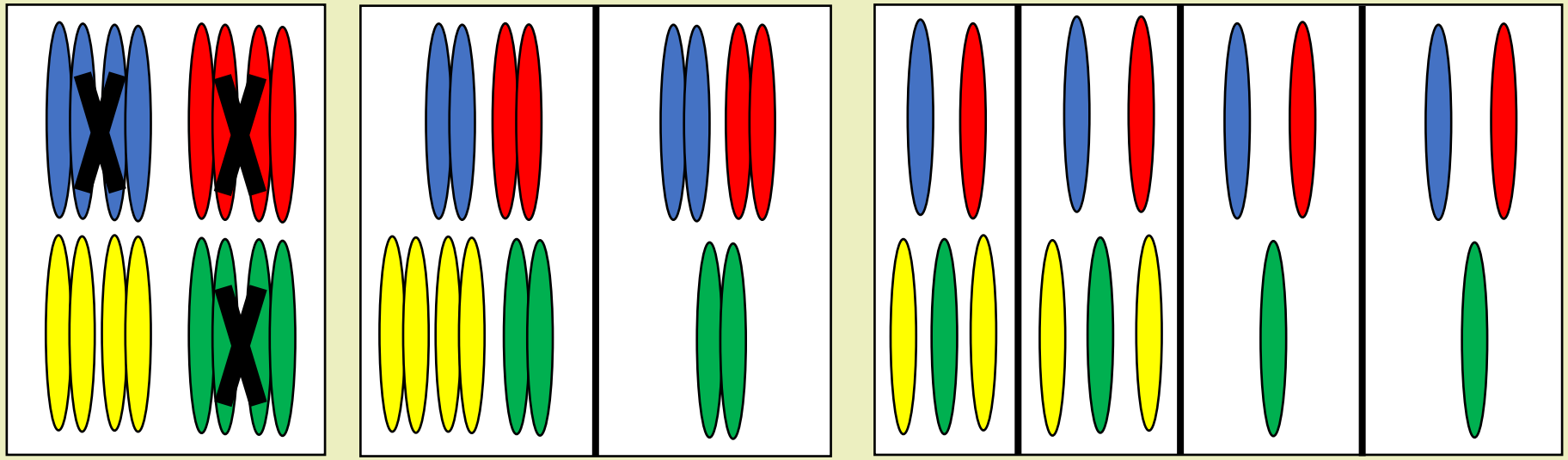
(d) Crossing over (Figure 1A) creates physical connections that are required for proper separation of homologous chromosomes during meiosis. A diploid cell with four pairs of homologous chromosomes undergoes meiosis to produce four haploid cells. Crossing over occurs between only three of the pairs. **Predict** the number of chromosomes most likely present in each of the four haploid cells. Provide reasoning to **justify** your prediction. **Explain** how plant breeders can use the information in Table 1 to help develop new varieties of corn.



- Two cells will have three/n-1 chromosomes; two cells will have five/n+1 chromosomes.

- During meiosis I, (three homologous pairs separate normally, and) one pair does not separate/experiences nondisjunction. In meiosis II, the sister chromatids separate normally.

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- Two cells will have three/n-1 chromosomes; two cells will have five/n+1 chromosomes.

d) Two of the haploid cells will have three chromosomes while two of the haploid cells will have five chromosomes. This is because if only three of the four pairs have crossing over then the fourth pair will not be properly separated. Thus, at the first division one cell will get three chromosomes while the other cell gets five since one of the pairs were not properly separated and instead had both chromosomes of the pair put into one cell. Now, at the second division, the cell with three chromosomes will have its sister chromatids separate to make cells with three chromosomes each. On the other hand the cell with five chromosomes will have its ~~get~~ sister chromatids separate to divide into two cells with five chromosomes each.

- During meiosis I, (three homologous pairs separate normally, and) one pair does not separate/experiences nondisjunction. In meiosis II, the sister chromatids separate normally.

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Accept one of the following:

- Because crossing over increases genetic diversity, the plant breeders can breed strains with high crossover numbers/double-strand breaks.
- They can increase the number of double-stranded breaks, which may lead to more crossovers that increase genetic variation.

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Plant breeders can use the information in Table 1 to see which corn strains of corn have the most number of double stranded breaks and thus the largest average number of crossovers. If the breeder breeds two strains of corn that both have high averages of the number of crossovers, the genes of the corns will mix and the offspring

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of the corn will be more genetically diverse. ~~Gaith~~ The breeder can continue breeding corn to create offspring that are even more genetically ~~diverse, corn~~ diverse, which can then eventually become its own new variety of corn.