Past-paper walk-through

Artificial Selection ▪ 7.3

eXercise

Questions in this set

- 2022 Q2
- 2014 Q4

Reading the mark scheme

- **B1** a mark that stands on its own – the point is either made or not.
- **M1** a *method* mark: the right approach, even if the number is wrong.
- **A1** an *answer* mark, and it usually needs its M mark first.
- **C1** a working mark on the way to the answer.
- // separates answers the examiner accepts equally.
- **ecf** = error carried forward: a later part is marked on your own earlier answer.
- **owtte** = "or words to that effect" – the wording need not match.

Question 2

2022 ▪ Q2

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: two diagrams of paired homologous chromosomes (each shown as two X-shaped sister-chromatid pairs, one gray and one white, joined at a chiasma near the bottom). Panel A: shows a double-strand break being repaired WITH crossing over — the chromatid pair undergoes an intermediate exchange step (crossed strands shown) and resolves into two chromosomes each with a mix of gray and white chromatid segments. Panel B: shows a double-strand break repaired WITHOUT crossing over —

Question 2

the chromatid pair resolves directly back into the original all-gray and all-white chromosomes with no exchange of segments.]

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

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

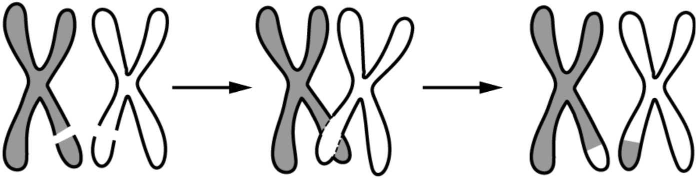
Strain of Corn	Number of Double-Strand Breaks	Average Number of Crossovers ($\pm 2\mathrm{SE}_{\bar{x}}$)
I	710	19.5 ± 0.5
II	650	18.0 ± 0.7
III	600	17.5 ± 1.0
IV	510	16.0 ± 1.0
V	425	14.0 ± 0.5
VI	325	11.0 ± 1.5

Question 2

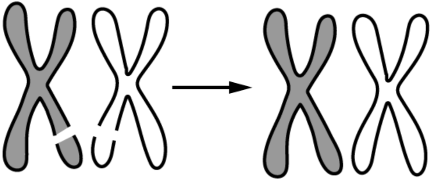
(a) The double-strand breaks occur along the DNA backbone. Describe the process by which the breaks occur.

Question 2

A



B



Question 2

2022 ▪ Q2

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: two diagrams of paired homologous chromosomes (each shown as two X-shaped sister-chromatid pairs, one gray and one white, joined at a chiasma near the bottom). Panel A: shows a double-strand break being repaired WITH crossing over — the chromatid pair undergoes an intermediate exchange step (crossed strands shown) and resolves into two chromosomes each with a mix of gray and white chromatid segments. Panel B: shows a double-strand break repaired WITHOUT crossing over — the chromatid pair resolves directly back into the original all-gray and all-white chromosomes with no exchange of segments.]

Question 2

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

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

(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

Question 2

data, determine whether corn strains I, II, and III differ in their average number of crossovers.

Question 2

2022 ▪ Q2

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: two diagrams of paired homologous chromosomes (each shown as two X-shaped sister-chromatid pairs, one gray and one white, joined at a chiasma near the bottom). Panel A: shows a double-strand break being repaired WITH crossing over — the chromatid pair undergoes an intermediate exchange step (crossed strands shown) and resolves into two chromosomes each with a mix of gray and white chromatid segments. Panel B: shows a double-strand break repaired WITHOUT crossing over — the chromatid pair resolves directly back into the original all-gray and all-white chromosomes with no exchange of segments.]

Question 2

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

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

(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.

Question 2

2022 ▪ Q2

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: two diagrams of paired homologous chromosomes (each shown as two X-shaped sister-chromatid pairs, one gray and one white, joined at a chiasma near the bottom). Panel A: shows a double-strand break being repaired WITH crossing over — the chromatid pair undergoes an intermediate exchange step (crossed strands shown) and resolves into two chromosomes each with a mix of gray and white chromatid segments. Panel B: shows a double-strand break repaired WITHOUT crossing over — the chromatid pair resolves directly back into the original all-gray and all-white chromosomes with no exchange of segments.]

Question 2

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

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

(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

Question 2

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.

Solution 2

(a)

Mark scheme

- The double-strand breaks occur through (enzymatic) hydrolysis of the covalent bonds between the sugars and phosphates (nucleotides) of the DNA backbone.

Solution 2

(b) Mark scheme

1 pt Appropriate axis scaling on the graph (x-axis: number of double-strand breaks, roughly 0-800; y-axis: average number of crossovers, roughly 0-20+, both with regular, appropriate intervals). [1 pt] Accurately plotted X,Y points for each of the six corn strains (I-VI): (710,19.5) I, (650,18.0) II, (600,17.5) III, (510,16.0) IV, (425,14.0) V, (325,11.0) VI. [1 pt] Accurate error bars (+/-2SE) plotted on each point per Table 1, e.g. Strain I: 19.5+/-0.5; Strain VI: 11.0+/-1.5. [1 pt] Determination: there is no statistical difference in the average number of crossovers between Strains II and III (their error bars overlap); Strain I is higher/different from Strains II and III.

Solution 2

(c)

Mark scheme

- There is, in general, a direct correlation / positive relationship between the average number of double-strand breaks and the average number of crossovers across the corn strains analyzed - as double-strand breaks increase, crossovers increase.

Solution 2

(d) Mark scheme

1 pt Prediction: two of the four haploid cells will have three chromosomes (n-1) and two will have five chromosomes (n+1). [1 pt] Justification: during Meiosis I, three of the four homologous pairs (the ones with crossing over) separate normally, but the one pair without crossing over does not separate properly (experiences nondisjunction); in Meiosis II the sister chromatids separate normally, producing the n-1/n+1 combination in the four resulting cells. [1 pt] Application for plant breeders: because crossing over increases genetic diversity, breeders can breed/select corn strains with high double-strand-break numbers (which correlate with high crossover numbers), or increase the number of double-strand breaks, to increase genetic variation for developing new varieties.

Question 4

2014 ▪ Q4

Adult male guppies (*Poecilia reticulata*) exhibit genetically determined spots, while juvenile and adult female guppies lack spots. In a study of selection, male and female guppies from genetically diverse populations were collected from different mountain streams and placed together in an isolated environment containing no predators. The study population was maintained for several generations in the isolated area before being separated into two groups. One group was moved to an artificial pond containing a fish predator, while a second group was moved to an artificial pond containing no predators. The two groups went through several generations in their new environments. At different times during the experiment, the mean number of spots per adult male guppy was determined as shown in the figure below. Vertical bars in the figure represent two standard errors of the mean (SEM).

Question 4

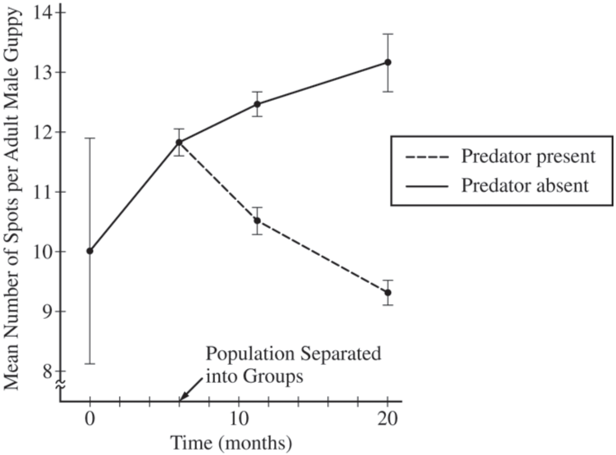
[Line graph titled "Mean Number of Spots per Adult Male Guppy" vs. "Time (months)"; y-axis from ~8 (with a break symbol) to 14 in increments of 1; x-axis from 0 to 20, tick marks at 0, 10, 20. A vertical dotted arrow labeled "Population Separated into Groups" points to approximately month 6. Two data series with error bars ($\pm$2 SEM): "Predator present" (dashed line) starting at (0,10) with a very large error bar (from about 8.2 to 11.9), rising to a peak at (6,11.8), then declining to (10,10.5) and (20,9.3). "Predator absent" (solid line) starting at (0,10) with the same large error bar, rising to (6,11.8), continuing to rise to (10,12.5) and (20,13.2). Both lines coincide from month 0 to month 6, then diverge after separation into groups.]

(a) Describe the change in genetic variation in the population between 0 and 6 months and **provide** reasoning for your description based on the means and SEM.

Question 4

(b) Propose ONE type of mating behavior that could have resulted in the observed change in the number of spots per adult male guppy between 6 and 20 months in the absence of the predator.
(c) Propose an evolutionary mechanism that explains the change in average number of spots between 6 and 20 months in the presence of the predator.

Question 4



Mean Number of Spots per Adult Male Guppy
14
13
12
11
10
9
8
Predator present
Predator absent
Population Separated into Groups
0
10
20
Time (months)

Solution 4

(a)

Mark scheme

- Describe change (1 point): genetic variation is decreasing between 0 and 6 months. Provide reasoning (1 point): the SEM (standard error of the mean) gets smaller over this interval.

Solution 4

(b)

Mark scheme

- 1 point for proposing a plausible mating behavior, e.g.: sexual selection for individuals with more spots, OR random mating behavior resulted in an increased number of spots by chance.

Solution 4

(c)

Mark scheme

- 1 point for proposing a plausible evolutionary mechanism, e.g.: directional selection against individuals with large numbers of spots / directional selection for individuals with fewer spots (natural selection used in context), OR genetic drift resulting in several generations of decreased numbers of spots.