Past-paper walk-through

Meiosis ▪ 5.1

eXercise

Questions in this set

- 2026 Q2
- 2026 Q4
- 2025 Q6
- 2024 Q1
- 2022 Q2
- 2016 Q7
- 2015 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

2026 ▪ Q2

Eukaryotic cells use small interfering RNA (siRNA) molecules that regulate the expression of certain genes by binding to complementary sequences in target mRNAs. This binding causes the protein AGO2 to cleave the target mRNAs. As a result of the cleavage, the mRNAs are not translated.

The following information applies to parts B, C, and D.

To investigate the role of AGO2 in the cleavage of mRNA transcribed from two genes, Gene *G* and Gene *H*, scientists determined the amount of Gene *G* and Gene *H* mRNA produced in cells with three different *AGO2* genotypes:

- Homozygous for the wild-type AGO2 protein ($AGO2^{+/+}$) - Heterozygous for the allele encoding a nonfunctional AGO2 protein ($AGO2^{+/-}$) - Homozygous for the allele encoding a nonfunctional AGO2 protein ($AGO2^{-/-}$)

Question 2

The scientists then calculated the amount of Gene *G* and Gene *H* mRNA produced from cells of each genotype relative to that in $AGO2^{+/+}$ cells. These results are shown in the table.

Relative Average Amounts of Gene *G* and Gene *H* mRNA in Cells with Different *AGO2* Genotypes

	mRNA in $AGO2^{+/+}$ Cells $\pm SE_{\bar{x}}$	mRNA in $AGO2^{+/-}$ Cells $\pm SE_{\bar{x}}$	mRNA in $AGO2^{-/-}$ Cells $\pm SE_{\bar{x}}$
Gene *G*	1.0 ± 0.1	0.9 ± 0.4	1.5 ± 0.5
Gene *H*	1.0 ± 0.1	2.0 ± 0.1	3.0 ± 0.4

(a) Describe one location where ribosomes are found in eukaryotic cells.

Question 2

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(b)(i) Using the template in the space provided for your response, **construct** a bar graph that represents the data in the table. Your graph should be appropriately plotted and labeled.

(b)(ii) Based on the table, **determine** all the cells in which the amount of Gene *G* mRNA produced is statistically the same as the amount in the cells with the $AGO2^{+/+}$ genotype.

Question 2

2026 ▪ Q2

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(c)(i) Based on the table, **describe** the relationship between the number of wild-type copies of the *AGO2* gene and the amount of Gene *H* mRNA in the cells.

(c)(ii) Based on the data in the table for Gene *H*, **calculate** the percent by which the average amount of mRNA in $AGO2^{-/-}$ cells increases compared with that in $AGO2^{+/-}$ cells.

Question 2

2026 ▪ Q2

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(d)(i) The scientists claim that siRNA binding and AGO2 cleavage of mRNAs play a greater role in the regulation of Gene *H* expression than in the regulation of Gene *G* expression. Based on the table, **support** the scientists' claim.

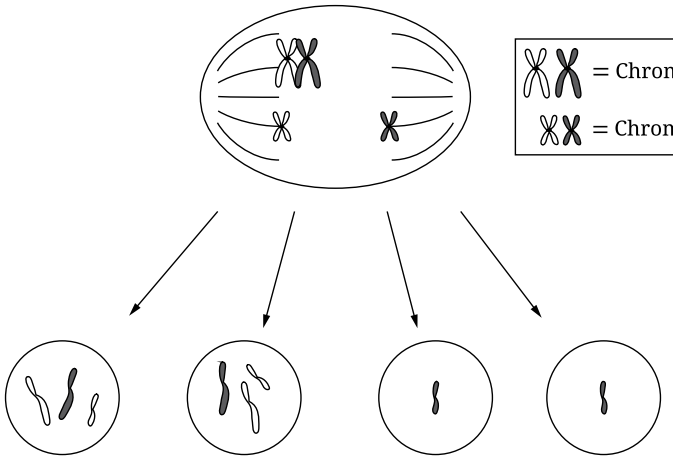
(d)(ii) Anaphase I of meiosis is blocked in mice with the $AGO2^{-/-}$ genotype. Scientists hypothesize that the block in meiosis occurs because the continued presence of a spindle-fiber stabilizing protein prevents the chromosomes from separating. Based on the table, **explain** how the $AGO2^{-/-}$ genotype could cause this effect on the dividing cells.

Question 4

2026 ▪ Q4

The process of meiosis enables animals that reproduce sexually to produce gametes.
(a) Describe one characteristic of chromosome movement during Meiosis I.

Question 4



Question 4

2026 ▪ Q4

The process of meiosis enables animals that reproduce sexually to produce gametes.

(b) Explain why chromosomes are more visible when viewed under a microscope during mitosis or meiosis than at any other time in the cell cycle.

Question 4

2026 ▪ Q4

The process of meiosis enables animals that reproduce sexually to produce gametes.

(c) An animal cell with two pairs of homologous chromosomes (a diploid number of four) has undergone meiosis to produce four gametes, and an error occurred at one step, as shown in the figure. One set of chromosomes is represented in white, and the other set is represented in gray.

An Animal Cell Undergoing Meiosis

[Diagram of a dividing cell (undergoing Meiosis II, anaphase-like stage) with spindle fibers, showing an error where chromosomes failed to separate properly on one side. Legend: a white/gray joined pair of sister chromatids = Chromosome 1; a smaller white/gray joined pair = Chromosome 2. In the cell: the left half shows one Chromosome 1 pair (still joined, both chromatids) plus one single Chromosome 2 chromatid; the right half shows one single Chromosome 2 chromatid and one single

Question 4

(unpaired) small chromatid. Four arrows point from the cell to four resulting gamete circles: gamete 1 contains three chromatids (an extra copy of Chromosome 1 plus Chromosome 2 material); gamete 2 similarly contains three chromatids; gamete 3 contains one single small chromatid; gamete 4 contains one single small chromatid. (Net effect: two gametes end up with an extra copy of Chromosome 1, and two gametes are missing a copy of Chromosome 1 - i.e., nondisjunction of Chromosome 1 during Meiosis II.)]

Assume that each gamete produced by the cell shown in the figure is fertilized by a gamete with a complete haploid set of chromosomes. Also assume gene regulation on Chromosome 1 is not affected by the number of copies of Chromosome 1 in the four resulting viable zygotes. **Predict** the difference in mRNA production from genes on Chromosome 1 among the four possible zygotes.

Question 4

2026 ▪ Q4

The process of meiosis enables animals that reproduce sexually to produce gametes.

(d) Triploidy describes a condition in which an organism has three complete sets of chromosomes in each cell. Provide reasoning to **justify** the claim that most organisms with triploidy cannot produce gametes with the chromosome number typical of the species.

Question 6

2025 ▪ Q6

The *ald* gene of fruit flies encodes the ALD protein, which is associated with both the centromeres of chromosomes and protein filaments produced during meiosis. In the absence of functional ALD proteins, gamete-producing cells enter anaphase I before homologous chromosomes are correctly aligned. As a result, the gametes produced do not contain the correct numbers of chromosomes.

Scientists generated four mutations in the *ald* gene: *ald1*, *ald3*, *ald23*, and *del*, which was a deletion of the gene. To study the role of the ALD protein in meiosis, scientists used gameteforming metaphase cells from groups of flies with different *ald* genotypes. Some of the flies were homozygous for the wild-type allele of *ald*: *WT/WT*. Other flies were heterozygous for different *ald* alleles: *WT/del*; *ald1/del*; *ald3/ald23*; *ald23/del*. The scientists measured the

Question 6

percent of metaphase cells that contained ALD-associated filaments (Figure 1A) and the amount of ALD protein produced by each of the cell types (Figure 1B).
Figure 1. (A) The average percent of gamete-forming metaphase cells that contained filaments associated with ALD and (B) the amount of ALD protein produced by each cell type. A thicker band indicates a greater amount of ALD protein.
[Panel A: Bar graph; y-axis "Percent of Metaphase Cells with ALD-Associated Filaments" from 0 to 100 in increments of 20. x-axis "*ald* Genotype" with five bars labeled "WT/WT", "WT/del", "ald1/del", "ald3/ald23", "ald23/del". Approximate values with error bars: WT/WT ≈ 63 (error bar roughly 45-80), WT/del ≈ 77 (error bar roughly 65-88), ald1/del ≈ 13 (error bar roughly 5-20), ald3/ald23 ≈ 6 (small error bar), ald23/del ≈ 1 (negligible, near 0).
Panel B: Gel-blot style diagram labeled "ALD Protein" showing bands of varying thickness for the same five genotypes in the same order (WT/WT, WT/del, ald1/del,

Question 6

ald3/ald23, ald23/del): WT/WT shows a thick solid band; WT/del shows a medium-thick band; ald1/del shows a medium-thick band similar to WT/del; ald3/ald23 shows a thin band; no band is shown for ald23/del (or an extremely faint/absent line).]

(a) Based on Figure 1A, identify the fly genotype in which the average percent of metaphase cells with ALD-associated filaments is close to 12%.

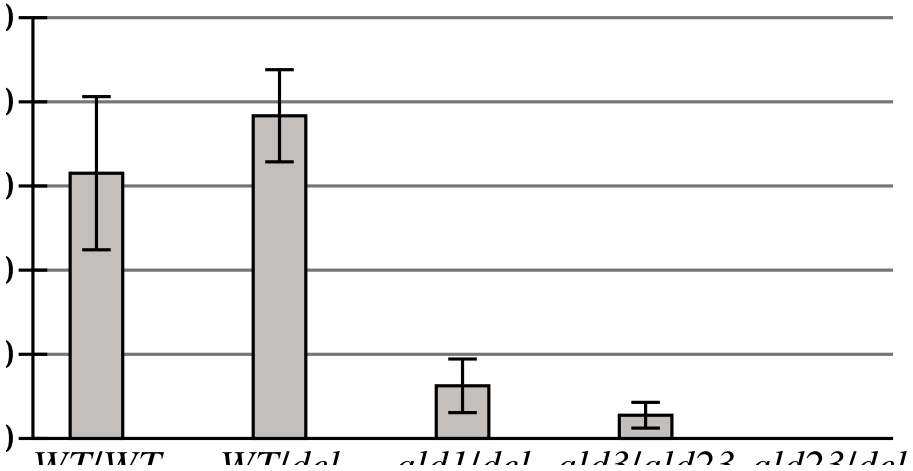
(b) Based on Figure 1B, describe the difference in ALD protein production between gamete-forming metaphase cells of flies with the genotype *ald3/ald23* and flies with the genotype *ald23/del*.

(c) Scientists hypothesize that gamete-forming metaphase cells can produce a normal amount of ALD-associated filaments even when they produce about half as much ALD protein as the wild-type cells produce. Use the data in Figures 1A and 1B to support the scientists' hypothesis.

Question 6

(d) For gamete-forming metaphase cells of the *WT/del* and *ald1/del* flies, explain why the phenotypes observed in Figure 1A differ even though the amount of ALD protein produced (Figure 1B) does not.

Question 6



Solution 6

(a)

Mark scheme

- The genotype ald1/del has an average of about 12% of metaphase cells with ALD-associated filaments, based on Figure 1A.

Solution 6

(b)

Mark scheme

- More ALD protein is produced by ald3/ald23 cells than by ald23/del cells (Figure 1B shows a thin but visible band for ald3/ald23, while ald23/del shows little to no detectable band) — equivalently, ald23/del cells produce little to no ALD protein compared with ald3/ald23 cells.

Solution 6

(c)

Mark scheme

- The WT/del cells produce about half as much ALD protein as WT/WT cells (Figure 1B, a thinner band), yet show no substantial difference from WT/WT in the percent of metaphase cells with ALD-associated filaments (Figure 1A, roughly 76% vs 63%, with overlapping error bars) — this comparison supports the hypothesis that gamete-forming metaphase cells can produce a normal amount of ALD-associated filaments with about half the normal ALD protein.

Solution 6

(d)

Mark scheme

- The phenotypes differ because it is protein function, not quantity, that differs: WT/del flies produce ALD protein from their functional WT allele, which is enough to generate a wild-type phenotype (~76% of cells with filaments), whereas ald1/del flies produce a similar total amount of ALD protein (Figure 1B) but it comes from the nonfunctional/impaired ald1 allele, so it cannot properly support filament formation, giving a much lower percentage of cells with ALD-associated filaments (~12%, Figure 1A).

Question 1

2024 ▪ Q1

Crossing over in meiosis I is required for homologous chromosomes to properly align during metaphase and segregate during the first cell division.
Some regions of a chromosome called hotspots display a higher frequency of crossing over than other regions do. Crossing over is suppressed in chromosomal regions near the centromeres. The centromere region of a duplicated chromosome includes a collection of proteins that form a structure called the kinetochore. Scientists hypothesized that one or more of these kinetochore proteins are responsible for suppressing crossing over around the centromere.
To investigate their hypothesis, scientists modified chromosome 8 in yeast such that, in each cell, one chromosome from the pair of homologous chromosome 8s contained the gene encoding red fluorescent protein (RFP), while the other chromosome from the pair contained the gene encoding green fluorescent protein (GFP). Cells expressing

Question 1

RFP emit (give off) red light, and cells expressing GFP emit green light. Models of the modified chromosome 8 both before and after crossing over are shown in Figure 1. [Figure 1. Models of modified chromosome 8 used in the experiment (A) before and (B) after crossing over occurs at the hotspot. Panel A "Before Crossing Over": two homologous chromosome 8 pairs are drawn, each as a pair of sister chromatids joined at a Centromere. On the upper homolog, the region near one end is labeled "Gene Encoding RFP" (shown as a filled gray box on both sister chromatids near the tip). On the lower homolog, the corresponding region is labeled "Gene Encoding GFP" (shown as a hatched/striped box on both sister chromatids). A "Hotspot" region is marked between the centromere and the RFP/GFP genes with double-arrow brackets. Panel B "After Crossing Over": the same two homologous chromosomes are shown after a crossover has occurred at the hotspot, so that one chromatid of the upper homolog now carries the "Gene Encoding GFP" marker (hatched box) instead of RFP, and one

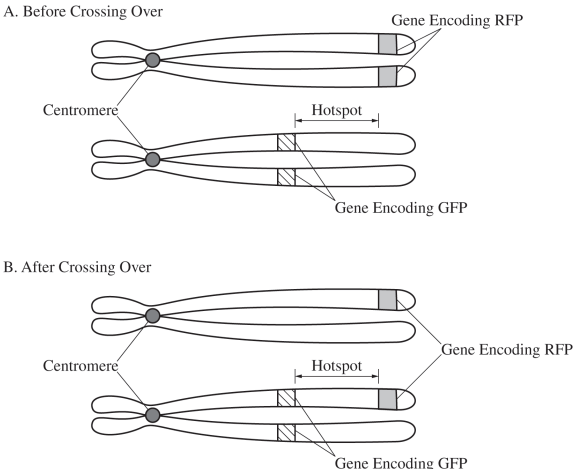
Question 1

chromatid of the lower homolog now carries the "Gene Encoding RFP" marker (filled gray box) instead of GFP — i.e., the fluorescent markers have been exchanged between one chromatid of each homolog. Centromere and Hotspot are again labeled.] The scientists then investigated whether attaching individual kinetochore proteins to a specific DNA sequence present in a known crossing-over hotspot on chromosome 8 affected the frequency of crossing over at this location. In their first experiment, they examined three groups of yeast cells containing the modified chromosome 8. Group 1 contained no kinetochore proteins attached to the hotspot, group 2 contained the kinetochore protein CTF attached to the hotspot, and group 3 contained the kinetochore protein IML attached to the hotspot. For each group, the scientists determined the frequency of crossing over between the RFP and GFP genes. To determine the frequency, the scientists added the number of cells emitting both red

Question 1

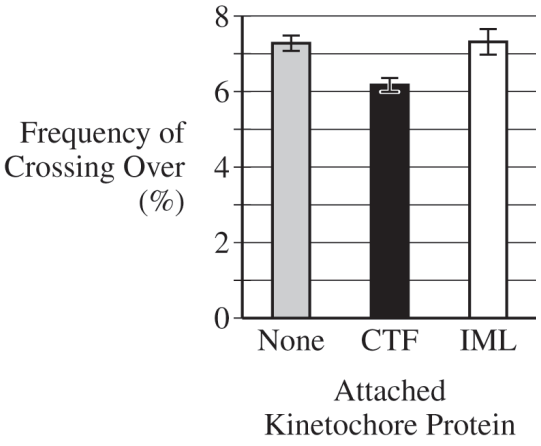
and green light to the number of cells that emitted no light and divided by the total number of cells (Figure 2).
[Figure 2. Bar graph, "The frequency of crossing over in a hotspot on yeast chromosome 8 for cell groups treated with different kinetochore proteins. Error bars represent $\pm 2SE_{\bar{x}}$." Y-axis: Frequency of Crossing Over (
(a)(i) Describe the function of S phase of interphase.
(a)(ii) Explain why some haploid cells formed after meiosis in this experiment will have only one fluorescent marker.

Question 1


A. Before Crossing Over
Gene Encoding RFP
Centromere
Hotspot
Gene Encoding GFP
B. After Crossing Over
Gene Encoding RFP
Centromere
Hotspot
Gene Encoding GFP

Question 1

Question 1


Frequency of Crossing Over (%)
8
6
4
2
0
None
CTF
IML
Attached Kinetochore Protein