2025

AP® Biology

Scoring Guidelines

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Question 1: Interpreting and Evaluating Experimental Results — 9 points

Most proteins that are secreted from a cell must be transported to the endoplasmic reticulum (ER) either during translation or after translation.

For proteins transported during translation, this process begins in the cytosol and pauses when a specific sequence of amino acids is translated. The translation complex is then transported to the surface of the ER where translation continues. Proteins that are transported after translation are translated entirely in the cytosol and then transported to the ER. In both instances, the translated proteins enter the ER through a protein channel in the membrane of the ER.

Researchers studying the two types of protein transport identified that the ER membrane protein SR is necessary for transport during translation, while the ER membrane protein Sec62 is necessary for transport after translation. To investigate which transport mechanism is used for different proteins, researchers first created small interfering RNAs (siRNAs) that reduce expression of either SR or Sec 62. They then treated groups of cells with either the SR siRNA or the Sec62 siRNA and determined the relative amount of SR and Sec 62 protein in each group of cells compared with cells treated with a control siRNA. (Figure 1).

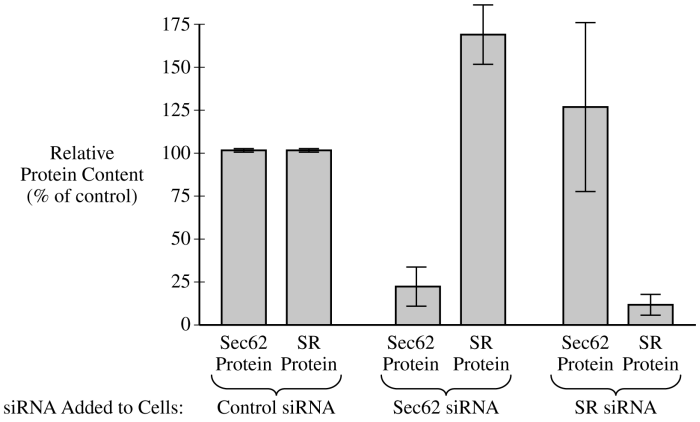

Figure 1. Average relative amounts of Sec62 and SR proteins in cells treated with control siRNA, Sec62 siRNA or SR siRNA. Error bars represent $\pm SE_{\bar{x}}$.

The researchers then measured the amount of each of three different proteins that was transported to the ER in cells treated with Sec62 siRNA or SR siRNA. The researchers calculated the percent transported relative to the cells treated with control siRNA (Figure 2).

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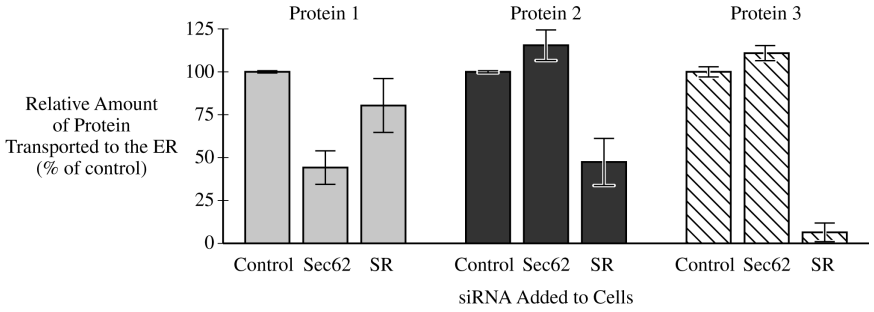

Figure 2. Average relative amounts of three proteins that were transported to the ER when treated with control siRNA, Sec62 siRNA, or SR siRNA. Error bars represent $\pm SE_{\bar{x}}$.

A	**Describe** the function of ribosomes. Examples of acceptable responses may include the following: • Ribosomes synthesize polypeptides/proteins. • Ribosomes perform translation. • Ribosomes are sites of polypeptide/protein synthesis.	**Point A1**
B	(i) **Identify** the dependent variable in the experiments shown in Figure 1. • The (relative) amount of protein/protein content	**Point B1**
	(ii) **Justify** why the researchers included the control of measuring the relative amounts of both Sec62 and SR proteins in cells that were treated with Sec62 siRNA only (data shown in Figure 1). Examples of acceptable responses may include the following: • (The control allowed the researchers) to determine whether the (Sec62) siRNA reduced/affected the content of both proteins (relative to protein content in the presence of the control siRNA). • (The control allowed the researchers) to determine whether the (Sec62) siRNA reduced/affected Sec62 (protein content) only.	**Point B2**
	(iii) Based on Figure 1, **describe** the effect on the production of SR protein when cells are treated with Sec62 siRNA. Examples of acceptable responses may include the following: • (SR protein production) increased. • (SR protein production) increased by 65% (accept 50–80%).	**Point B3**

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C	(i) **Identify** the independent variable in the researchers' second experiment (data shown in Figure 2). Examples of acceptable responses may include the following: • (The type of) siRNA (added to the cells) • The type of protein whose amount was measured	**Point C1**
	(ii) Based on Figure 2, **identify** the protein(s) that when treated with Sec62 siRNA showed an increase in percent transport to the ER compared with the control. Examples of acceptable responses may include the following: • Proteins 2 and 3 • Protein 2 • Protein 3	**Point C2**
	(iii) Protein 1 is encoded by 234 nucleotides, while protein 2 is encoded by 495 nucleotides. Assuming all nucleotides for both proteins encode amino acids, **calculate** the difference in the number of amino acids between the two proteins. • 87 (amino acids) [(495/3)−(234/3)]	**Point C3**
D	(i) Researchers claim that protein 1 is the only tested protein that is transported to the ER following its complete translation in the cytosol. Using data from Figure 2, **support** the researchers' claim. • Only protein 1 showed a reduced amount/percentage of transport when cells were treated with Sec62 siRNA.	**Point D1**
	(ii) For any protein that enters the ER, researchers claim that amino acids close to the protein's amino terminus determine how likely the protein is to pass through the protein channel within the ER membrane. **Justify** the researchers' claim based on your understanding of factors that affect the transport of proteins across membranes. • Amino acids (at the amino terminus) that have similar polarity to/opposite charge to (the R groups of amino acids lining) the protein channel are more likely to pass through the channel (than are proteins where the amino terminus contains amino acids with dissimilar polarity or similar charge).	**Point D2**

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Question 2: Interpreting and Evaluating Experimental Results with Graphing — 9 points

Many insects rely on pheromones (chemical signals) that are released by the females to find mating partners. Scientists hypothesize that, in a certain type of moth, the behavior of male moths in response to pheromones is regulated by the extracellular signaling molecule 20E.

To investigate whether the binding of 20E to its receptor, DopEcR, affects behavior in moths, scientists injected male moths with saline (control solution) or with small interfering RNA molecules (siRNAs) that inhibit the expression of the gene encoding DopEcR. The scientists then exposed the moths to the pheromone and determined the percent of total time observed that the moths engaged in general activity, defined as movement in any direction. The scientists also determined the percent of the general activity time that the moths spent in oriented activity, defined as movement toward an area of high pheromone concentration (Table 1).

Table 1. Average General and Oriented Activity in Male Moths Injected With Saline or siRNA Molecules

Treatment	General Activity (percent of total time observed, average $\pm 2\mathrm{SE}_{\bar{x}}$)	Oriented Activity (percent of general activity, average $\pm 2\mathrm{SE}_{\bar{x}}$)
Male moths injected with saline (control solution)	95 ± 5	60 ± 4
Male moths injected with siRNAs that inhibit expression of the gene encoding DopEcR	90 ± 8	25 ± 6

DopEcR is a G protein-coupled receptor. When 20E binds to DopEcR, GTP displaces the GDP bound to the G protein, and a signaling pathway is activated. The scientists hypothesize that this leads to the transcription of genes associated with the oriented activity observed in the male moths (Figure 1).

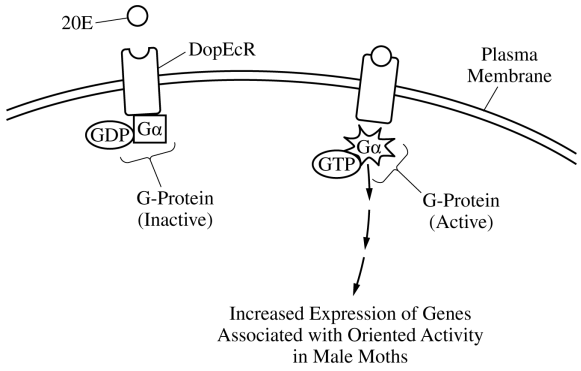

Figure 1. A simplified model of a signaling pathway activated by the binding of 20E to its receptor, DopEcR

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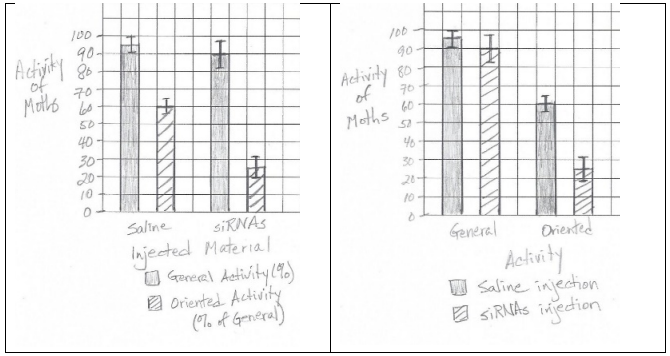
A — Many receptors are embedded in the plasma membrane. **Describe** the polarity of the portion of the receptor that is inside the membrane. — **Point A1**

Examples of acceptable responses may include the following:

- (The portion of the receptor inside the membrane) is nonpolar.
- (The portion of the receptor inside the membrane) is hydrophobic.

B — (i) Using the template in the space provided for your response, **construct** an appropriate type of graph that represents the data in Table 1. Your graph should be appropriately plotted and labeled. — **Point B1**

- Data are represented in a bar/modified bar graph.
- Examples of acceptable responses may include the following:



(i) Using the template in the space provided for your response, **construct** an appropriate type of graph that represents the data in Table 1. Your graph should be appropriately plotted and labeled. — **Point B2**

- Data and error bars are accurately plotted.

(i) Using the template in the space provided for your response, **construct** an appropriate type of graph that represents the data in Table 1. Your graph should be appropriately plotted and labeled. — **Point B3**

- Graph is appropriately labeled.

(ii) Based on the data in Table 1, **determine** the type of activity that was affected by inhibiting the expression of the DopEcR receptor. — **Point B4**

- Oriented activity (was affected).

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C	(i) Based on Table 1, identify the treatment group in which the oriented activity was greater than 50% of the general activity. Examples of acceptable responses may include the following: • The control/saline-treated group • Male moths injected with saline/control solution	**Point C1**
	(ii) The scientists studied some moths with a mutation in the gene encoding the G protein. The mutation prevents GTP from displacing the GDP bound to the G protein. Based on Figure 1, **predict** the effect of this mutation on the oriented activity in male moths exposed to the pheromone. • (The moths will show) decreased (oriented) activity.	**Point C2**
D	(i) Expression of the gene encoding DopEcR is low in the male moths during their first few days as adults, when they are sexually immature. Gene expression rapidly increases as the moths reach sexual maturity. The scientists claim that this increase in gene expression increases the likelihood of males finding females with whom to mate. Use evidence from the information provided to **support** the scientists' claim. Examples of acceptable responses may include the following: • (Increased expression of DopEcR) will increase oriented activity (and the moths' ability to find a mate). • (An increase in DopEcR expression) will enable the binding of 20E to more receptors. • (An increase in DopEcR expression) will make the males more sensitive to pheromones from the females. • (An increase in DopEcR expression) will enable the binding of 20E to more receptors and will make the males more sensitive to pheromones from the females.	**Point D1**
	(ii) Based on Figure 1, **explain** how an inhibitor of the DopEcR pathway might serve as an effective chemical to protect crops from moth damage. • (An inhibitor of the pathway) will reduce oriented activity/expression of genes associated with oriented activity and therefore decrease mating/population growth.	**Point D2**

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Question 3: Scientific Investigation — 4 points

Buffelgrass, an invasive grass species in southwestern desert ecosystems, is threatening the saguaro cactus, a keystone species in these ecosystems. Buffelgrass is drought-tolerant and can survive wildfires. However, the dry buffelgrass also acts as fuel for wildfires, causing the fires to be more severe. Older saguaro cacti can survive wildfires; however, many of the young cacti cannot.

Scientists conducted an experiment to determine whether they could control the abundance of the buffelgrass population. The scientists identified several native grass species that, when grown with buffelgrass, might reduce the abundance of buffelgrass. They grew buffelgrass in the presence of several different native grass species in greenhouses, in either nondrought (watered every 3 days) or drought (watered every 9 days) conditions. After twelve weeks, they measured the height and dry weight of the buffelgrass in each treatment group.

A	**Describe** the effect that removing a keystone species will have on an ecosystem. Examples of acceptable responses may include the following: • (Removal of a keystone species) reduces biodiversity/diversity/resilience (of the ecosystem). • (Removal of a keystone species) will cause the ecosystem to collapse.	**1 point**
B	**Identify** a control group the scientists should include in their experiment. Examples of acceptable responses may include the following: • (A treatment group with) only buffelgrass planted • (A treatment group with) no native grass species	**1 point**
C	**State** the null hypothesis of the experiment in which buffelgrass is grown in the presence of native grass species. Examples of acceptable responses may include the following: • There will be no difference in/effect on the abundance/dry weight/height/size of buffelgrass (when grown alone as compared with) when grown with native plants. • There will be no difference in/effect on the abundance/dry weight/height/size of buffelgrass grown in drought and nondrought conditions.	**1 point**
D	Scientists have found that the population growth rates of native grasses are much slower than the population growth rate of buffelgrass following a wildfire. The scientists claim that wildfires will therefore increase the abundance of buffelgrass plants in the ecosystem. Based on the information given, **justify** the scientists' claim. Examples of acceptable responses may include the following: • (With fewer native plant species after a wildfire) buffelgrass will have less competition/no competition (for resources). • (With fewer native plant species after a wildfire) buffelgrass will have more resources (for growth, development, and reproduction).	**1 point**

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Question 4: Conceptual Analysis — 4 points

Twenty million years ago the Caribbean Sea and Pacific Ocean were connected, and water flowed freely between the two bodies of water. Many of the same marine species were found in both areas. Over millions of years, the land referred to as the Isthmus of Panama formed, eventually closing off the connection between the Caribbean Sea and Pacific Ocean and creating two separate bodies of water. The ecology of these two marine habitats was dramatically altered by this land formation. The warmer Caribbean water could no longer flow west, so the Pacific water cooled and became more nutrient-rich, while the Caribbean water became warmer.

A	**Describe** the genetic evidence that evolution is occurring in a population. Examples of acceptable responses may include the following: • There are changes in allele/gene frequencies. • There are heritable changes in phenotypes.	**1 point**
B	**Explain** how the isolation of marine species by the formation of a land barrier can lead to divergent evolution of those species. Examples of acceptable responses may include the following: • Selective pressures could result in different allele/gene frequencies. • (The land barrier) results in reproductive isolation/lack of gene flow/allopatric speciation. • Different environmental conditions/pressures select for different alleles/genotypes/phenotypes.	**1 point**
C	The formation of the Isthmus of Panama connected two continents, North America and South America. Many North American land animal species migrated to South America after the formation of the isthmus and occupied similar niches as South American species. **Predict** the effect the formation of the isthmus had on resource availability for South American species. • (Resource availability) would have decreased.	**1 point**
D	**Justify** your prediction in part C. • More species would now be competing for the same resources, (resulting in fewer resources for each individual).	**1 point**

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Question 5: Analyze Model or Visual Representation of a Biological Concept or Process — 4 points

Figure 1 shows the reactions of the metabolic pathway used to synthesize amino acid B from amino acid A in cells.

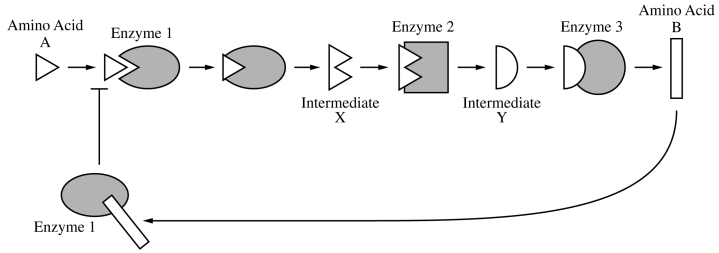

Figure 1. Synthesis of amino acid B from amino acid A

A	**Describe** a characteristic of an enzyme's active site that allows it to catalyze a specific chemical reaction. Examples of acceptable responses may include the following: • (The active site) is able to bind to a (specific) substrate/amino acid. • The shape/charge of the active site of an enzyme is compatible with a (specific) substrate/amino acid. • (The active site) positions the substrate/amino acid in a way that makes the reaction more likely. • Induced fit stresses bonds so that a reaction is more likely to occur.	**1 point**
B	Based on Figure 1, **explain** how the binding of amino acid A to enzyme 1 is regulated by amino acid B. Examples of acceptable responses may include the following: • Amino acid B inhibits the binding of amino acid A to enzyme 1. • Amino acid B binds to an allosteric site of enzyme 1 and prevents amino acid A from binding to enzyme 1. • The binding of amino acid B causes the enzyme to change shape and prevents amino acid A from binding to enzyme 1.	**1 point**
C	Using the information in Figure 1, **identify** the product of the reaction catalyzed by enzyme 2: intermediate X, intermediate Y, or amino acid B. • (Intermediate) Y	**1 point**
D	Based on Figure 1, **explain** how a change in pH could affect enzyme 3 in such a way that amino acid B cannot be produced. Examples of acceptable responses may include the following: • (A change in pH) could change the structure/active site/enzyme so that intermediate Y/the substrate cannot bind. • (A change in pH) could denature (enzyme 3) so that intermediate Y/the substrate cannot bind.	**1 point**

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Question 6: Analyze Data — 4 points

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 gamete-forming 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 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).

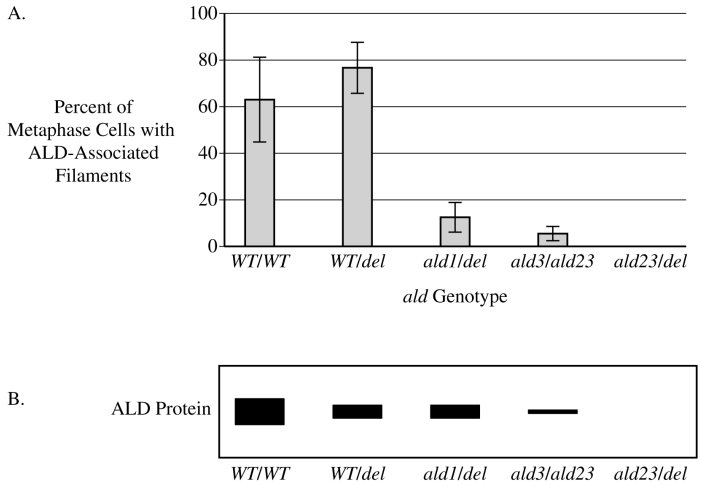

Figure 1. (A) The average percent of gamete-forming metaphase cells that contained filaments associated with ALD and (B) the amount of ALD protein produced by each cell type. A thicker band indicates a greater amount of ALD protein.

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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%. • *ald1/del*	**1 point**
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*. Examples of acceptable responses may include the following: • More ALD protein is produced by *ald3*/*ald23* cells (than by *ald23*/*del* cells). • Less ALD protein is produced by *ald23*/*del* cells (than by *ald3*/*ald23* cells). • No ALD protein is produced by *ald23*/*del* cells (whereas it is produced by *ald3*/*ald23* cells).	**1 point**
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. Examples of acceptable responses may include the following: • (With half as much protein) the *WT/del* cells show no difference in percent of (gamete forming metaphase cells with) ALD-associated filaments. • The data for the *WT/del* relative to/in comparison with the *WT/WT* cells support the scientists' hypothesis.	**1 point**
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. Examples of acceptable responses may include the following: • (The phenotypes) differ because only the *WT*/*del* flies produce enough functional (ALD) protein to generate a wild-type phenotype. • When one allele encodes functional ALD protein (in *WT/del* flies), the flies can generate a wild-type phenotype/produce ALD-associated filaments in a similar amount as *WT/WT* flies. • Both genotypes produced ALD protein, but the *ald1* mutation resulted in a protein with reduced function (compared with *WT*, resulting in a different phenotype).	**1 point**

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