2025

AP® Biology

Sample Student Responses and Scoring Commentary

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Free-Response Question 1

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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).

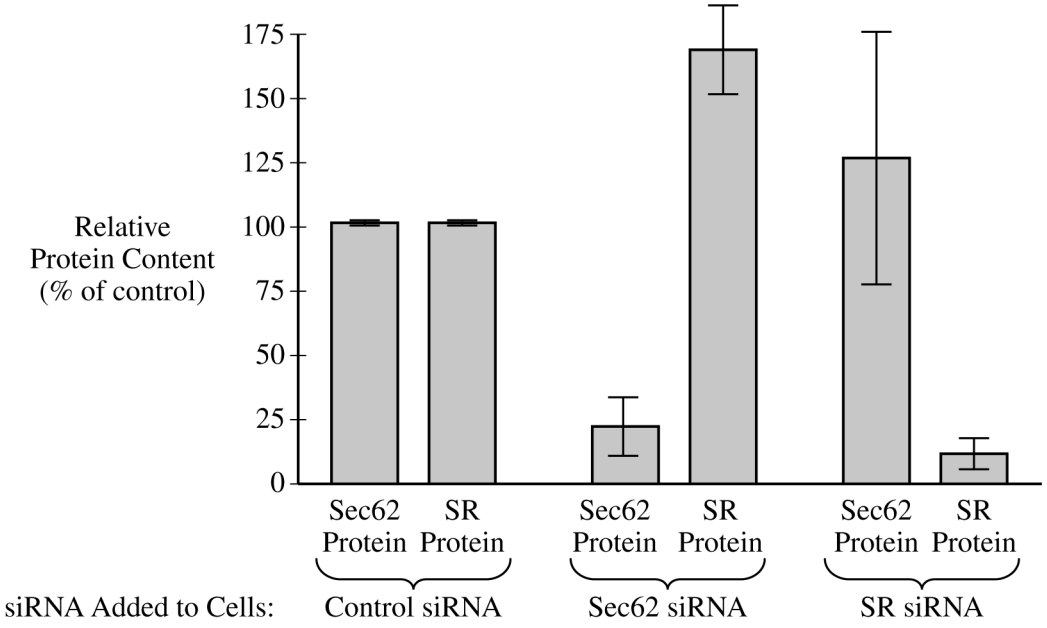

Figure 1. Average relative amounts of Sec62 and SR proteins in cells treated with control siRNA, Sec62 siRNA or SR siRNA. Error bars represent $\pm SE_{\bar{X}}$.

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).

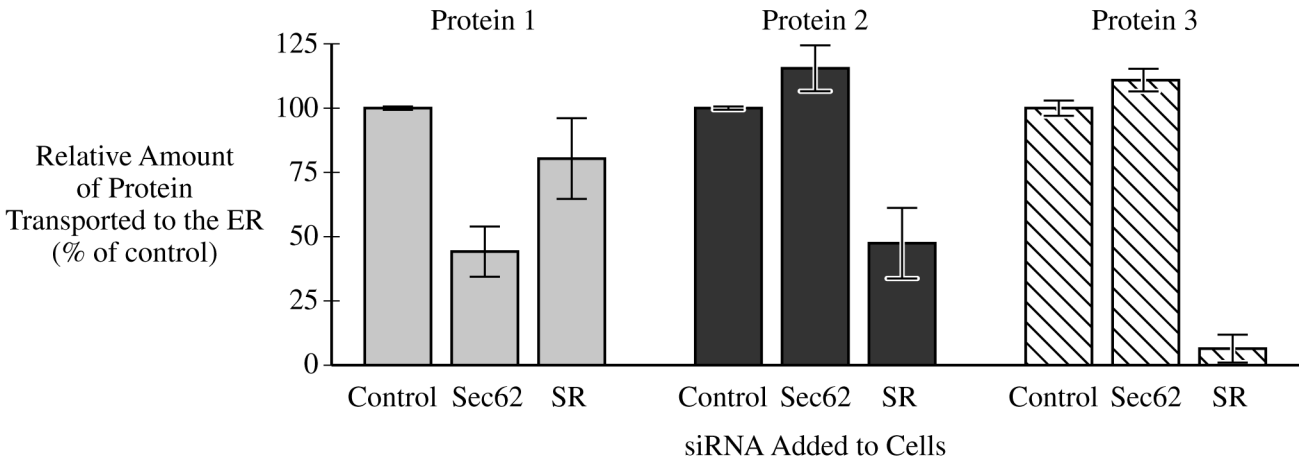

Figure 2. Average relative amounts of three proteins that were transported to the ER when treated with control siRNA, Sec62 siRNA, or SR siRNA. Error bars represent $\pm SE_{\bar{X}}$.

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**

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**

BEGIN Question 1

Begin your response to **QUESTION 1** on this page. Do not skip lines.

a) ribosomes aid in protien synthesis, specifically in the translation stage of gene expression. The ribosome is the organelle ~~[illegible]~~ that facilitates the creation of a polypeptide chain.

b) i) dependent variable was the relative protien content (% of control)

ii) a control was included to have results to compare that of the experimented groups do. since the control models how the normal conditions would be, it allows researchers to see what changed in the experimental groups

iii) the production of the SR protien when treated with sec62 siRNA increased dramatically.

c) ~~[illegible]~~

i) the independent variable was the kind of siRNA ~~[illegible]~~ used to treat the protien

ii) protien 2 and ~~protein~~ protien 3

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Additional page for answering Question 1

Continue your response to **QUESTION 1** on this page. Do not skip lines.

iii) protien 1:
nucleotides = 234
amino acids = 234/3 = 78

protien 2:
nucleotides = 495
amino acids = 495/3 = 165

165 - 78 = 87

proteins 1 and 2 have a difference in the number of amino acids of 87 amino acids.

d) i) Sec 62 is needed for transportation after translation. If a protien is mostly transported after translation then it will require use of sec62. however, if the cell ~~is~~ is treated with siRNA sec62, which reduced expression of sec62, a reduced amount of protien will be able to be transported, since sec62 is needed. according to figure 2, of the 3 proteins, protien 1 is the only one that reduces in response to siRNA sec62, signifying that it needs sec62, which means it is ~~the~~ the only one that gets transported after translation.

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Q5526/03

Additional page for answering Question 1

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ii) membranes are typically made of phospholipids, which require molecules to be nonpolar and uncharged while passing through. because those around the amino terminus come into contact with the membrane, those amino acids should be non-polar.

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BEGIN Question 1

Begin your response to **QUESTION 1** on this page. Do not skip lines.

1A) Ribosomes act as the site for protein synthesis by facilitating mRNA to feed through and tRNA to donate amino acids to the sequence.

1B) i. Relative protein content is the dependent variable.

ii. Doing this allowed them to compare the experimental results to what happens under normal conditions.

iii. The production of the SR protein increases significantly when cells are treated with Sec62 siRNA.

1C) i. The type of siRNA cells were treated with.

ii. Protein 2 and protein 3 exhibited this.

iii. There is a difference of 87 amino acids.

1D) i. With this protein, the control group is the one which is transported to the ER reliably, whereas the experimental samples both don't go there as much.

ii. The amino acids close to the terminus would interact the most with the outside environment, and thus their charge, attraction/repulsion relative to water, etc., as opposed to that of other amino acids, would be the deciding factor in whether or not a membrane channel protein would let the polypeptide in.

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BEGIN Question 1

Begin your response to **QUESTION 1** on this page. Do not skip lines.

a) Ribosomes transport proteins

b) The dependent variable is the type of siRNA. The control was included to measure the effects of the treated protein. It allows you to compare results. The production of SR protein being treated with Sec62 siRNA is increasing and much greater, meaning this treatment increase the relative protein content.

c) The independent variable is proteins. The proteins treated with Sec62 siRNA that show an increase are proteins 2 and 3. The difference in the number of amino acids between protein 1 and 2 is 87 amino acids

d) Protein 1 is the only protein that causes both Sec62 and SR to be lower than the control. The amino acids closer determine if they'll pass through the protein channel because they code for certain things and will help facilitate what enters the membranes, acting as channal proteins

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Question 1

Note: Student samples are quoted verbatim and may contain spelling and grammatical errors.

Overview

NEW for 2025: The question overviews can be found in the *Chief Reader Report on Student Responses* on AP Central.

Sample: 1A
Score: 7

The response earned 1 point in part A for describing that "ribosomes aid in protein synthesis." Additional information is provided that supports and does not negate the initial description of the function.

The response earned 1 point in part B (i) for identifying "relative protien content" as the dependent variable. The response did not earn a point in part B (ii) because it does not specify that the control indicates whether the Sec62 siRNA only reduces Sec62 production. It includes only vague references to "have results to compare that of the experimental groups" and "how the normal conditions would be." The response earned 1 point in part B (iii) for describing that "the production of the SR protein ... increased."

The response earned 1 point in part C (i) for identifying "the kind of siRNA" as the independent variable. The response earned 1 point in part C (ii) for identifying that "protien 2 and protien 3" had increased transport. The response earned 1 point in part C (iii) for calculating that the difference in number of amino acids was "87 amino acids."

The response earned 1 point in part D (i) for indicating that "of the 3 protiens, protien 1 is the only one that reduces in response to siRNA sec62." It includes additional information that accurately explains how this pattern supports the researcher's claim. The response did not earn a point in part D (ii) because it incorrectly connects the idea that the "amino acids should be non-polar" to the properties of the phospholipid bilayer rather than to the interior of a membrane protein channel.

Sample: 1B
Score: 6

The response earned 1 point in part A for describing that "Ribosomes act as the site for protein sinthesis."

The response earned 1 point in part B (i) for identifying that "Relative protein content is the dependent variable." The response did not earn a point in part B (ii) because it incorrectly justifies that this "allowed them to compare the experimental results to what happens under normal conditions." It does not specify that the control indicates whether the Sec62 siRNA only reduces Sec62 production. The response earned 1 point in part B (iii) for describing that "the production of the SR protein increases."

The response earned 1 point in part C (i) for identifying the independent variable as "the type of siRNA cells were treated with." The response earned 1 point in part C (ii) for identifying that "Protein 2 and protein 3" showed increased transport. The response earned 1 point in part C (iii) for calculating "a difference of 87 amino acids."

Question 1 (continued)

The response did not earn a point in part D (i) because it does not indicate that only protein 1 had reduced transport when treated with Sec62 siRNA. The response did not earn a point in part D (ii) because, although it describes the "charge, attraction/repulsion relative to water" of the amino acids close to the amino terminus, it does not indicate that the protein channel must have similar polarity or opposite charge to these amino acids.

Sample: 1C
Score: 3

The response did not earn a point in part A because to "transport proteins" is only one step in the function of ribosomes, which is to synthesize proteins.

The response did not earn a point in part B (i) because it incorrectly identified "the type of siRNA" rather than the relative protein content as the dependent variable. The response did not earn a point in part B (ii) because it includes only a vague reference to "measure the effects of the treated protein" and "allows you to compare results." It does not specify that the control indicates whether the Sec62 siRNA only reduces Sec62 production. The response earned 1 point in part B (iii) for describing that the "production of SR protein being treated with Sec62 siRNA is increasing."

The response did not earn a point in part C (i) because it does not specify which proteins can be considered an independent variable. Because there are two types of proteins referenced in this question—Sec62/SR and proteins 1/2/3—any response that identifies proteins as the independent variable rather than type of siRNA must specify the type of protein whose amount was measured, or proteins 1/2/3, to earn the point. The response earned 1 point in part C (ii) for identifying that the "proteins ... that show an increase are proteins 2 and 3." The response earned 1 point in part C (iii) for calculating the difference as "87 amino acids."

The response did not earn a point in part D (i) because it explains that "Protein 1 is the only protein that causes both Sec62 and SR to be lower than the control." This incorrectly refers to Sec62 and SR as dependent variables that have a change that is caused by protein 1, rather than explaining that the transport of protein 1 was reduced by treatment with Sec62 siRNA, while proteins 2 and 3 did not show this pattern. The response did not earn a point in part D (ii) because it does not describe the polarity or charge of the amino acids at the amino terminus of the protein being synthesized or of the membrane channel.