

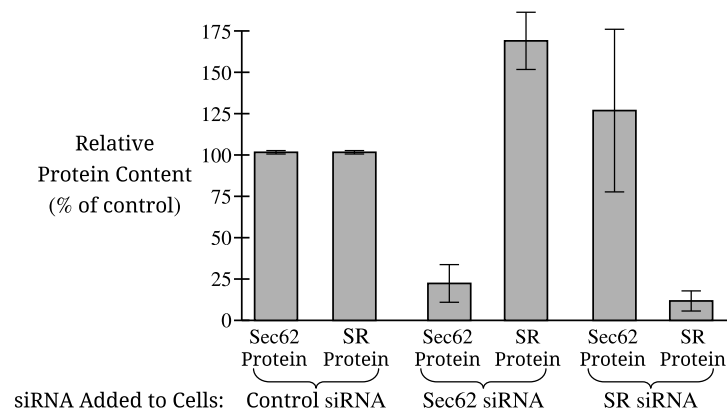
1. Most proteins that are secreted from a cell must be transported to the endoplasmic reticulum (ER) either during translation or after translation.

A. Describe the function of ribosomes.

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 Sec62. They then treated groups of cells with either the SR siRNA or the Sec62 siRNA and determined the relative amount of SR and Sec62 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 $\pm SE_{\bar{x}}$.

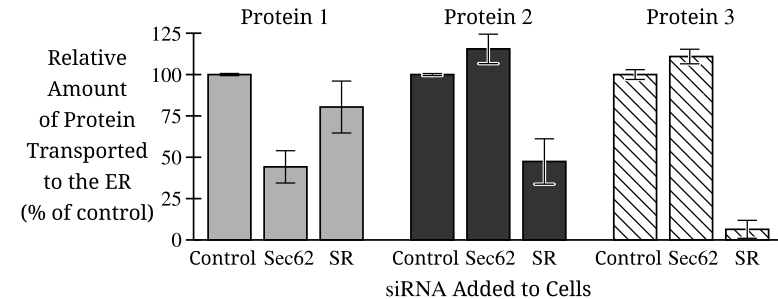


B.

- Identify** the dependent variable in the experiments shown in Figure 1.
- 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).
- Based on Figure 1, **describe** the effect on the production of SR protein when cells are treated with Sec62 siRNA.

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 $\pm SE_{\bar{x}}$.



C.

- Identify** the independent variable in the researchers' second experiment (data shown in Figure 2).
- 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.
- 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.

D.

- 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.
- 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.

2. 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.

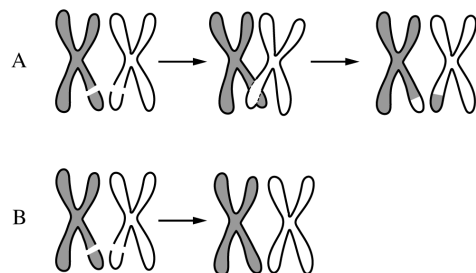


Figure 1. Double-strand breaks in chromatids are repaired with crossing over (A) or without crossing over (B).

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

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

Write your responses to this question only on the designated pages in the separate Free Response booklet.

6. Researchers are studying the use of RNA vaccines to protect individuals against certain diseases. To develop the vaccines, particular cells are first removed from an individual. Then mRNAs coding for specific proteins from a pathogen are introduced into the cells. The altered cells are injected back into the individual, where the cells make the proteins encoded by the introduced mRNAs. The individual then produces an immune response to the proteins that will help to protect the individual from developing a disease if exposed to the pathogen in the future.

When introduced into cells, the mRNAs used for vaccines must be stable so that they are not degraded before the encoded proteins are produced. Researchers developed several modified caps that they hypothesized might make the introduced mRNAs more stable than mRNAs with the normal GTP cap. To test the effect of the modified caps, the researchers produced mRNAs that differed only in their cap structure (no cap, the normal cap, or modified caps I, II, or III). They introduced the same amount of each mRNA to different groups of cells and measured the amount of time required for half of the mRNAs to degrade (mRNA half-life) and the total amount of protein translated from the mRNAs (Table 1).

TABLE 1. EFFECT OF mRNA CAP STRUCTURE ON mRNA HALF-LIFE AND PROTEIN TRANSLATED FROM THE INTRODUCED mRNA

5' Cap Structure	mRNA Half-Life $\pm 2SE_{\bar{x}}$ (hours after introduction into cells)	Total Amount of Protein Translated from mRNA $\pm 2SE_{\bar{x}}$ (relative to amount in normal cap)
No cap	1.41 ± 0.02	0.011 ± 0.000
Normal GTP cap	16.10 ± 1.83	1.000 ± 0.007
Modified cap I	15.50 ± 1.57	4.777 ± 0.042
Modified cap II	27.00 ± 2.85	13.094 ± 0.307
Modified cap III	18.09 ± 0.81	6.570 ± 0.075

- (a) Based on the data, **identify** which cap structure is most likely to protect the end of the mRNAs from degradation.
- (b) Based on the data for the mRNAs with modified caps, **describe** the relationship between the mRNA half-life and the total amount of protein produced.
- (c) After examining the data on mRNA half-lives and the amount of protein produced, the researchers hypothesized that each mRNA molecule with modified cap I was translated more frequently than was each mRNA molecule with the normal GTP cap. **Evaluate** their hypothesis by comparing the data in Table 1.
- (d) Introduction of mRNAs into cells allows the cells to produce foreign proteins that they might not normally produce. **Explain** why the production of a foreign protein may be more likely from the introduction of mRNA than DNA into cells.

Write your responses to this question only on the designated pages in the separate Free Response booklet.

STOP

END OF EXAM