The common bedbug (*Cimex lectularius*) is a species of insect that is becoming increasingly resistant to insecticides. Bedbugs possess several genes suspected of contributing to the resistance, including *P450*, *Abc8*, and *Cps*. To investigate the role of these genes in insecticide resistance, researchers deleted one or more of these genes in different strains of bedbugs, as indicated in Figure 1, and treated the strains with the insecticide beta-cyfluthrin. Each strain was genetically identical except for the deleted gene(s) and was equally fit in the absence of beta-cyfluthrin. The percent survival of each strain following beta-cyfluthrin treatment is shown in Figure 1.

(a) **Identify** the control strain in the experiment. Use the means and confidence intervals in Figure 1 to **justify** the claim that *Abc8* is effective at providing resistance to beta-cyfluthrin.

**Identification (1 point)**
- Strain I

**Justification (1 point)**
- Error bars/CIs from strain I/control/WT do not overlap with strain III/Abc8 deleted strain.
- Mean % survival of strain III/Abc8 deletion falls outside the 95% confidence interval of strain I/control/WT.
- Strain III/Abc8 deletion shows a statistically significant difference from strain I/control.
(b) \( P450 \) encodes an enzyme that detoxifies insecticides. \( Abc8 \) encodes a transporter protein that pumps insecticides out of cells. \( Cps \) encodes an external structural protein located in the exoskeleton that greatly reduces the absorption of insecticides. Based on this information and the data in Figure 1, explain how a deletion of both \( P450 \) and \( Abc8 \) results in lower survival in bedbugs compared with a deletion of \( Cps \) only.

**Explanation (1 point per row; 2 points maximum)**

<table>
<thead>
<tr>
<th>Strain</th>
<th>( P450 ) and ( Abc8 )</th>
<th>( Cps ) only</th>
<th>Explanation</th>
</tr>
</thead>
<tbody>
<tr>
<td>V</td>
<td>Deleted</td>
<td>Present</td>
<td>Bedbugs can neither detoxify nor pump out insecticide, which results in a lower chance of bedbug survival.</td>
</tr>
<tr>
<td>IV</td>
<td>Present</td>
<td>Deleted</td>
<td>Bedbugs can detoxify and pump out insecticide, which results in a higher chance of bedbug survival.</td>
</tr>
</tbody>
</table>
Percent survival of five strains of bedbugs treated with beta-cyfluthrin. A (+) indicates the gene is present; a (−) indicates the gene is deleted. Error bars represent the 95% confidence interval.

<table>
<thead>
<tr>
<th>Strain</th>
<th>I</th>
<th>II</th>
<th>III</th>
<th>IV</th>
<th>V</th>
</tr>
</thead>
<tbody>
<tr>
<td>P450</td>
<td>+</td>
<td>−</td>
<td>+</td>
<td>+</td>
<td>−</td>
</tr>
<tr>
<td>Abc8</td>
<td>+</td>
<td>+</td>
<td>−</td>
<td>+</td>
<td>−</td>
</tr>
<tr>
<td>Cps</td>
<td>+</td>
<td>−</td>
<td>+</td>
<td>−</td>
<td>+</td>
</tr>
</tbody>
</table>

 common bedbug (Cimex lectularius) is a species of insect that is becoming increasingly resistant to insecticides. Bedbugs possess several genes suspected of contributing to the resistance, including P450, Abc8, and Cps. To investigate the role of these genes in insecticide resistance, researchers deleted one or more of these genes in different strains of bedbugs, as indicated in Figure 1, and treated the strains with the insecticide beta-cyfluthrin. Each strain was genetically identical except for the deleted gene(s) and was equally fit in the absence of beta-cyfluthrin. The percent survival of each strain following beta-cyfluthrin treatment is shown in Figure 1.

(a) Identify the control strain in the experiment. Use the means and confidence intervals in Figure 1 to justify the claim that Abc8 is effective at providing resistance to beta-cyfluthrin.

(b) P450 encodes an enzyme that detoxifies insecticides. Abc8 encodes a transporter protein that pumps insecticides out of cells. Cps encodes an external structural protein located in the exoskeleton that greatly reduces the absorption of insecticides. Based on this information and the data in Figure 1, explain how a deletion of both P450 and Abc8 results in lower survival in bedbugs compared with a deletion of Cps only.

A. Strain I was the control strain. Abc8 is effective at providing resistance because when Abc8 was deleted on 20% survived and the confidence intervals between the strain without Abc8 (III) and the
CONTROL (I) did not overlap, meaning there is a reliable statistical difference between having the AbCP gene and not having it. When both AbCP and P450 are deleted, the cell cannot get rid of the insecticide that has been absorbed. So because CPS doesn't encode for an exoskeleton that completely stops the insecticide from getting into the cell, any insecticide that does get into the cell remains toxic and has no way of leaving. When just CPS is deleted, the survival rate is much higher because although a higher concentration of insecticide is getting into the cell, it is getting detoxified and being removed through the transporter pumps encoded by AbCP.
4. The common bedbug (*Cimex lectularius*) is a species of insect that is becoming increasingly resistant to insecticides. Bedbugs possess several genes suspected of contributing to the resistance, including *P450*, *Abc8*, and *Cps*. To investigate the role of these genes in insecticide resistance, researchers deleted one or more of these genes in different strains of bedbugs, as indicated in Figure 1, and treated the strains with the insecticide beta-cyfluthrin. Each strain was genetically identical except for the deleted gene(s) and was equally fit in the absence of beta-cyfluthrin. The percent survival of each strain following beta-cyfluthrin treatment is shown in Figure 1.

(a) **Identify** the control strain in the experiment. Use the means and confidence intervals in Figure 1 to **justify** the claim that *Abc8* is effective at providing resistance to beta-cyfluthrin.

(b) *P450* encodes an enzyme that detoxifies insecticides. *Abc8* encodes a transporter protein that pumps insecticides out of cells. *Cps* encodes an external structural protein located in the exoskeleton that greatly reduces the absorption of insecticides. Based on this information and the data in Figure 1, **explain** how a deletion of both *P450* and *Abc8* results in lower survival in bedbugs compared with a deletion of *Cps* only.

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*Figure 1. Percent survival of five strains of bedbugs treated with beta-cyfluthrin. A (+) indicates the gene is present; a (−) indicates the gene is deleted. Error bars represent the 95% confidence interval.*
lowest survival rate when only one gene is deleted
with a survival rate of about \(15\% \text{ to } 40\%\).

(b) With the deletion of \(P450\) the insecticide-
insecticidal insecticides would be toxic and
with the deletion of \(Abc8\), the transporter-
protein would not be able to pump the
insecticides out of the cell. Even though the
\(Cps\) would reduce the absorption of the insecticides,
two of the main genes would not be present
to combat the amount that did get through
which leads to a lower survival rate which
can be seen on strain \(V\). However, when only
\(Cps\) is deleted the remaining genes, \(P450\) and
\(Abc8\), can effectively (mostly) fight off the
insecticides that have reached the cell by
pumping it out of the cell and detoxifying it.
This can be seen in strain \(iv\) that shows a higher
survival rate than strain \(v\).
Figure 1. Percent survival of five strains of bedbugs treated with beta-cyfluthrin. A (+) indicates the gene is present; a (−) indicates the gene is deleted. Error bars represent the 95% confidence interval.

4. The common bedbug (Cimex lectularius) is a species of insect that is becoming increasingly resistant to insecticides. Bedbugs possess several genes suspected of contributing to the resistance, including P450, Abc8, and Cps. To investigate the role of these genes in insecticide resistance, researchers deleted one or more of these genes in different strains of bedbugs, as indicated in Figure 1, and treated the strains with the insecticide beta-cyfluthrin. Each strain was genetically identical except for the deleted gene(s) and was equally fit in the absence of beta-cyfluthrin. The percent survival of each strain following beta-cyfluthrin treatment is shown in Figure 1.

(a) **Identify** the control strain in the experiment. Use the means and confidence intervals in Figure 1 to justify the claim that Abc8 is effective at providing resistance to beta-cyfluthrin.

(b) **P450** encodes an enzyme that detoxifies insecticides. **Abc8** encodes a transporter protein that pumps insecticides out of cells. **Cps** encodes an external structural protein located in the exoskeleton that greatly reduces the absorption of insecticides. Based on this information and the data in Figure 1, explain how a deletion of both P450 and Abc8 results in lower survival in bedbugs compared with a deletion of Cps only.

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**a.** The control strain in the experiment is **Strain I**. Abc8 is effective at providing resistance to beta-cyfluthrin because without Abc8 we can see that the average percent of survival is

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only 15.5% with a small confidence interval. However, with Abcs the average percent of survival is around 54.7% with a larger confidence interval.

b.) The deletion of both Py50 and Abc8 results in lower survival in bed bugs compared with a deletion of Cps only because without Py50 and Abc8, there is no mechanism inside the cell that detoxifies or pumps out the insecticides. Cps only protects some on the outside of the cell which means that if the insecticides get into the cell, the cell will automatically die.
Question 4

Overview

The first part of the question focused on the interpretation of data presented both in graphic and tabular form. Students were provided with the results of an experiment involving five different strains of genetically altered bedbugs. The presence or absence of three different genes, P450, Abc8, and Cps, was given for each strain. The corresponding graph showed the average percent survival, with corresponding 95 percent confidence intervals, when each of the strains was exposed to the insecticide beta-cyfluthrin. Students were asked to identify the control strain and to justify the claim that Abc8 is effective at providing resistance to the insecticide. Next, the students were provided with information on how each gene product functions in contributing to insecticide resistance. The students were then asked to explain the relationships among the functions of the gene products in providing resistance when either: 1) P450 and Abc8 are both deleted, or 2) when only Cps is deleted.

The key understandings and skills students were expected to demonstrate included the following:

- Knowledge of how organisms are affected by abiotic factors was used to investigate insecticide resistance.
- The understanding that expression, or lack thereof, of genes can alter phenotypes was used in an experimental investigation to help determine the function of the gene products in a biological process (insecticide resistance).
- Knowledge of experimental design and statistics was used to interpret the results of an experiment.

Sample: 4A
Score: 4

The response earned 1 point in part (a) for correctly identifying the control strain in the experiment as Strain I. The response earned 1 point in part (a) for correctly justifying the claim by stating that “the confidence intervals between the strain without Abc8 (III) and the control (I) did not overlap.” The response earned 1 point in part (b) for correctly explaining that when both P450 and Abc8 are deleted the insecticide “remains toxic and has no way of leaving.” Lower survival is implied because the response specifies a higher survival rate when just Cps is deleted. The response earned 1 point in part (b) for correctly explaining that “when just Cps is deleted the survival rate is much higher” because insecticide “is getting detoxified and being removed through the transporter pumps.”

Sample: 4B
Score: 3

The response earned 1 point in part (a) for correctly identifying the control strain in the experiment as Strain I. The response earned 1 point in part (b) for correctly explaining that “with the deletion of P450 the insecticides would be toxic and with the deletion of Abc8, the transporter protein would not be able to pump the insecticides out … which leads to a lower survival rate.” The response earned 1 point in part (b) for correctly explaining “when only Cps is deleted … P450 and Abc8 … fight off the insecticide … by pumping it out of the cell and detoxifying it,” resulting in a higher survival rate.
Sample: 4C
Score: 2

The response earned 1 point in part (a) for correctly identifying the control strain in the experiment as Strain I. The response earned 1 point in part (b) for correctly explaining that the “deletion of both P450 and Abc8 results in lower survival ... because ... there is no mechanism ... that detoxifies or pumps out the insecticides.”