2024

AP® Biology

Sample Student Responses and Scoring Commentary

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Free-Response Question 2

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

To investigate how increases in environmental temperatures affect the metabolism of certain organisms, researchers incubated liver cells from toads at different temperatures and measured two markers of metabolic activity (Table 1): the rate of oxygen consumption and the rate of ATP synthesis.

TABLE 1. RATE OF OXYGEN CONSUMPTION AND ATP SYNTHESIS AT DIFFERENT TEMPERATURES

Metabolic Marker	20°C	25°C	30°C
Rate of Oxygen Consumption (nmol/min/mg of mitochondrial protein $\pm 2\mathrm{SE}_{\bar{X}}$)	12.8 ± 2.2	16.5 ± 2.0	22.1 ± 0.7
Rate of ATP Synthesis (nmol/min/mg of mitochondrial protein $\pm 2\mathrm{SE}_{\bar{X}}$)	12.6 ± 1.6	16.8 ± 2.0	21.07 ± 0.8

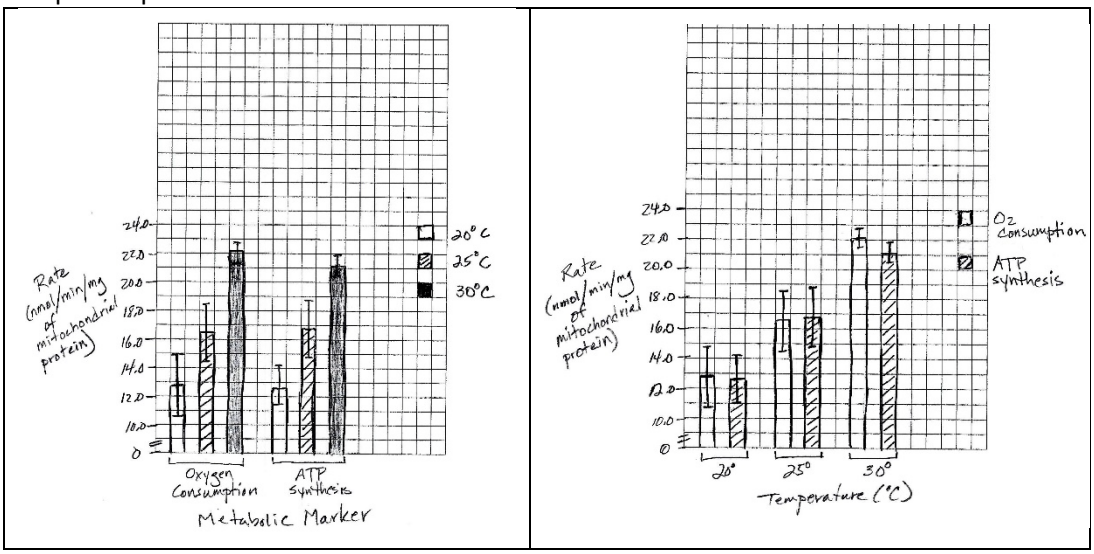
(a) **Describe** the role of water in the hydrolysis of ATP. **1 point**

Accept one of the following:

- Water is added in the process of cleaving/splitting (a phosphate from) ATP.
- Water breaks down/splits ATP.

(b) Using the template in the space provided for your response, **construct** a bar graph that represents the data shown in Table 1. Your graph should be appropriately plotted and labeled. **1 point**

Sample Responses:



- Data are represented in a bar graph.

Using the template in the space provided for your response, **construct** a bar graph that represents the data shown in Table 1. Your graph should be appropriately plotted and labeled. **1 point**

- Graph is appropriately labeled.

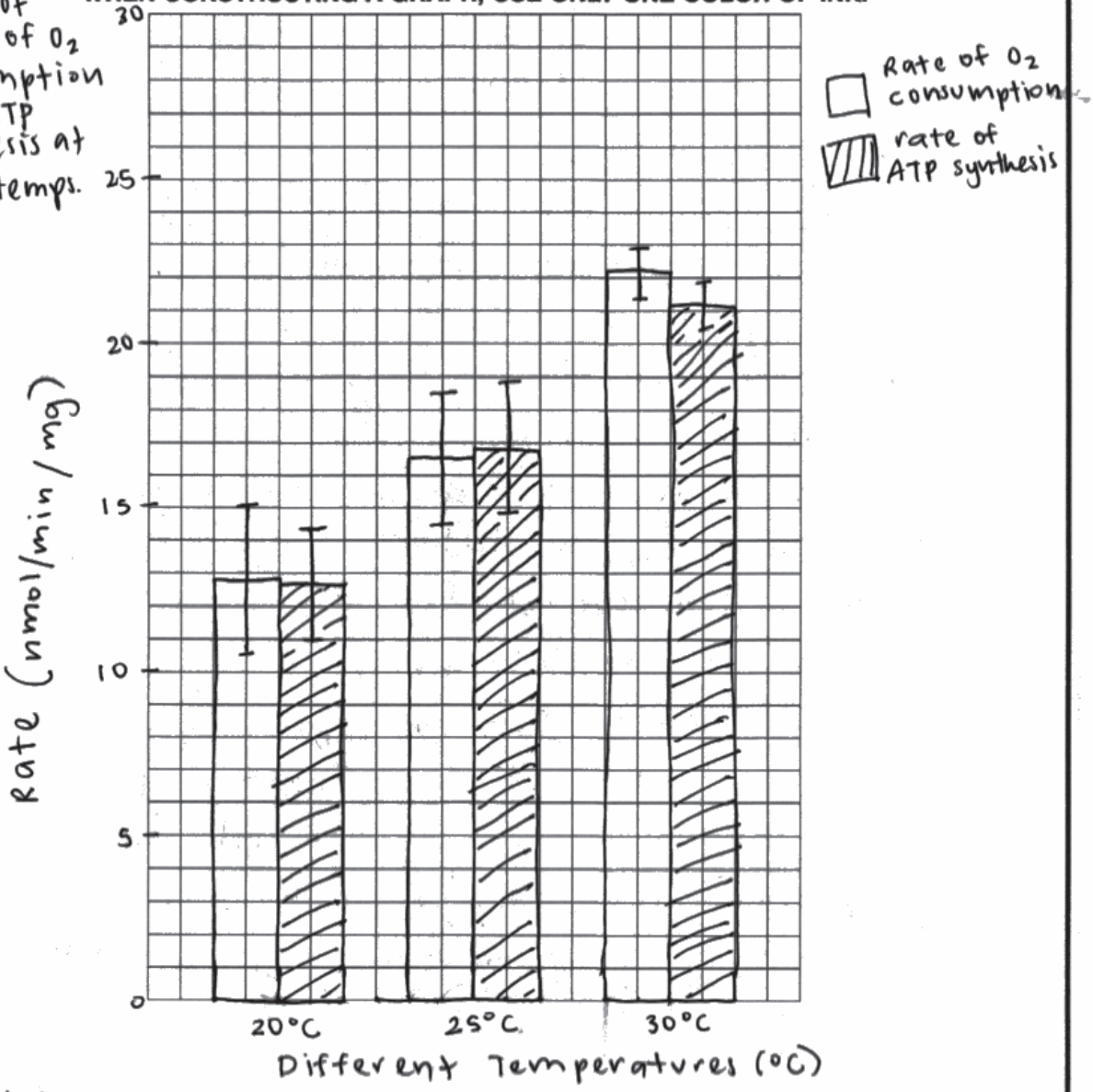
	Using the template in the space provided for your response, **construct** a bar graph that represents the data shown in Table 1. Your graph should be appropriately plotted and labeled. • Data points and error bars are correctly plotted.	**1 point**
	Based on the data provided, **determine** the temperature in $°C$ at which the rate of oxygen consumption is different from the rate of oxygen consumption at $25°C$. • 30	**1 point**
		Total for part (b) 4 points
(c)	Based on the data in Table 1, **describe** the effect of temperature on the rate of ATP synthesis in liver cells from toads. Accept one of the following: • As the temperature increases, the rate of ATP synthesis also increases. • There is a positive relationship (between temperature and ATP synthesis). • Temperature and ATP synthesis are directly correlated.	**1 point**
	Based on the data in Table 1**, calculate** the average amount of oxygen consumed, in $nmol$, for 10 mg of mitochondrial protein after 10 minutes at $25°C$. 1,650 [$16.5\ nmol/min/mg \times 10\ mg \times 10\ min$]	**1 point**
		Total for part (c) 2 points
(d)	Oligomycin is a compound that can block the channel protein function of ATP synthase. **Predict** the effects of using oligomycin on the proton gradient across the inner mitochondrial membrane. Accept one of the following: • (The proton gradient) will increase/become steeper (and may eventually plateau). • The difference in the concentration of protons/pH (across the inner mitochondrial membrane) will increase. • There will be an increase in the concentration of protons/a decrease in pH in the intermembrane space relative to that found within the mitochondrial matrix.	**1 point**
	Justify your prediction. Accept one of the following: • (Without protons being able to flow back into the matrix through ATP synthase), more protons will accumulate in the intermembrane space/between the two mitochondrial membranes. • (Without protons being able to flow back into the matrix through ATP synthase), there will be a lower pH in the intermembrane space/between the two mitochondrial membranes. • Protons will not be able to flow across the membrane (through ATP synthase), but the electron transport chain will still pump protons into the intermembrane space.	**1 point**
		Total for part (d) 2 points
		Total for question 2 9 points

BEGIN Question 2

Begin your response to **QUESTION 2** on this page. Do not skip lines.

WHEN CONSTRUCTING A GRAPH, USE ONLY ONE COLOR OF INK.

Graph of Rate of O_2 consumption and ATP synthesis at diff. temps.



a. Water dephosphorylates ATP in hydrolysis, making it ADP and breaking it apart.

b. ii. 30°C bc error bars don't overlap

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Additional page for answering Question 2

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c. i. As the temperature increases, the ATP synthesis in liver cells from toads also increases. There is a positive and direct relationship.

ii. 16.5 nmol/min/mg × 10 mg × 10 min = 1650 nmol for 10 mg after 10 min.

d. i. Using oligomycin ~~on the~~ will cause the proton gradient to be uneven, with more protons in the ~~inner~~ inter membrane space and less in the matrix.

ii. This is because as cellular respiration ~~occure~~ occurs, the electron transport chain pushes protons out of the mitochondrial matrix into the intermembrane space. Then, an electrochemical proton gradient is established, and ATP synthase pumps protons back in, generating ATP and reaching a proton equilibrium. But, oligomycin blocks ATP synthase from bringing protons back in, causing the uneven gradient created by the electron transport chain to remain.

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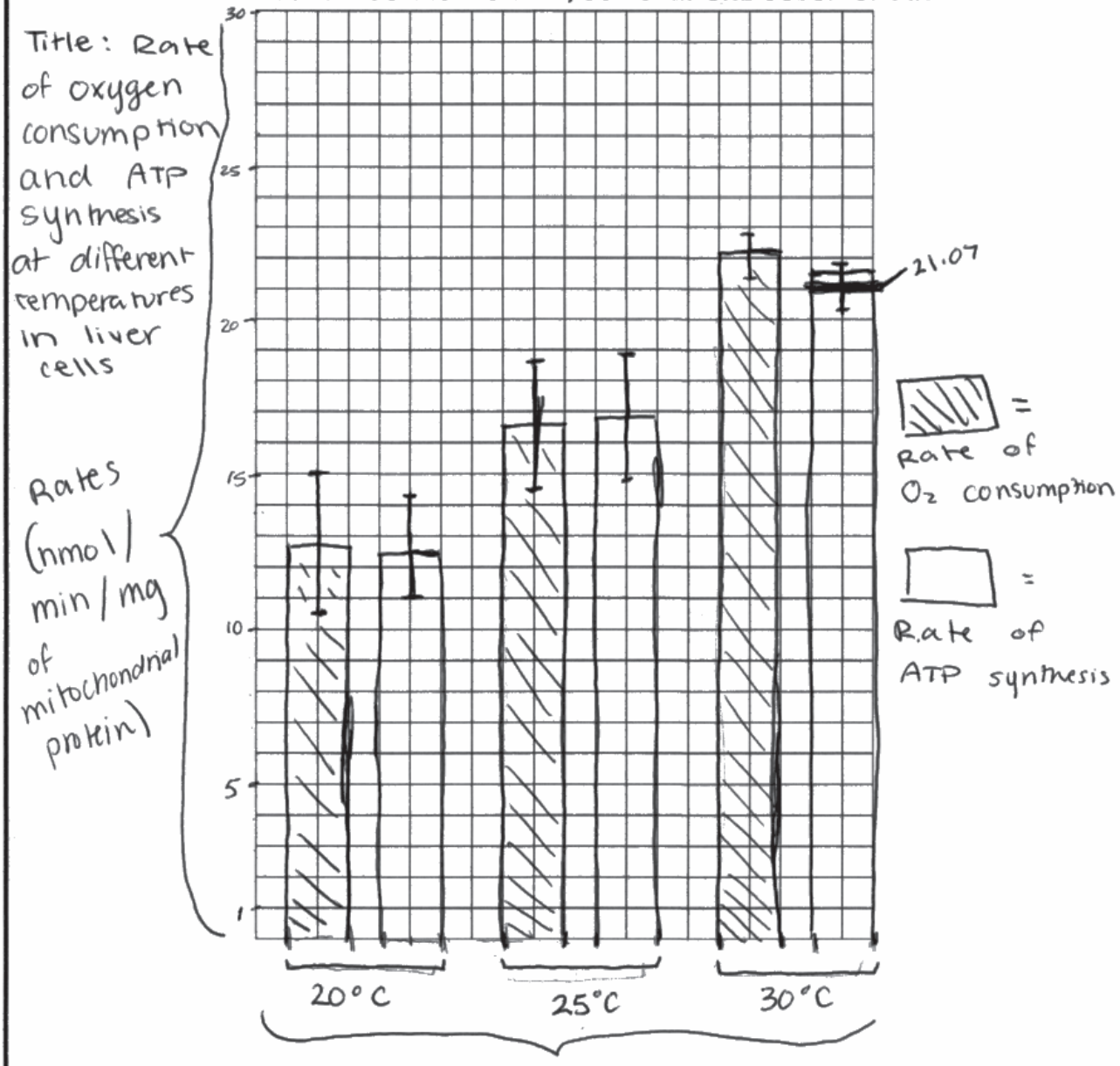

(b) At 30°C

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Additional page for answering Question 2

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(a) Water will be spliced apart ~~in hydrolysis~~ and the oxygen molecule will act as the final electron acceptor

(c) (i) - As the temperature increases, the rate of ATP synthesis in liver cells from toads increase as well.

(ii) 1.65 ± 2 nmol

(d) The rate of O_2 consumption and ATP synthesis will decrease.

(ii) It will decrease because the blocking of the channel protein will prevent molecules from passing through the membrane, O_2 will not pass.

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BEGIN Question 2

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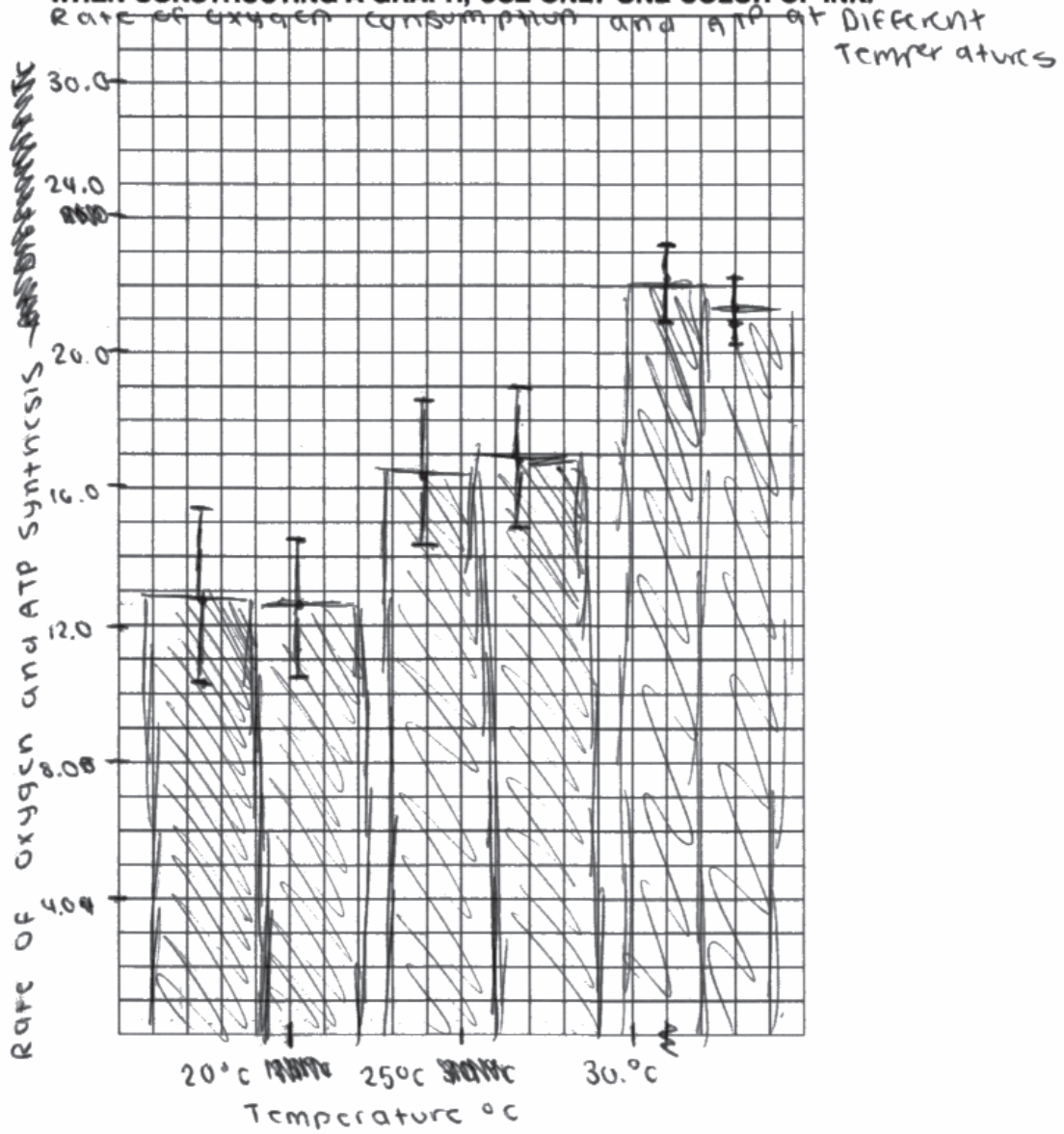

2a) The role of hydrolysis in ATP is to break the phos-phodiester covalent bond through the addition of water, ~~[illegible]~~ water adds the

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H+ and OH- to the sugar in ATP, breaking the covalent bond and creating two monomers.

ii) The ~~rate~~ temperature of oxygen consumption is different from the rate of oxygen is. 30°C

c) i. The effect of temperature on the rate of ATP synthesis in liver cells in toads is that as the temperature increases, so will the production of ATP, as heat will increase the Kinetic Energy, based on the table above

ii. the amount of oxgen consumed at 10 minutes is 18.5 and 14.5 nmol.

d. i. Using oligonycin will prevent the synthesis of ATP and will cause a build up of H+ protons in the inner mitochondrial membrane

ii. Since ATP uses H+, inputting it into the ATP synthase pump from the inner mitochondrial membrane, it will cause a build up of the H+ protons, as the functionality of the ATP synthase will stop.

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Question 2

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

Overview

Question 2 presented a table of data from an experiment designed to determine the effect of temperature on metabolic rate in toads. In the experiment, researchers measured the rate of oxygen consumption and the rate of ATP synthesis in isolated liver cells at three different temperatures.

Part (a) expected responses to describe "the role of water in the hydrolysis of ATP." This prompt assessed student understanding that hydrolysis cleaves covalent bonds (Skill 1.A; LO SYI-1.B).

In part (b)(i), responses were expected to construct a bar graph representing the experimental data (Skill 4.A). Part (b)(ii) expected responses to use the error bars to "determine the temperature in °C at which the rate of oxygen consumption is different from the rate of oxygen consumption at 25 °C" (Skill 5.B).

In part (c)(i), responses were expected to describe a trend in the data by describing "the effect of temperature on the rate of ATP synthesis" (Skill 4.B). Responses to part (c)(ii) were expected to perform a calculation based on the data in the table (Skill 5.A).

Part (d) presented the additional information that oligomycin "can block the channel protein function of ATP synthase." Responses were expected to predict "the effects of using oligomycin on the proton gradient across the inner mitochondrial membrane" (Skill 6.E) and then justify the prediction (Skill 6.C). Responses were expected to demonstrate understanding that the gradient would increase as protons accumulate in the intermembrane space of the mitochondrion because the protons are prevented from flowing through ATP synthase into the mitochondrial matrix (LO ENE-1.K).

Sample: 2A
Score: 9

The response earned 1 point in part (a) for describing that "water dephosphorylates ATP..." The response earned 1 point in part (b)(i) for constructing a bar graph. The response earned 1 point in part (b)(ii) for appropriately labeling the bar graph. The response earned 1 point in part (b)(iii) for correctly plotting the data points and error bars on the bar graph. The response earned 1 point in part (b)(iv) for determining that 30 °C is the temperature at which the rate of O_2 consumption is different from the rate of O_2 consumption at 25 °C. The response earned 1 point in part (c)(i) for describing that the effect of temperature on the rate of ATP synthesis "is a positive and direct relationship." The response earned 1 point in part (c)(ii) for correctly calculating the amount of O_2 consumed after 10 minutes at 25 °C. The response earned 1 point in part (d)(i) for predicting that "oligomycin will cause...more protons in the inter membrane space..." The response earned 1 point in part (d)(ii) for justifying the prediction, stating that "the electron transport chain pushes protons out of the mitochondrial matrix into the intermembrane space...oligomycin blocks ATP synthase from bringing protons back in."

Question 2 (continued)

Sample: 2B
Score: 5

The response did not earn a point in part (a) because it does not describe the role water plays in the hydrolysis of ATP. The response earned 1 point in part (b)(i) for constructing a bar graph. The response earned 1 point in part (b)(ii) for appropriately labeling the bar graph. The response earned 1 point in part (b)(iii) for correctly plotting the data points and error bars on the bar graph. The response earned 1 point in part (b)(iv) for determining that $30\,°C$ is the temperature at which the rate of O_2 consumption is different from the rate of O_2 consumption at $25\,°C$. The response earned 1 point in part (c)(i) for describing the effect of temperature on the rate of ATP synthesis. The response did not earn a point in part (c)(ii) because it does not correctly calculate the amount of O_2 consumed after 10 minutes at $25\,°C$. The response did not earn a point in part (d)(i) because it does not correctly predict the effect oligomycin has on the proton gradient across the inner mitochondrial membrane. The response did not earn a point in part (d)(ii) because it does not justify the intended prediction.

Sample: 2C
Score: 3

The response did not earn a point in part (a) because it incorrectly describes that water "...breaks the phosphodiaster covalent bond...creating two monomers." The response earned 1 point in part (b)(i) for constructing a bar graph including 6 data points. The response did not earn a point in part (b)(ii) because it does not appropriately label the graph by including units on the Y-axis and a key to which bars represent which metabolic marker. The response did not earn a point in part (b)(iii) because it does not correctly plot all the error bars of the bar graph. The response earned 1 point in part (b)(iv) for determining that $30\,°C$ is the temperature at which the rate of O_2 at consumption is different from the rate of O_2 consumption at $25\,°C$. The response earned 1 point in part (c)(i) for describing that "...as temperature increases, so will the production of ATP..." The response did not earn a point in part (c)(ii) because it does not calculate the amount of oxygen consumed to be $1{,}650$ nmol. The response did not earn a point in part (d)(i) because it predicts that oligomycin "...will cause a build up of protons in the inner mitochondrial membrane..." and not the intermembrane space. The response did not earn a point in part (d)(ii) because it does not correctly justify the prediction with an accurate location of where the "...build up of the H^+ protons..." will occur.