

2023



AP[®] Biology

Sample Student Responses and Scoring Commentary

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Question 2: Interpreting and Evaluating Experimental Results with Graphing

9 points

Elevated levels of CO_2 increase the rate of photosynthesis and growth in plants. Scientists studying the mechanisms involved in these increases examined a variety of species and found that when plants are exposed to elevated levels of CO_2 , there is an increase in the number of chloroplasts per cell. To investigate whether the elevated levels of CO_2 have a similar effect on the number of mitochondria in plant cells, the scientists then selected six of these species to quantify the number of mitochondria per cell when the plants were exposed to both normal and elevated levels of CO_2 (Table 1).

TABLE 1. AVERAGE NUMBER OF MITOCHONDRIA IN PLANTS EXPOSED TO
NORMAL AND ELEVATED LEVELS OF CO_2

Species	Mitochondria at Normal CO_2 (per $100 \mu\text{m}^2$ of cell area) $\pm 2\text{SE}_{\bar{x}}$	Mitochondria at Elevated CO_2 (per $100 \mu\text{m}^2$ of cell area) $\pm 2\text{SE}_{\bar{x}}$
1	1.0 ± 0.10	1.6 ± 0.10
2	0.4 ± 0.05	0.9 ± 0.08
3	0.5 ± 0.07	0.9 ± 0.10
4	0.3 ± 0.03	0.6 ± 0.06
5	0.7 ± 0.06	1.5 ± 0.22
6	1.3 ± 0.15	2.4 ± 0.22

(a) Describe the role of the inner mitochondrial membrane in cellular respiration.

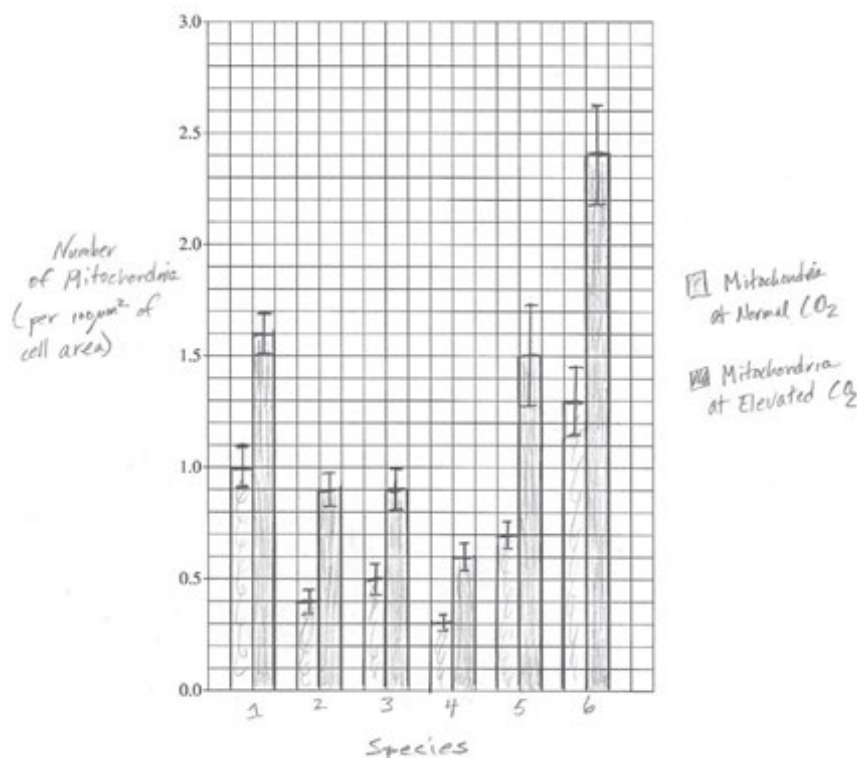
1 point

Accept one of the following:

- It provides the location for the components of the electron transport chain/ATP synthase/oxidative phosphorylation.
- It separates (reactions in) the intermembrane space from (reactions in) the matrix.
- It allows the establishment of a proton gradient.

- (b) Using the template in the space provided for your response, **construct** an appropriately labeled graph that represents the data in Table 1. **1 point**

Sample response:



- Appropriate labelling

Using the template in the space provided for your response, **construct** an appropriately labeled graph that represents the data in Table 1. **1 point**

- Data are represented in a bar/modified bar graph.

Using the template in the space provided for your response, **construct** an appropriately labeled graph that represents the data in Table 1. **1 point**

- Data points and error bars are correctly plotted.

Determine which species show(s) a difference in the number of mitochondria between normal and elevated levels of CO₂. **1 point**

- All of the species

Total for part (b) 4 points

- (c) Based on the data in Table 1, **describe** the relationship between the level of CO₂ and the average number of mitochondria per unit area of a cell. **1 point**

Accept one of the following:

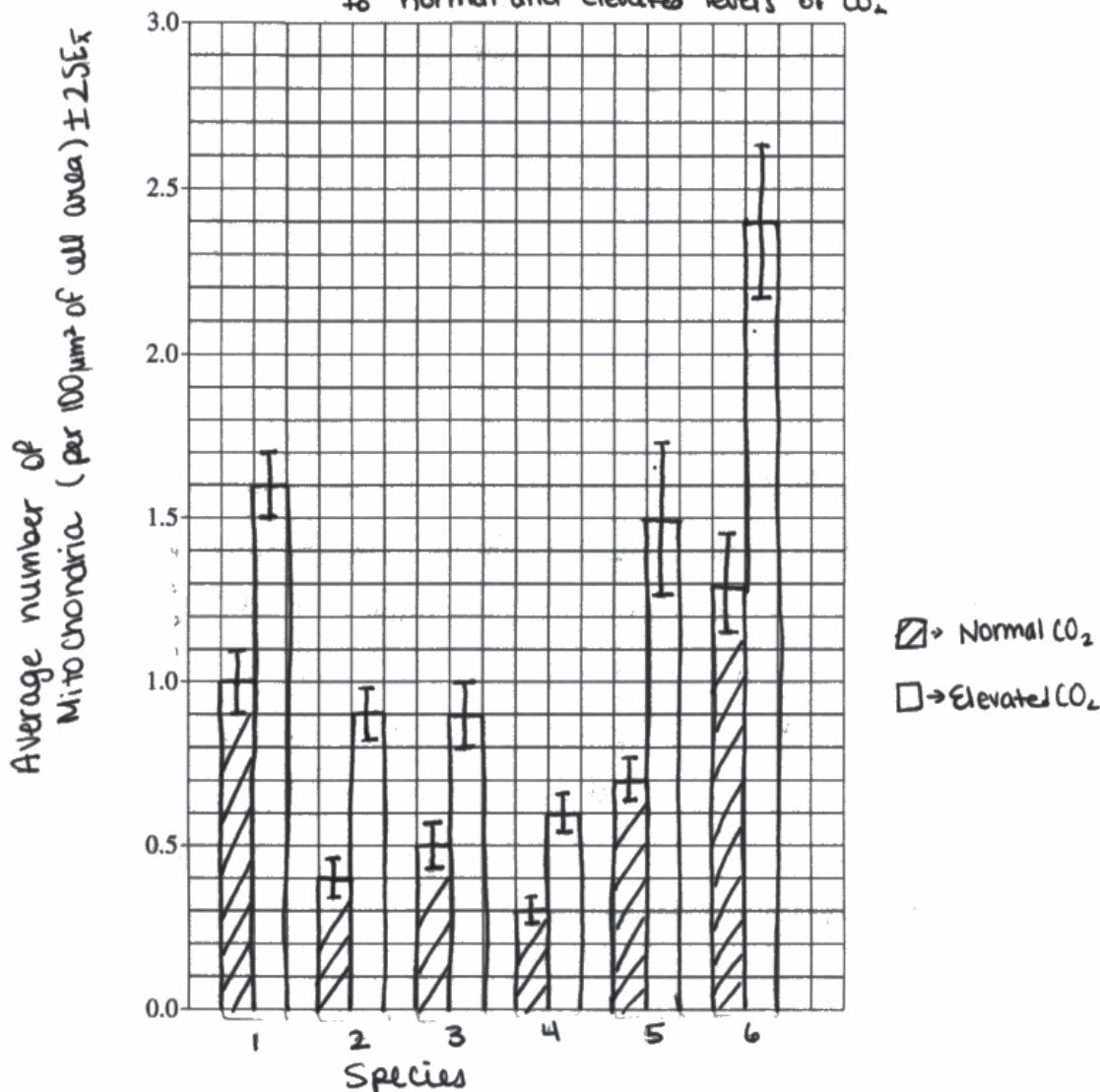
- The number of mitochondria is greater under conditions of elevated CO₂ (than under normal CO₂).
- It is a positive relationship/correlation.

(d)	The leaves of a particular plant species are typically green, but scientists notice a plant in which the leaves have white stripes. They determine that the stripes result from a mutation in mitochondrial DNA that interferes with the development of chloroplasts. The scientists crossed plants using pollen from the plant with white-striped leaves and ovules from a plant with green leaves. Predict the phenotype(s) of the leaves of offspring produced from this cross.	1 point
	<ul style="list-style-type: none">The leaves will <u>be (all) green/not have white stripes</u>.	
	Provide reasoning to justify your prediction.	1 point
	<ul style="list-style-type: none">(All offspring will have the same leaf phenotype as the ovule-producing plant because) mitochondria are <u>maternally inherited/transferred by the ovule</u>.	
	Explain why plants with the same genotype are able to differ in the structure and/or number of certain organelles in response to changes in atmospheric levels of CO ₂ .	1 point
	<ul style="list-style-type: none">(Plants have different phenotypes because) changes in <u>CO₂ levels/the environment</u> affect the expression of certain genes.	
	Total for part (d)	3 points
	Total for question 2	9 points

BEGIN Question 2

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

Average number of Mitochondria in plants exposed to normal and elevated levels of CO₂



a) The inner mitochondrial membrane (cristae) is used for the electron transport chain, which is essential to create the proton concentration gradient for the production of ATP.

Use a pen with black or dark blue ink only. Do NOT write your name. Do NOT write outside the box.

0069735



Additional page for answering Question 2

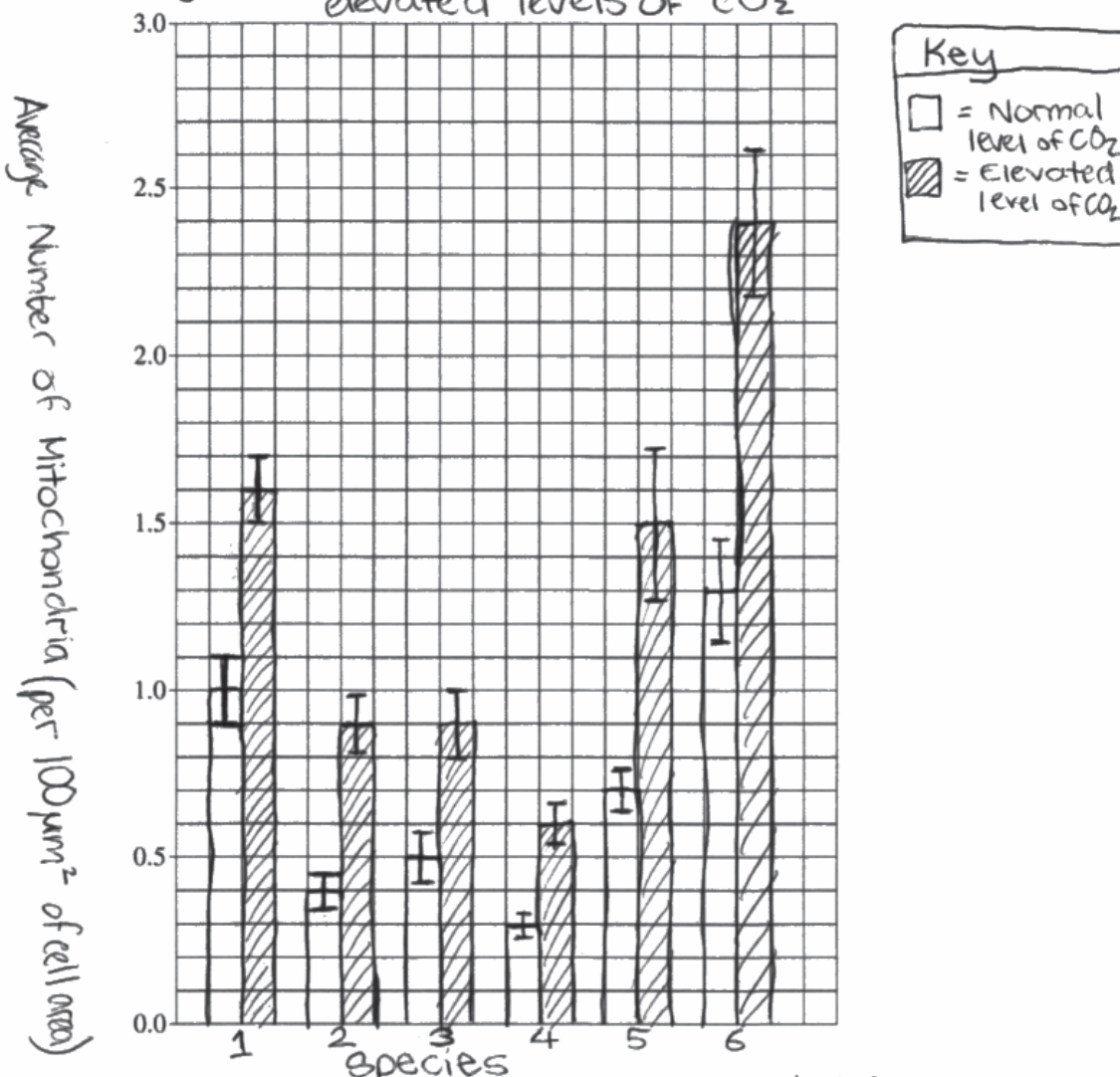
Continue your response to QUESTION 2 on this page. Do not skip lines.

- b) All the species show ^{significant} difference in the number of mitochondria between normal and elevated levels of CO_2 .
- c) Levels of CO_2 and average number of mitochondria per unit area of ~~the~~ a cell have positive correlation because ~~the~~ the plants with higher CO_2 levels have ~~more~~ ^{greater} number of mitochondria per unit.
- d) Phenotype of the leaves of the offspring would be green. That is because mutations in mitochondrial DNA can only be passed from the female parent. Plants with same genotype are able to differ in structure and/or number of organelles in response to levels of CO_2 because different factors play a role in phenotypes and gene expression of organisms. Since CO_2 is an important factor, it could have an effect.

BEGIN Question 2

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

Average Number of Mitochondria in plants vs normal and elevated levels of CO₂



a) The role of the inner mitochondrial membrane is to allow molecules to move in and out during cellular respiration. In cellular ~~resp~~ respiration, the ~~semi~~ selectively permeable membrane lets in CO₂ and other substances while releasing O₂.

Use a pen with black or dark blue ink only. Do NOT write your name. Do NOT write outside the box.

0177259



Additional page for answering Question 2

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

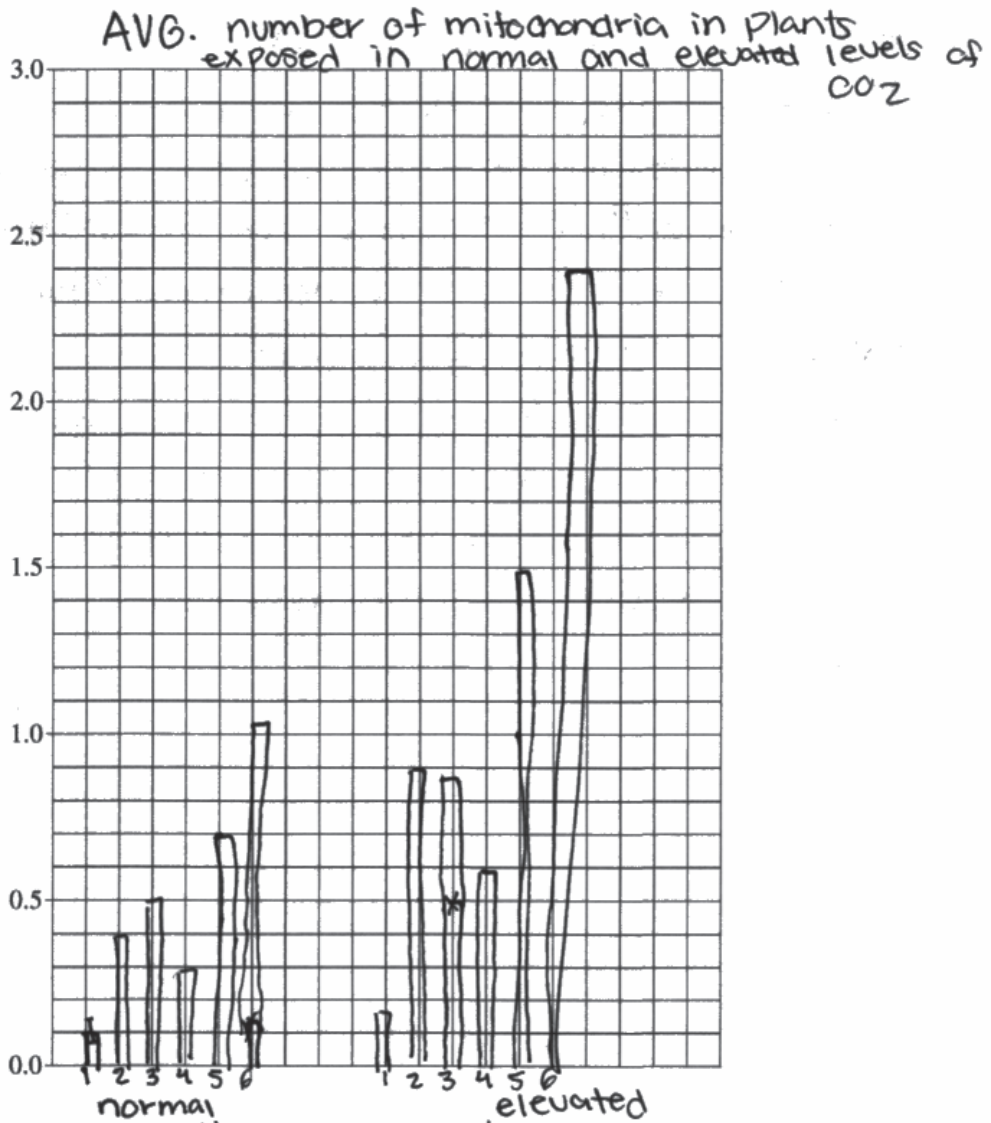
b) All of the species show a difference in number of mitochondria between normal and elevated as the error bars don't overlap, illustrating significant difference between the normal levels of CO_2 and elevated levels of CO_2 .

c) Based on Table 1, as level of CO_2 increases, the average number of mitochondria per unit area increases as more are used to do cellular respiration.

d) The possible phenotypes would be a plant with green leaves or a plant with ~~striped~~ white striped leaves. Using the Punnett square, we can see that there is 50% it can be striped and 50% it can be green. Plants with same genotype can differ in response to CO_2 levels because if there are more CO_2 , to absorb more, the plant would need to change its structure, so they have more stomata openings to get CO_2 to perform photosynthesis. Once they have more CO_2 , they would need more organelles such as chloroplasts and mitochondria, so they can perform photosynthesis and cellular respiration to create ATP and do oxidative phosphorylation.

BEGIN Question 2

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



A) In the inner mitochondrial ~~matrix~~ membrane it has the site for the kreb cycle which guides future production of ATP synthesis.

B) Species G.

C) Elevation of CO₂ causes an increase in the amount of

Use a pen with black or dark blue ink only. Do NOT write your name. Do NOT write outside the box.

0116019



Additional page for answering Question 2

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

mitochondria observed in the cell.

D) The phenotypes could be dominant with green, recessive in the white-striped analysis. ~~or heterozygous~~ Each percentage has the capability of 25% variance. With green plants being "typically green" in contribution to the prompt this would result in favorable dominance with recessive integrity as the mutation. The difference of plants can be attributed to the fact that CO₂ increase in atmospheric levels causes an increase in chloroplast and mitochondrial organelles.

Question 2

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

Overview

Question 2 presented results, in a table, from an experiment designed to study the effect of elevated CO₂ on the density of mitochondria in the cells of six different species of plants.

In part (a) students were asked to describe the role of the inner mitochondrial membrane in cellular respiration (Skill 1.A; Learning Objective [LO] SYI-1.F from the AP Biology Course and Exam Description [CED]).

In part (b) students were expected to construct “an appropriately labeled graph that represents” the data in the provided table (Skill 4.A). Students were then expected to use the data to “determine which species show(s) a difference in the number of mitochondria between normal and elevated levels of CO₂” (Skill 5.B).

In part (c) students were asked to describe the relationship between the independent and dependent variables (Skill 4.B).

Part (d) presented information about a mutation in mitochondrial DNA that inhibits the development of chloroplasts and results in leaves with white stripes. Students were asked to predict the phenotype(s) of the offspring from a cross between white-striped and green plants (Skill 6.E; LO IST-1.J). Finally, students were asked to explain why plants with the same genotype could exhibit differences in the number of organelles in response to differences in environmental CO₂ levels (Skill 6.D; LO SYI-3.B).

Sample: 2A

Score: 9

The response earned 1 point in part (a) for describing that the inner mitochondrial membrane “is used for the electron transport chain.” The response earned 1 point in part (b) for constructing a graph containing appropriate axis labels and legend. The response earned 1 point in part (b) for constructing a graph where the data are represented in a bar graph. The response earned 1 point in part (b) for constructing a graph where the points are accurately plotted with appropriate error bars. The response earned 1 point in part (b) for determining that all the species show a significant difference. The response earned 1 point in part (c) for describing that it is a positive correlation. The response earned 1 point in part (d) for predicting that the leaves will be green. The response earned 1 point in part (d) by justifying that mitochondrial DNA “can only be passed from the female parent.” The response earned 1 point in part (d) for explaining that “different factors play a role in phenotypes and gene expression of organisms. Since CO₂ is an important factor, it could have an effect.”

Sample: 2B

Score: 5

The response did not earn a point in part (a) because it does not accurately describe the role of the inner mitochondrial membrane in cellular respiration. The response earned 1 point in part (b) for constructing a graph containing appropriate axis labels and legend. The response earned 1 point in part (b) for constructing a graph where the data are represented in a bar graph. The response earned 1 point in part (b) for constructing a graph where the points are accurately plotted with appropriate error bars. The response earned 1 point in part (b) for determining that all of the species show a difference. The response earned 1 point in part (c) for describing that, as the level of CO₂ increases, the average number of mitochondria per unit area increases. The response did not earn a point in part (d) because it does not predict the leaves will be all green. The response did not earn a point in part (d) because it does not justify that mitochondria are maternally inherited. The response did not earn a point in part (d) because it does not explain that changes in CO₂ levels change/affect the expression of certain genes.

Question 2 (continued)

Sample: 2C

Score: 2

The response did not earn a point in part (a) because it does not accurately describe the role of the inner mitochondrial membrane in cellular respiration. The response did not earn a point in part (b) because it does not include appropriate axis labels on the graph. The response earned 1 point in part (b) for constructing a graph where the data are represented in a bar graph. The response did not earn a point in part (b) because the data points and error bars are incorrectly plotted. The response did not earn a point in part (b) because it does not determine that all of the species show a difference. The response earned 1 point in part (c) for describing that as the level of CO₂ increases, the number of mitochondria increases. The response did not earn a point in part (d) because it does not predict the leaves will be all green. The response did not earn a point in part (d) because it does not justify that mitochondria are maternally inherited. The response did not earn a point in part (d) because it does not explain that changes in CO₂ levels change/affect the expression of certain genes.