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# AP<sup>®</sup> Biology

## Sample Student Responses and Scoring Commentary

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#### **Free Response Question 3**

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**Question 3: Scientific Investigation****4 points**

Researchers hypothesize that the plant compound resveratrol improves mitochondrial function. To test this hypothesis, researchers dissolve resveratrol in dimethyl sulfoxide (DMSO). The solution readily passes through cell membranes. They add the resveratrol solution to mammalian muscle cells growing in a nutrient-rich solution (culture medium) that contains glucose. They measure ATP production at several time points after the addition of the resveratrol solution and find an increase in ATP production by the muscle cells.

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- (a) **Describe** the primary advantage for a mammalian muscle cell in using aerobic respiration over fermentation. **1 point**
- More ATP (per glucose molecule) is produced by aerobic respiration.
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- (b) **Identify** an appropriate negative control for this experiment that would allow the researchers to conclude that ATP is produced in response to the resveratrol treatment. **1 point**
- Accept one of the following:
- The researchers must run the experiment without adding resveratrol.
  - The researchers must treat the cells with DMSO alone.
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- (c) **Predict** the effect on short-term ATP production when resveratrol-treated mammalian muscle cells are grown in a culture medium that lacks glucose or other sugars. **1 point**
- Accept one of the following:
- No ATP production
  - Reduced ATP production
- 
- (d) The researchers find that resveratrol stimulates the production of components of the electron transport chain. The researchers claim that treatment with resveratrol will also increase oxygen consumption by the cells if glucose is not limiting. **Justify** the claim. **1 point**
- More electrons can be transferred so that more oxygen is required as the final electron acceptor.
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**Total for question 3 4 points**

Begin your response to **QUESTION 3** on this page. Do not skip lines.

- a) Aerobic respiration can produce up to 36 ATP from a single glucose molecule, while fermentation produces only two ATP. This means that cells produce more energy per glucose molecule with aerobic respiration.
- b) A negative control would be to repeat the experiment with mammalian muscle cells grown in a nutrient-rich solution without resveratrol.
- c) ATP production will decrease because the cells will not have carbohydrates to utilize for respiration and the production of energy.
- d) Oxygen acts as the final electron acceptor for the electron transport chain, so if resveratrol stimulated production of ETC components, the electron transport chain will become more active and require more oxygen molecules to transfer electrons to when ~~renew~~ establishing the proton gradient.

Begin your response to **QUESTION 3** on this page. Do not skip lines.

- a) The primary advantage of aerobic respiration over fermentation for muscle cells is that it produces much more ATP. The electron transport chain in aerobic respiration generates about 34 molecules of ATP while glycolysis and fermentation only produces 2 each cycle. Also, fermentation has a byproduct of lactic acid that is toxic when built up and the body has to expend of it.
- b) A negative control would be to use a muscle cell without resveratrol added to it.
- c) Without any glucose or sugar the muscle cells would not be able to undergo glycolysis or cellular respiration in general, so ATP production would cease. Or, the cell might break down lipids or proteins in the place of glucose/sugars to continue ATP production.
- d) Resveratrol will increase oxygen consumption because oxygen is used as an electron transporter during the ~~etc~~ electron transport chain. If the products are increased, then more electrons and therefore, oxygen, will be needed.

Begin your response to **QUESTION 3** on this page. Do not skip lines.

(a) An advantage of aerobic respiration over fermentation is that there is more output, and that the output comes more quickly than in fermentation.

(b) An appropriate negative control for this experiment would be to take away the ~~DMSO~~ to see how much ATP is produced on resveratrol alone. mammalian muscle cells that are enriched in glucose

(c) The amount of ATP will probably decrease if there are fewer sugars like glucose ~~because they need the 5' and 3' molecules~~ because sugars are part of the process that makes ATP.

(d) Mitochondria requires molecules in sugars like oxygen to function. So, if ~~resveratrol~~ resveratrol increases mitochondrial function, the mitochondria will need more fuel to operate. There must be enough glucose, though, because it's a source of oxygen.

### Question 3

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

#### Overview

This question described an experiment in which mammalian muscle cells were treated with resveratrol dissolved in dimethyl sulfoxide (DMSO).

In part (a) students were asked to describe the advantage of aerobic respiration over fermentation in the mammalian muscle cells. Responses were expected to demonstrate an understanding of the ATP yields of fermentation and aerobic respiration (Learning Objective ENE-1.K in Topic 3.6).

In part (b) students were asked to identify an appropriate negative control. Responses were expected to demonstrate proficiency in identifying experimental procedures (Science Practice 3.C).

In part (c) students were asked to predict the effect on short-term ATP production if resveratrol-treated cells are grown in the absence of sugar. Responses were expected to demonstrate an understanding of the process of cellular respiration (ENE-1.K in Topic 3.6).

In part (d) students were asked to justify the claim that, because resveratrol stimulates the production of the components of the electron transport chain, treatment with resveratrol will increase oxygen consumption by the cells. Responses were expected to demonstrate an understanding that oxygen acts as the terminal electron acceptor in the electron transport chain in mitochondria (ENE-1.K.3 in Topic 3.6).

#### Sample: 3A

##### Score: 4

The response earned 1 point in part (a) for describing that aerobic respiration “can produce up to 36 ATP from a single glucose molecule, while fermentation produces only two ATP.” The response earned 1 point in part (b) for identifying that the negative control would be a “nutrient-rich solution without resveratol.” The response earned 1 point in part (c) for predicting that ATP production will “decrease.” The response earned 1 point in part (d) for justifying that “oxygen acts as the final electron acceptor for the electron transport chain and will “require more oxygen molecules to transfer electrons to.”

#### Sample: 3B

##### Score: 3

The response earned 1 point in part (a) for describing that aerobic respiration produces more ATP. The response earned 1 point in part (b) for identifying the negative control would be to “use a muscle cell without resveratrol added.” The response earned 1 point in part (c) for predicting that ATP production “would cease. The response did not earn a point in part (d) for justifying that oxygen is “an electron transporter” rather than the final electron acceptor in the increased transfer of electrons.

#### Sample: 3C

##### Score: 1

The response did not earn a point in part (a) because it does not describe that “more output” is more ATP. The response did not earn a point in part (b) because it identifies the negative control as “to take away the mammalian muscle cells that are enriched in glucose” rather than withholding resveratrol. The response earned 1 point in part (c) for predicting the amount of ATP “will probably decrease.” The response did not earn a point in part (d) because it does not justify that more electrons are transferred to oxygen as the final electron acceptor.