



Student Performance Q&A: 2015 AP[®] Biology Free-Response Questions

The following comments on the 2015 free-response questions for AP[®] Biology were written by the Chief Reader, Domenic Castignetti of Loyola University Chicago, and the Question Leaders, Geoff Gerner, Sean Bennett, Cynthia Beale, and Kathleen Ireland. They give an overview of each free-response question and of how students performed on the question, including typical student errors. General comments regarding the skills and content that students frequently have the most problems with are included. Some suggestions for improving student performance in these areas are also provided. Teachers are encouraged to attend a College Board workshop to learn strategies for improving student performance in specific areas.

Question 1

What was the intent of this question?

This question was based on a laboratory investigation of the effects of both environmental conditions and genetics on the activity pattern of mice. Students were presented with actograms representing the daily activity patterns of mice exposed to daily periods of 12 hours of light followed by 12 hours of dark (L12:D12) and of mice exposed to continuous darkness (DD). Students were asked to describe the role of a photoreceptor, the brain, and a motor neuron in the behavioral response of the mice to light-dark stimuli. Students were then asked to use the actogram to describe the activity pattern of the mice exposed to L12:D12 conditions. Students were then asked to compare the activity pattern of mice exposed to L12:D12 conditions with mice exposed to continuous darkness (DD), and to use the data to support a claim that the genetically controlled circadian rhythm does not follow a 24-hour period. Students were then asked to provide support for a claim that light can override the genetically controlled circadian rhythm by predicting the activity pattern of mice lacking a gene that controls the circadian rhythm under L12:D12 and DD conditions. Finally, students were asked to propose two features of a model representing how predation by birds may have resulted in the evolution of the observed activity pattern of the mice.

How well did students perform on this question?

The mean score for this question was 3.81 out of a possible 10 points.

What were common student errors or omissions?

In part (a) many students struggled to correctly describe the role of a motor neuron, with many students attributing sensory function to the motor neuron, or mischaracterizing the role of the motor neuron as causing movement directly or actually moving, rather than transmitting the signal from the brain to the effector (i.e., muscles).

In part (b) many students incorrectly addressed the activity pattern under either the light period or the dark period, but not under both conditions. In part (c) many students failed to recognize that the duration of the active period was shorter than 12 hours (or the daily circadian rhythm was less than 24 hours), or that the active period began earlier each day. Students instead described a randomness in start times or a random duration of the activity periods. Very few students supported the researchers' claim that the genetically controlled circadian rhythm in the mice does not follow a 24-hour cycle by connecting the fact that light was responsible for the L12:D12 pattern and that without light, active/inactive periods are determined only by the genetically controlled circadian rhythm. In part (d) many students incorrectly predicted that mutant mice would be arrhythmic under any conditions. In part (e) many students described a selective advantage for individuals who were active at night. However, many of those same students did not go on to describe differential reproductive success for selected mice. Many students who did not earn this point made Lamarckian statements (e.g., in order to survive ...) as a description of a selective advantage.

Based on your experience of student responses at the AP® Reading, what message would you like to send to teachers that might help them to improve the performance of their students on the exam?

In addition to having students create various types of graphs, teachers should have students analyze and describe different types of charts and graphs. Challenge students to identify patterns and trends within the data, to recognize similarities and differences between data sets, and to use data to support a scientific claim. Teachers could consider a daily warm-up exercise that involves analyzing and interpreting unfamiliar data.

Teachers should make a connection to the model of evolution early in the course and repeat it often. Clarify that natural selection acts on individuals in a population, but that populations evolve. Teachers should also stress that adaptation is not a choice or something that is learned. Have students articulate the mechanisms of evolution and have them identify Lamarckian and Darwinian statements. Finally, stress the importance of not only survival of individuals, but also the reproductive success of those individuals as components of an evolutionary model.

Question 2

What was the intent of this question?

This question was based on the biochemistry and evolution of aerobic cellular respiration. Students were presented with three figures illustrating the distinct metabolic pathways contributing to the synthesis of ATP. Students were asked to describe one contribution from each of the metabolic pathways to ATP synthesis. Students were then asked to use three observations to justify the claim that glycolysis first occurred in the common ancestor of all living organisms. Students were then asked to calculate the amount of energy released from 30 moles of ATP and to calculate the efficiency of ATP synthesis from 1 mole of glucose. Students were then asked to describe the fate of excess energy that is released from the metabolism of glucose. Finally, students were asked to pose a scientific question connecting the cellular location of the Krebs cycle in prokaryotes and eukaryotes to the evolution of eukaryotes.

How well did students perform on this question?

The mean score for this question was 2.89 out of a possible 10 points.

What were common student errors or omissions?

In part (a) many students wrote that NADH from glycolysis is used in the Krebs cycle, or that NADH makes ATP. Students also used the terms "proton" with "protein" interchangeably. Many students were also confused about the function of the proton pumps of the electron transport chain and often stated that protons

were pumped through ATP synthase. In addition, students wrote that electrons pass through ATP synthase, and the main product of the electron transport chain is water.

In part (b) while many students simply restated information from the stem of the question they did not describe or offer evidence to justify the claims. Many students presented an argument for convergent evolution rather than providing evidence of how glycolysis actually arose in a common evolutionary lineage, which actually justifies the claim that glycolysis did NOT originate in multiple evolutionary lines. While students often described conservation in general terms, they did not identify it as conservation. Finally, many students used generic terms like “complex” or “specialized” instead of a specific term (i.e., membrane-bound) when attempting to justify the observation that glycolysis occurs only in the cytosol. Many students failed to recognize that there was a lack of O₂ in the primitive Earth atmosphere and incorrectly associated anaerobic conditions as meaning “without air.”

In part (c) students were unsure of how to perform the correct calculation and, therefore, applied many different combinations of values in the calculation. While many students correctly described that excess energy is lost as heat, some students claimed the excess energy is stored in fats or carbohydrates inside the body.

In part (d) students often provided correct information about mitochondria but were unable to translate that knowledge into a testable scientific question.

Based on your experience of student responses at the AP[®] Reading, what message would you like to send to teachers that might help them to improve the performance of their students on the exam?

When teaching cellular respiration, make sure that students can articulate how each process (and its related products) are connected. While many students demonstrated an understanding of each metabolic pathway in isolation, they often had difficulty applying this to the process of cellular respiration as a whole. Integrating cellular respiration within many topics (e.g., evolution, genetics) will better help students to make those connections. Teachers should also work to increase students’ comfort level with performing mathematical calculations in a biological context. These skills can be introduced (and assessed) early in the year and included throughout the course. Finally, having students practice posing questions is a critical skill and should be practiced throughout the course.

Question 3

What was the intent of this question?

This question focused on using evidence to support biological evolution. Students were asked to evaluate amino acid sequences from five related species to construct a phylogenetic tree reflecting the evolutionary relationships among them, and justify the placement on the tree of the species that is least related to the others. Students were then asked to identify whether morphological or amino acid sequence data was more likely to accurately represent the true evolutionary relationships among the species for constructing the most accurate phylogenetic tree and to provide reasoning to support their answer.

How well did students perform on this question?

The mean score for this question was 1.90 out of a possible 4 points.

What were common student errors or omissions?

In part (a) many students failed to correctly interpret the amino acid sequence data provided in the table. As an example, many students incorrectly identified *E. africanus* as having the most amino acid differences

simply because there are five entries in that column, or by adding the total differences in each column. Often students placed the organisms on the tree in the order they were presented in the table, rather than placing *D. polylepis* on the branch corresponding to the outgroup. Many students incorrectly identified *D. polylepis* as the common ancestor rather than the least related species among the group. As part of their reasoning, students often confused amino acids, DNA, and nucleic acids, or stated that DNA comes from amino acids.

In part (b) many students correctly identified amino acids as more likely to represent true evolutionary relationships, but provided inadequate reasoning by stating that amino acid sequence data were “more precise” or simply expressed that “counting the number of differences” provided adequate reasoning. Several misconceptions became apparent concerning the definitions of analogous and homologous structures and students often confused convergent and divergent evolution. If students chose morphological evidence as more likely to show true evolutionary relationships, their answers often did not provide reasoning supporting a preponderance of evidence, and no points were earned.

Based on your experience of student responses at the AP[®] Reading, what message would you like to send to teachers that might help them to improve the performance of their students on the exam?

When students are interpreting data tables that compare number of amino acid differences or other molecular data, encourage them to work through more than one example and make sure the students know how to interpret and read the data table. Provide students with pre-labeled phylogenetic trees and/or cladograms and have them identify the errors; then move to a blank template for the students to label, and finally have students construct their own phylogenetic trees and/or cladograms. Make sure students understand the reasons that scientists use amino acid and DNA differences along with morphology, and the strengths and weaknesses of each type of data. Take the time to clearly articulate the differences between analogous and homologous structures, and convergent and divergent evolution, and make sure students can clearly articulate these differences and provide examples of each.

Question 4

What was the intent of this question?

This question was based on a comparison of cell division processes. Students were asked to describe two events common to both mitosis and meiosis that ensure the proper allocation of chromosomes to daughter cells. Students were then asked to describe two features of mitosis and meiosis that result in the contrasting genetic composition of daughter cells after both cell division processes.

How well did students perform on this question?

The mean score for this question was 1.47 out of a possible 4 points.

What were common student errors or omissions?

While students often articulated correct information about mitosis and meiosis, their responses frequently did not address the question. Students equated mitosis and meiosis with the entire cell cycle, not just nuclear division and were unclear about the events occurring specifically during this part of the cell cycle. For example, many students identified chromosome replication or DNA synthesis as happening during mitosis or meiosis instead of prior to the commencement of each process. Many students failed to identify spindle fiber formation as a distinct event in mitosis or meiosis. While students are aware that checkpoints exist, they are not clear as to their purpose or when they occur. Many students erroneously identified homologous chromosomes as lining up during mitosis or meiosis II. Some students claimed that “cells” lined up in the middle. Students also confused haploid cells and diploid cells. Many misconceptions about meiosis were evident (e.g., gametes only contain X and Y chromosomes, meiosis is the fusion of egg and sperm, or

gametes divide during the process of meiosis). Other unrelated processes were sometimes included, including transcription or translation.

Based on your experience of student responses at the AP® Reading, what message would you like to send to teachers that might help them to improve the performance of their students on the exam?

Teach students to read the prompt carefully, take note of the action words in the question, or underline the important parts of the prompt. Teach the skill of comparing and contrasting different processes to identify similarities and differences. Emphasize the distinct stages of the cell cycle, and focus on events that are specific to each stage. While students are no longer required to know the names of the phases in mitosis or meiosis, ensure that they know the sequence of events and how this sequence contributes to the appropriate number, composition, and chromosomal complementing the resulting daughter cells.

Question 5

What was the intent of this question?

This question focused on the results from classic investigations into the phototropic response of plants. Students were provided with a figure illustrating the results from five treatment groups. Students were asked to analyze experimental results from three treatment groups to justify the claim that the phototropic response of plants is controlled by cells in the tips of the shoots. Students were then asked to describe two characteristics of the phototropism response in plants based on the results from two specific treatment groups where either a permeable barrier or an impermeable barrier separated the tip of the shoot from the rest of the plant.

How well did students perform on this question?

The mean score for this question was 1.95 out of a possible 4 points.

What were common student errors or omissions?

Students commonly either failed to address the specified treatments or failed to adequately compare the results from each treatment. Students also struggled to provide reasoning beyond restating what was provided in the question. Students often confused phototropism with photosynthesis, roots with shoots, or described substances moving up from the roots rather than down from the shoots.

Many student responses did not clearly describe that the tip of the plant produces a diffusible substance in response to light signals and that the substance initiates a response through cell signaling mechanisms. Rather, ambiguous answers described communication or information being sent from the tip of the plant, or even that the plant's nervous systems were involved in the signaling. Additionally, students mistakenly described light as what was moving through the permeable barrier.

Based on your experience of student responses at the AP® Reading, what message would you like to send to teachers that might help them to improve the performance of their students on the exam?

Students should practice justifying answers with clear reasoning, rather than just restating what is shown in a diagram or model. When teaching about mechanisms of cell signaling, make sure to highlight what specific *chemicals, hormones, or substances* are being synthesized and how those substances travel through various biological systems and include plant models of cell-to-cell communication. While the specific names of plant hormones are out of scope for the AP Biology curriculum and exam, it is important for students to know that specific substances allow plants to respond to changes in the environment. Teaching that plants CAN

respond to changes in their environment, even if they aren't mobile, is a valuable tool and an important piece of biology to include in the course.

Question 6

What was the intent of this question?

This question focused on possible evolutionary mechanisms underlying changes in population size. Students were presented with a graph representing changes in the size of a small, isolated population of snakes before and after the introduction of outside males. Students were asked to use the data to describe one characteristic of the original population that led to the population decline. Students were then asked to propose a reason to explain how the introduction of snakes from an outside population rescued the population from decline. Finally, students were asked to use the data to support the claim that the snake population inhabited an area with abundant resources over the entire course of the study.

How well did students perform on this question?

The mean score for this question was 1.95 out of a possible 3 points.

What were common student errors or omissions?

The most common errors in this question resulted from students misunderstanding the capture and release methodology used to estimate population size. In part (a) many students ascribed the population decrease to the capture of snakes. Students also described outside effects on the population instead of characteristics of the original population (e.g., predation, climate change, or hunting pressures as population characteristics). Students often incorrectly discussed a lack of female snakes or cannibalism by the male snakes.

Many students misunderstood the terms “small isolated population” and “several larger populations” to mean the individual snakes were small or large. Often, students confused the terminology in their answers: biodiversity was used for genetic diversity, and “populations were thriving” was used for population growth.

Based on your experience of student responses at the AP[®] Reading, what message would you like to send to teachers that might help them to improve the performance of their students on the exam?

Teachers should discuss current ecological issues with students and review and practice the capture and release method of population estimation. Teachers should also clearly differentiate between genetic diversity and biodiversity in ecology and genetics respectively. Providing students with ample opportunities to analyze data is necessary throughout the course. Removing data from graphs and having students predict possible outcomes will prepare students to make predictions and support those predictions with evidence.

Question 7

What was the intent of this question?

This question focused on the structure and function of olfactory neurons and on the transmission and integration of sensory information to the brain. Students were asked to describe how signals are transmitted across a synapse from an olfactory sensory neuron to an interneuron. Students were then asked to explain how the expression of a limited number of odorant receptor genes could lead to the perception of thousands of odors. Students were finally asked to use evidence about the total number of odorant receptor genes to justify their response.

How well did students perform on this question?

The mean score on this question was 0.43 out of a possible 3 points.

What were common student errors or omissions?

In part (a) while most students addressed the release of the neurotransmitter from the presynaptic neuron, many students provided an incomplete response by not specifying the binding of neurotransmitters to the receptors on the postsynaptic membrane. Some students confused neurotransmitters with hormones, odors, and ions.

In part (b) many students used the terms gene and odor interchangeably and wrote that genes react with odors to perceive smells. Students also asserted that genes were activated, regulated, or encoded directly by odors and that genes interpreted odors. It was obvious in many cases that students thought that the gene binds to the odorant molecules to elicit a response.

Based on your experience of student responses at the AP[®] Reading, what message would you like to send to teachers that might help them to improve the performance of their students on the exam?

Teachers should attempt to address the misconception that one ligand can be recognized by only one receptor and that one receptor can only bind to one ligand. Students have clearly applied their knowledge of enzyme-substrate specificity to ligand-receptor function. Reinforcing the concept of gene to protein to function/phenotype will help students internalize the role of genes and gene expression in many different biological processes.

Question 8

What was the intent of this question?

This question focused on the ability of an individual lacking B cells to mount an immune response. Students were asked to propose one direct consequence of the loss of B-cell activity on the humoral immune response of the individual during an initial exposure to a bacterial pathogen. Students were then asked to propose one direct consequence of the loss of B-cell activity on the speed of the immune response of the individual during a second exposure to the same pathogen. Finally, students were asked to describe one characteristic of the individual's immune response that is not affected by the loss of B-cell activity.

How well did students perform on this question?

The mean score was 0.82 out of a possible 3 points.

What were common student errors or omissions?

In part (a) most students were unable to propose a direct consequence of the loss of B-cell activity on an individual's humoral immune response. Many students confused the terms antibody, antigen, and antibiotic and often wrote that each was produced by a T cell or a B cell.

In part (b) speed and strength were used interchangeably, as many students proposed a stronger secondary response instead of addressing the speed of the response. Furthermore, students often did not compare a faster or slower response to the initial response.

In part (c) many students were able to describe an aspect of non-specific immunity as part of the immune response that is not affected by the loss of B cells.

Based on your experience of student responses at the AP[®] Reading, what message would you like to send to teachers that might help them to improve the performance of their students on the exam?

A solid understanding of immune system structure and function takes time for students to develop. By scaffolding and integrating immunity throughout the course, students will have multiple opportunities for learning. Providing students with opportunities to construct and interpret graphs, make predictions and provide justifications, and construct explanations related to immune system function is a way to coordinate knowledge and skills.