Student Performance Q&A:

2014 AP® Biology Free-Response Questions

The following comments on the 2014 free-response questions for AP® Biology were written by the Chief Reader, Domenic Castignetti of Loyola University in Chicago, Ill., and the Question Leaders, Nancy Morvillo, Sean Bennett, Bobbie Hinson, and Amy Dykstra. 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?

Question 1 is based on a laboratory investigation of the evolution of trichomes, a structural and functional feature of plants, when exposed to herbivores. Students were presented with the sample mean trichome densities and standard error of the means (SEM) of three populations of plants. Students were asked to appropriately graph the means, including the 95percent confidence intervals ($\pm$ 2×SEM) for each of the three samples. Students were then asked to identify the two populations most likely to be significantly different, and to justify the difference based on an analysis of the sample means and standard errors of the mean. Students were then asked to design a plan to test the hypothesis that trichomes provide protection from herbivory and are a phenotype that is acted on by natural selection. For the experimental design, students were asked to describe an independent variable, a dependent variable, and an appropriate control treatment, as well as to identify the appropriate duration of the experiment to ensure that natural selection is measured. Finally, students were asked to select the kind of data necessary to predict a measurable experimental result supporting the original hypothesis.

How well did students perform on this question?

The mean score for this question was 3.37 out of a possible 10 points.

What were common student errors or omissions?

In part (a), most students were able to correctly label, scale, and orient the graph. Student responses included bar graphs, modified bar graphs, scatter plots, and line graphs. Of the students who constructed a bar graph, very few correctly graphed the 95% confidence intervals (sample mean ± 2xSEM). The majority of students who attempted to include some type of confidence interval only included the sample mean ± 1xSEM).

In part (b), very few students used the non-overlapping confidence intervals of Samples I and III to justify the claim that population I and population III were the most likely populations to be statistically different.

In part (c), several students suggested an herbivore preference experiment where the independent variable was the number of trichomes and the dependent variable was the percent of plants preyed upon; but the experiment did not connect the results of the experiment to the relative reproductive success of plants with an increased number of trichomes. Many students also failed to explicitly give a number of generations; some measured the time in days, months, years or seasons of the year.

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 continue to stress the importance of data manipulation and analysis. Selecting the appropriate type of graph (e.g., line graph, bar graph, box and whiskers plot, pie chart, etc.) is critical for communicating different types of data accurately and efficiently. Correctly labeling and scaling axes, and accurately plotting data is equally critical, and students should have many opportunities to practice this skill.

Students should routinely practice analyzing different types of data, both hypothetical and laboratory, to identify patterns, connect variables, and perform statistical analysis. Teachers are encouraged to use available resources (e.g., AP® Biology Quantitative Skills Guide) to increase their level of comfort with the use of statistics in experimental biology. An awareness of the importance of statistics is useful in planning experiments and drawing appropriate conclusions based upon the data. Focusing students' attention on how to construct a scientific argument will help them critically analyze data as evidence and provide appropriate support for any claims or conclusions they make about the data.

Students should practice designing experiments and implementing data collection strategies that address scientific questions. Students should practice identifying and justifying the role of experimental variables and controls. Teachers should also stress the difference between a controlled experiment and experimental controls or constants.

Question 2

What was the intent of this question?

Question 2 focuses on the evolutionary history of mammals and on the role of the immune system in responding to infection by a specific pathogen. The question asks students to use the presence or absence of derived characters in milk to construct a cladogram indicating the evolutionary relationships of the mammals. Students were asked to justify the placement of the derived characters on the cladogram. Students were then asked to describe the activation of the immune system in response to the infection. Finally, students were asked to predict the most likely consequence for a nursing infant who is exposed to a pathogen to which the mother was exposed three months earlier and to justify their prediction with evidence.

How well did students perform on this question?

The mean score for this question was 4.62 out of a possible 10 points.

What were common student errors or omissions?

In part (a) most students correctly constructed the cladogram showing the evolutionary relationship among the organisms, but students had difficulty indicating where on the cladogram the milk characters arose. Justifying the placement of those characters further challenged many students, as one of the common errors was justifying the position of the animals on the cladogram rather than justifying the evolutionary history of all of the characters.

In part (b) many students began with a discussion of nonspecific immunity and described the role of skin, mucus, and hairs in fighting a pathogen. Many students demonstrated a cursory knowledge of the specific

immune system but attributed specific actions to incorrect cells and/or molecules. Specifically, students indicated that T cells engulf the pathogen and produce antibodies. Students also indicated that antibodies can engulf, attack, and destroy the pathogen. Students often used the term bacteriophage in place of macrophage and confused bacteria and virus. Additionally, some students indicated that the nervous system was involved in the immune response and that the specific immune response could be inherited with specific antibodies present before an immune response is initiated.

In part (c) some students demonstrated a lack of understanding of passive immune transfer between a mother and her baby both in utero and through nursing. Some students indicated that the mother and fetus share blood and that the infant was infected by the mother during nursing. Students who predicted that the baby would be unprotected against the pathogen were unable to provide a justification to support the prediction.

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?

Knowledge of the vertebrate immune system is required by the curriculum framework and should be emphasized in the course. Additionally, the ability to apply the science practices is critically important. Teachers should use an inquiry approach that fosters critical thinking to teach the immune system, as it is often difficult for students.

Teachers should provide opportunities for students to practice reading and analyzing many different types of data. Data analysis and scientific argumentation is of critical importance; students should practice supporting claims by using evidence and reasoning. Teachers should encourage students to read the question carefully, answer the specific prompts in the question, and follow through with a complete, but concise, answer to each prompt.

Question 3

What was the intent of this question?

Question 3 asks students to consider the effects of expansion of human populations on local plant and animal communities, respectively. Students were asked to predict a likely ecological consequence to a plant community during the site preparation and construction of a sports complex in a formerly wooded area. Students were then asked to predict a likely effect on the animal community that might result from regular use and maintenance of the playing fields. Finally, students were asked to use appropriate data to support the effects of the expansion of human populations.

How well did students perform on this question?

The mean score for this question was 3.34 out of a possible 4 points.

What were common student errors or omissions?

Overall, students demonstrated a strong understanding of ecological consequences of human expansion. Common errors included statements indicating that organisms in a specific area would either go extinct or undergo speciation. Students attempted to connect the removal of plants from the area with effects on the atmosphere, but incorrectly claimed that carbon dioxide is a pollutant or that loss of trees resulted in loss of oxygen in the atmosphere for animals in the local area. Many students provided only superficial support as justification of the ecological consequence. Students also described the impact of human expansion on the wrong type of community, often skipping the discussion of the impact on plants and discussing only the impact on animals.

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 provide students with frequent opportunities to construct scientific arguments where students use evidence and reasoning to support claims. Teachers should ask students to make predictions and also ask them to identify the appropriate type of data to support those predictions.

Question 4

What was the intent of this question?

Question 4 asks students to analyze data from an investigation of natural selection in a population of guppies and connect changes in the phenotype with different selective pressures. The question presented a graph of the data, and asked students to describe the change in genetic variation in the population over the first 6 months of the experiment. Students were asked to use appropriate evidence from the graph to support their description. Students were asked to propose a type of mating behavior that could have resulted in the change in phenotype experienced by the guppy population in the absence of predators. Students were asked to propose an evolutionary mechanism that explains the change in phenotype experienced by the guppy population in the presence of predators.

How well did students perform on this question?

The mean score for this question was 1.37 out of a possible 4 points.

What were common student errors or omissions?

Many students were unable to appropriately analyze the data provided in the question. The graph showed the relationship between the mean number of spots per male guppy and time, but the y-axis units were misinterpreted by many students as the number of individuals instead of the mean number of spots. Other errors included confusing the lines representing the population in the absence of predators with the line representing the population in the presence of predators.

Students struggled to correctly assess the variation in the number of spots over time and frequently responded that genetic variation of the population was increasing because the slope of the line is positive.

Students made the assumption that the allele for spots was dominant because the mean number of spots increased, or that the male guppies have spots and the females do not. Students were unable to speak clearly about the mechanism of natural selection as it relates to evolution, including that organisms choose to evolve (i.e., Lamarckian evolution), or that individuals evolve rather than populations.

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 provide many opportunities for students to engage with data from many sources. Analyzing data, drawing conclusions based upon an analysis of that data, and constructing scientific arguments based upon evidence are of critical importance. Statistical analysis should be a key component of quantitative data analysis so that students understand the role of experimental statistics in biology and have a conceptual understanding of the statistical formulae on the AP® Biology Equations and Formulas Sheet. Teachers should emphasize statistical analysis and demonstrate that the Standard Error of the Mean (SEM) reflects how the experimental sample mean most likely relates to the true mean of a population.

Question 5

What was the intent of this question?

Question 5 focuses on the impact of humans on the stability of populations, communities, and ecosystems. Students were asked to describe two potential biological risks to the ecosystem due to the large-scale cultivation and use of genetically modified crops by humans. Students were then asked to provide a proposed mitigation to reduce the effects of genetically modified crops on the ecosystem for each of the proposed risks.

How well did students perform on this question?

The mean score for this question was 1.78 out of a possible 4 points.

What were common student errors or omissions?

Overall, students demonstrated a poor understanding of genetically modified (GM) crops. Many students made the assumption that if any plant was genetically modified, it was bad and should be viewed as a threat to the ecosystem. Students often confused herbicides with pesticides and stated that GM plants may have developed resistance to a pesticide rather than an herbicide. Errors included the assumption that the GM crops were sprayed with insecticide rather than produce the insecticidal proteins as a result of the genetic modification or that generic chemicals were applied to the crops rather than specific treatments. Students also asserted that the modification of a small number of genes in a plant would cause a disruption of many other genes in the plant. Some students indicated that all, not just some, of the plant's genes had been genetically modified.

Finally, students misidentified one of the goals of the genetic modification, i.e., to kill insect pests, as one of the potential risks of their use. Students also incorrectly answered the question by providing non-biological risks (e.g., economic or policy).

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 stress that any experimental genetic manipulation creates a GMO, and that GMOs include modified crop plants, laboratory model organisms (e.g., fruit flies or mice), or medical biotechnology applications. Further, teachers should encourage discussion of both the risks and the benefits of the use of any biotechnology. Based on this discussion, teachers should then provide students with the opportunity to construct scientific arguments that use evidence and reasoning to support claims or predictions.

Question 6

What was the intent of this question?

Question 6 focuses on the response of the nervous system due to interactions between its constituent parts. Students were presented with a visual representation of a reflex arc and a brief description of neural pathways and asked to differentiate among pathways of information transmission within the nervous system. Students were then asked to describe differences between a reflex arc and a typical stimulus-response pathway, based on their analysis of the representation. Students were then asked to support the claim that reflex arcs are beneficial to organismal survival.

How well did students perform on this question?

The mean score for this question was 1.28 out of a possible 3 points.

What were common student errors or omissions?

Most students successfully described at least one difference between a reflex arc and a typical stimulus-response pathway. However, many students incorrectly claimed that without a reflex, organisms will not respond to any stimulus. Students often confused neural pathways with signal transduction pathways or with hormone signaling, and some students described neuron function (resting potentials, action potentials, etc.) rather than answering the question.

While students were able to provide adequate descriptions, many students failed to provide adequate reasoning connecting the reflex with the ability of the organism to avoid a threat.

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 emphasize that the central nervous system includes both the brain and spinal cord and have students investigate both the reflex and typical stimulus response pathways. Teachers should provide students with opportunities to describe models and representations and to carefully look at the information the model is providing. Teachers should also continue to emphasize the importance of carefully reading the question, as students used a great deal of time constructing unnecessarily long responses to this question. Teachers should provide every opportunity for students to connect concepts across organizational levels (e.g., molecules, cells, organisms, and communities).

Question 7

What was the intent of this question?

Question 7 asks students to analyze data to connect patterns in an abiotic factor to behavioral mechanisms used to maintain homeostasis. Students were asked to describe a method of thermoregulation most likely used by the animal species. Students were asked to justify their answer using a graph that shows an increasing rate of oxygen consumption with increasing environmental temperature. Students were then asked to refine a model (graph) by drawing a line illustrating the relationship between body temperature and environmental temperature for the species in question.

How well did students perform on this question?

The mean score for this question was 0.90 out of a possible 3 points.

What were common student errors or omissions?

Students often described the mode of thermoregulation as endothermic rather than ectothermic. Students incorrectly claimed that, as an endotherm, panting or sweating increases oxygen consumption or that the animal was hibernating. Students incorrectly claimed that the increased rate of oxygen consumption was a mechanism used by the animal to cool itself down i.e., oxygen consumption was the thermoregulatory behavior. Some students claimed that increased oxygen consumption causes increased metabolic rate.

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?

Most students successfully analyzed the data and described that increased temperatures led to increased rates of oxygen consumption. However, students were not able to extend their thinking to the strategies organisms use to maintain homeostasis. Students were also challenged to connect the effect of environmental temperature on metabolic rate with the effect of environmental temperature on body temperature.

Teachers should give students the opportunity to compare the strategies that different organisms use to respond to various environmental challenges (e.g., temperature, light). Teachers should also take every opportunity to connect physiological mechanism to evolutionary biology (i.e., asking students how natural selection has resulted in diverse homeostatic mechanisms).

Question 8

What was the intent of this question?

Question 8 asks students to refine evidence from hypothetical data to explain how genetic variation contributes to the process of evolution. Students were presented with a description of a strain of fruit flies that has been engineered to eliminate errors during DNA replication. Students were asked to provide evidence that would indicate new genetic variation has occurred in the engineered flies. Students were then asked to explain a process that could lead to genetic variation. Finally, students were asked to describe how genetic variation in a population contributes to the process of evolution, using the engineered fruit flies as a model.

How well did students perform on this question?

The mean score for this question was 1.19 out of a possible 3 points.

What were common student errors or omissions?

Many students confused mechanisms that lead to new genetic variation with processes that stabilize allele frequencies in populations (i.e., maintain Hardy-Weinberg equilibrium). Students often used buzzwords such as "fitness" and "natural selection" without demonstrating a conceptual understanding of the terms. Students demonstrated misconceptions about fitness, describing it in terms of "stronger" vs. "weaker" individuals, or "good" vs. "bad" traits.

Many students failed to connect the effect of new genetic variation in the population with the outcome of natural selection, i.e., reproductive success. Some students claimed that natural selection acts on genotypes or alleles rather than on phenotypes or that evolution occurs in individuals rather than in populations over time. Students often used Lamarckian or teleological language when describing evolution, (e.g., a changing environment — or predators — would cause natural selection; populations need genetic variation to adapt to their environment or to become more fit).

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 clarify the difference between changing allele frequencies (over generations) and processes that introduce genetic variation at the individual level. Teachers should also differentiate between mutations caused during DNA replication and other sources of genetic variation (e.g., crossing over and random assortment during meiosis, or spontaneous mutations). Teachers should emphasize that natural selection acts on phenotypes, not genotypes and connect natural selection with increased (or decreased) reproductive success.