Student Performance Q&A:

2016 AP® Biology Free-Response Questions

The following comments on the 2016 free-response questions for AP® Biology were written by the Chief Reader, Nancy Morvillo of Florida Southern College and the Question Leaders Cyndie Beale, Geoff Gearner, Trevor Gallant, 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 an investigation of the effects of salinity on the frequency of a specific allele of a leucine aminopeptidase gene (lap^{94}) in a population of mussels living in Long Island Sound. Students were presented with a figure depicting the Long Island Sound and the nearby Atlantic Ocean with eight sampling sites of increasing salinity. Students were also presented a table of data indicating the lap^{94} allele frequency at each sampling site. Students were asked to construct a graph to illustrate the observed allele frequencies and to describe the most likely effect of salinity on the lap^{94} allele frequency. Students were asked to use their analysis to predict the likely lap^{94} allele frequency at a different site in Long Island Sound. Students were then asked to describe the most likely effect of LAP^{94} on the osmolarity of the cytosol and the function of LAP^{94} in maintaining water balance in the organism. Finally, students were asked to explain the differences in allele frequency in adult mussels at the different sampling sites despite the dispersal of larval mussels throughout the study area. Students were asked to predict, with justification, the likely effect on the distribution of mussels in the study area if the lap^{94} allele was present in all mussels in the area.

How well did students perform on this question?

The mean score for this question was 5.2 out of a possible 10 points.

What were common student errors or omissions?

In part (a), there were some common graph construction errors: students struggled with correctly labeling the axes, often omitting the units for allele frequency (%), or not indicating *lap94* allele frequency. Scaling was not always accurate, and the spacing between values was sometimes inconsistent.

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In part (b), students sometimes tried to attribute cause and effect to the relationship between salinity and *lap94* allele frequency. There is a positive correlation between the two, but one doesn't cause the other. Sometimes students incorrectly indicated that LAP94 activity caused an increase in ocean salinity. A common error was incorrectly referring to *lap94* frequency as the number of alleles or the amount of enzyme present within individual mussels, rather than the frequency of the allele within a population.

In part (c), students were often confused when describing the effect of LAP94 activity on the osmolarity, solute concentration, or water potential of the cytosol. Some students incorrectly indicated that an increase in osmolarity due to amino acid concentration resulted in an increase in salinity in the cytosol, or that LAP94 controlled salt intake by the cells. Some students incorrectly stated that an increase in amino acids in the cytosol would cause a decrease in the osmolarity. Still others thought that salinity controlled the expression of the *lap94* gene. When describing the function of LAP94, students didn't always explain that it prevented water loss.

In part (d), many students didn't connect having the *lap94* allele to a selective advantage or disadvantage, or the ability or inability to survive. Many students correctly predicted that if all mussels had the *lap94* allele, they would be more likely found in areas of higher salinity, but incorrectly justified the prediction by saying mussels would move or migrate to those areas. Those who incorrectly thought the question referred to gene expression explained that there was more of the protein expressed in individual mussels in higher salinity. Many students did not tie a physiological justification for better survival in areas of high salinity, failing to tie the ability to osmoregulate to survival. Many students also used words like homeostasis without explaining what process would establish homeostasis.

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?

Create opportunities to have students analyze, describe, and make predictions utilizing a wide variety of charts, models, and graphs. Consistently require all aspects of creating a graph, including correct scaling and units.

Connect osmoregulation to maintaining homeostasis, and develop a comfort with terms osmolarity, water and solute potential, solute concentration, hypertonic, hypotonic, and isotonic. Provide opportunities for students to apply these terms to explain how osmoregulation occurs, and practice predicting how changing conditions might impact osmoregulation.

Teach the concepts of natural selection early, and apply them to topics throughout the year. Use a variety of examples or studies that apply the concepts of evolution, including how changes in allele frequencies are tied to the specific gene function.

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Question 2

What was the intent of this question?

This question was based on a graph showing the growth of a bacterial population in the presence of limiting amounts of two different nutrients, nutrient I and nutrient II. Students were also presented data showing the relative concentrations of the two nutrients in the growth medium during the experiment. Students were asked to use the data to estimate the maximum population density in the culture and to describe what likely prevents further growth of the population. Students were then asked to calculate the rate of growth of the bacterial population for a specific time period. Students were asked to identify the preferred nutrient source of the bacteria, to justify their selection using the data, and to propose an advantage of displaying a preference for one nutrient over another. Finally, students were asked to propose a mechanism whereby nutrient I may regulate the expression of genes involved in the metabolism of both nutrient I and nutrient II, and to provide two reasons for the lag in population growth that occurs midway through the experiment.

How well did students perform on this question?

The mean score for this question was 3.1 out of a possible 10 points.

What were common student errors or omissions?

For the estimate point in part (a), a small number of students failed to interpret the graph correctly, providing an over or under estimate of the population at 9 hours, or improperly indicating exponents (non-integers).

For the description point in part (a), students sometimes used the term resource instead of nutrient, and did not indicate that the depletion of both nutrients prevented further growth. Other students failed to recognize the closed culture and incorrectly cited carrying capacity as the limiting factor.

In part (b), a number of students were unable to do the calculations properly for values expressed in scientific notation. The most common mistake was subtracting exponents. Other students provided only an estimate rather than an exact value for the growth rate.

In part (c), many students indicated that nutrient II is the preferred nutrient and included the incorrect justification that it lasts longer in the culture or promotes a higher bacterial growth rate.

For students who earned the point for identifying the preferred nutrient, but did not earn the justification point in part (c), the most common error was being unable to demonstrate the exclusive use of nutrient I by the bacterial population before the use of nutrient II.

For the description points in part (d), relatively few students were able to demonstrate a conceptual understanding of how metabolites regulate gene expression. A number of students failed to articulate that nutrients play an active, not passive, role in both positive and negative regulation of gene expression.

For the reasoning points in part (d), many students earned the point for indicating that the depletion of nutrient I was a reason for the lag in bacterial growth at hours 5 to 6, but did not describe the time requirement for the expression of genes required to metabolize nutrient II.

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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?

As always, students should practice interpreting and critically evaluating a variety of graph types and styles. Students should also practice carrying out arithmetic functions (add, subtract, multiply, divide) with numbers expressed in scientific notation. Paying careful attention to what the question is asking will ensure candidates do not miss key words, for example “describe...” vs. “describe how...”.

There are many examples of how gene expression is regulated in bacteria and eukaryotes. The *lac* and *trp* operons in the bacterium *Escherichia coli* are good models to start with, and there are well-understood models in eukaryotic cells that can be included for discussion.

Question 3

What was the intent of this question?

This question focused on the energy allocation strategy in plants. Students were given a graph showing the percent dry weight allocated to different plant parts throughout a single growing season. Students were told that the percent dry weight is an indication of the energy used to produce a structure in the plant. Students were asked to identify the direct source of energy used for plant growth during a particular period and to identify the part of the plant that grew most during that same period. Students were then asked to estimate the percent of the total energy that has been allocated to the growth of the leaves on a particular day. Finally, students were asked to propose one evolutionary advantage of an annual plant allocating much more energy to the growth of its reproductive parts compared to perennial plants.

How well did students perform on this question?

The mean score for this question was 1.4 out of a possible 4 points.

What were common student errors or omissions?

In part (a), many students incorrectly identified sun, soil, water, roots, and ATP as possible sources of energy to support plant growth. Some students believed the process of germination itself to be the source of energy. In the second part of part (a), the most common error was incorrectly identifying stems as the plant part that grew the most during the first week of May.

In part (b), some students were unable to interpret the graph to estimate the amount of energy allocated to the leaves on the first day of July.

In part (c), the most common error was failing to stress the necessity of reproducing in one growing season since that is the plant’s only opportunity to reproduce. Many students incorrectly proposed that annual plants reproduce earlier, faster, more often, more successfully, or more effectively than do perennials. Some students proposed that the strategy increases the fitness of annual plants but failed to specifically articulate how the strategy did so. Students believed that producing more seeds, offspring, or genetic diversity was the advantage of the energy allocation strategy.

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?

Throughout the year, teachers should create opportunities to emphasize energy acquisition, use, and transfer strategies as a central theme in biology.

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Teachers should have students create, analyze, and describe different types of graphs. Teachers could use more graphs in daily lessons and assessment items to familiarize students with using graphed data to identify trends in data sets, make predictions, and to support scientific claims.

Teachers should provide students with many opportunities to deeply explore the topics of evolution and natural selection as foundations of all concepts in biology. Students should understand and be able to articulate the difference between a strategy and the reason for that strategy in the context of evolution.

Question 4

What was the intent of this question?

This question focused on the process of gene expression. Students were given a diagram representing the expression of a gene in a eukaryotic cell. Students were asked to describe the modification that most likely results in the mature mRNA being shorter than the primary transcript, and to identify the location in the cell where the modification occurs. Students were then asked to predict, with justification, the length of the mature mRNA if the same gene were expressed in a prokaryotic cell.]

How well did students perform on this question?

The mean score for this question was 1.4 out of a possible 4 points.

What were common student errors or omissions?

In part (a), some students were unsure of the differences between and locations of transcription and translation. Many of those same students used the terms DNA, gene, and primary transcript interchangeably. Many students did not have a clear understanding of the order of transcription and RNA processing, stating that introns are removed from DNA. In the second part of part (a), some students incorrectly identified spliceosomes, ribosomes, the cytosol, the ER, the Golgi apparatus, etc. as possible locations where RNA processing occurs.

In part (b), most students were able to correctly predict the length of the mature mRNA in the prokaryotic cell, but were unable to provide a justification for their prediction. Many students incorrectly justified that prokaryotes are too simple or that they do not have DNA, organelles, or a nucleus. Many students described the length of the gene rather than the length of the mature mRNA.

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 introducing more complex topics, teachers should be sure to review basic principles frequently. As students expand their understanding of biology, they need to revisit previously learned concepts to be sure that their foundation is solid. Teachers should administer regular quizzes or other short assessments to reinforce students' understanding of basic concepts and get formative feedback about student understanding.

Generally, teachers should create more opportunities to explore gene expression and its regulation to deepen student understanding of these complex topics.

For major concepts (such as homeostasis, reproduction, nutrition, cell division, cell processes, etc.), it might be helpful to have students keep track of the differences between groups of organisms (e.g., prokaryotes and eukaryotes, plants and animals, etc.).

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Question 5

What was the intent of this question?

This question focused on the topics of mutualism and parasitism. Students were given a graph showing the mass over a given time period of two plant species that grow while attached to one another. Students were given two templates and asked to graph the predicted shape of the lines following the separation of the plants if the plants are in an obligate mutualistic relationship, and the shape of the lines if one plant is a parasite of the other. Finally, students were asked to justify each of their predicted graphs.

How well did students perform on this question?

The mean score for this question was 1.9 out of a possible 4 points.

What were common student errors or omissions?

Many students graphed the predicted mass of the two plants as if they had not been separated and then justified those predictions based on a definition of mutualism and parasitism. A common error was describing rather than justifying the graphs of the predicted plant mass.

Many students did not understand the distinction between mutualism and obligate mutualism, predicting the two plant species would grow normally or at a slightly slower rate, but would not cease to grow or decline after separation.

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 give students opportunities to represent predictions and to illustrate trends using graphs. Teachers could use more graphs in daily lessons and assessment items to familiarize students with using graphed data to identify trends in data sets, make predictions, and to support scientific claims. It is important to reinforce students' understanding of the difference between describing and justifying by providing them with opportunities to practice these two skills.

Teachers should include discussions of ecology and ecological relationships between organisms in the scope of the course.

Question 6

What was the intent of this question?

This question focused on using DNA fragments shed from organisms into the environment (eDNA) to detect the presence of silver carp, an invasive species of fish. Students were given a graph showing the length of time that short or long fragments of eDNA can be detected after being shed from the organisms. Students were also given a map of Lake Michigan and a connected river system with sampling sites indicating whether eDNA from the silver carp had been detected. Students were asked to justify the use of eDNA for detecting silver carp in a community with many different species, and to propose an advantage of identifying long fragments rather than short fragments of eDNA. Students were then asked to provide reasoning to support a researcher's claim that the detection of eDNA at a single sampling site in Lake Michigan is a false positive.

How well did students perform on this question?

The mean score for this question was 0.79 out of a possible 3 points.

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What were common student errors or omissions?

In part (a), a common error was using molecular information given in the stem to justify the use of eDNA for detecting the presence of silver carp. Some students incorrectly proposed that detecting longer eDNA fragments was advantageous because they were easier to see/find/locate, took a shorter time to detect in the environment, indicated a higher number of silver carp in the environment, or indicated a longer time of residence for the silver carp.

In part (b), many students incorrectly indicated that the false positive could have been a short eDNA fragment from a common ancestor to the silver carp, a closely related species, a hybrid carp, or a different species of carp with mutations. Incorrect responses also included researcher error, technical problems with PCR, or field sampling problems.

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 try to incorporate new technologies and current scientific events into the curriculum. Exposing students to many different applications of the basic biological constructs they are learning increases their ability to approach and solve novel situations with confidence.

Teachers should relate topics they are teaching back to the Big Ideas of the course, providing a framework to identify the connections throughout the curriculum.

Question 7

What was the intent of this question?

This question focused on the process of meiosis and independent assortment. Students were given a diagram of a cell with two pairs of homologous chromosomes. Students were asked to construct a diagram to indicate the four normal products of meiosis from a doubly heterozygous F_1 individual. Students were then asked to predict the phenotype ratios from a testcross with the F_1 individual and to describe how the proportions of phenotypes would likely differ if the two genes in question were genetically linked.

How well did students perform on this question?

The mean score for this question was 0.51 out of a possible 3 points.

What were common student errors or omissions?

In part (a), many students were unable to illustrate the haploid products of meiosis. Common errors included failing to associate an allele with a chromosome, failing to separate sister chromatids, and incorrectly segregating chromosomes (i.e., segregating chromosome 1 from chromosome 2).

In part (b), the most common error was providing the phenotype ratio of a dihybrid cross (9:3;3:1) rather than a testcross with a double heterozygote (1:1:1:1). Another common error was providing genotype ratios rather than phenotype ratios.

In part (c), many students confused genetic linkage with sex linkage. Students did not specify which phenotypes would be more likely to occur, nor did they give an indication of how the predicted ratio would be altered.

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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 take the time to stress the relationship between the physical process of meiosis and the principles of Mendelian genetics. Circle back to the model of meiosis often when discussing genetics. Stressing the specific terminology of genetics will also improve student understanding.

Question 8

What was the intent of this question?

This question focused on experimental design and data analysis. Students were given a graph showing the results of an experiment to test the effect of exercise on prolactin release. Students were asked to justify the use of a without-exercise treatment as the experimental control. Students were then asked to analyze the data to determine whether prolactin release changes after exercise and to justify their response.

How well did students perform on this question?

The mean score for this question was 0.56 out of a possible 3 points.

What were common student errors or omissions?

In part (a), many students gave a general definition of an experimental control but did not relate it to the specific experimental treatment in question. Many students failed to connect the without-exercise treatment to baseline levels of prolactin or to isolating exercise as a variable.

In part (b), many students could not commit to an answer, instead saying data were inconclusive. Other students assumed there was a difference in prolactin release based only on changes in the mean without taking the standard errors of the mean into account.

In part (b), when asked to justify their determination most students did not look at the standard error bars, reporting only on the means. When error bars were mentioned, many students simply stated all error bars overlapped. Often students related the apparent increase in prolactin release after exercise to the increased levels of lactic acid that would be expected after exercise.

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?

Quantitative analysis, including descriptive statistics, remains an area where teachers need to place much more emphasis. Discussing appropriate statistical analyses after every bench experiment is an effective way to increase comfort with data analysis. Presenting data sets that require application of statistical analyses is also very important.

Teachers should take the time to stress experimental design, focusing on why specific groups/treatments are included in experiments. Modeling which data are from control treatments and which are from experimental treatments will give students practice interpreting experimental results. Finally, it is good to review and discuss experiments that show no significant effect of treatment, emphasizing that an experiment can be successful even if there is no change in outcomes.

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