Student Performance Q&A:

2013 AP® Biology Free-Response Questions

The following comments on the 2013 free-response questions for AP® Biology were written by the Chief Reader, Domenic Castignetti, Loyola University, Chicago, Illinois, in collaboration with the Question Leaders Pat Mote, Jeff Smith, 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 asks students to apply inquiry skills to a lab-based investigation of fruit-fly behavior. Students were presented with a description of an experimental setup for investigating whether fruit-fly behavior is affected by the presence of a substance (glucose). Students were asked to make a prediction about the behaviors underlying taxis in fruit flies and to justify their prediction using reasoning that relates the presence of the glucose to specific behaviors. Students were also asked to suggest improvements to the data collection strategies that were used in the investigation and to explain how the modifications will ensure the validity and reliability of the results. Students were then asked to perform data analysis (a chi-square test) on the results of a related experiment. Finally, students were asked to propose a general model of fruit-fly behavior that is based on current scientific knowledge and understanding about how organisms detect and act on information in their environment.

How well did students perform on this question?

The mean score for this question was 3.63 out of a possible 10 points.

What were common student errors or omissions?

Students were very successful in part (a) and most earned 1 point for the prediction and 1 point for the justification. Part (b), which required an improvement of the experiment, was more challenging. Many students failed to recognize that the experiment had two variables (glucose and water). The improvements to the experimental control and environmental factors should have ensured that the flies' response was to the glucose and not other factors. Students often confused experimental controls and environmental factors or mislabeled the responses.

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Part (c) had two tasks, the stating of a correct null hypothesis and determining the expected values based on the stated hypothesis. Students frequently stated an experimental hypothesis rather than a null hypothesis. This resulted in problems with correct expected values for the chi-square calculation.

Part (d) required the student to compare a calculated chi-square value to the critical value. Any calculated chi-square value was acceptable, but students often failed to clearly indicate the critical value used for comparison. Interpretations of when to accept or not accept the chi-square test were sometimes reversed.

Part (e) required the student to propose a model that described how environmental cues affect the behavior of the flies in the choice chamber. A model would be a highly simplified explanation of the relationship between environmental cues (stimulus) and behavior (response). Many different examples, including written explanations, labeled drawings, and graphs, were acceptable.

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?

Some students appear to be unclear about the importance of having only one independent variable in an experiment. Learning Objectives (LOs) 2.21 and 2.23 should be carefully emphasized and examined in the laboratory aspects of the course, especially in student designed experiments. The effects of experimental controls and environmental factors should be clearly identified. Classroom discussions about how to improve or refine experimental design should be considered in all laboratory activities.

Careful consideration is needed in the use of LOs 2.38 and 4.14 in the mathematical analysis of the experimental results. Teachers must pay close attention to the use of the chi-square test beyond the more traditional use in genetics. Students must understand the difference between an experimental hypothesis and a null hypothesis. Attention is also needed in the interpretation and application of the chi-square test results. Teachers may need to refresh their own understanding of the null hypothesis as used in the chi-square test so that this material is taught correctly. One suggestion is to collaborate with an AP® Statistics instructor for this information. Joint projects between AP® Biology and AP® Statistics would benefit students in both disciplines.

Many students appeared to be confused by what was meant by the term "modeling" and further work with LO 3.14 is suggested. Be more deliberate in their use of the term "model" in both the classroom and laboratory to demonstrate the pervasive use of models in the study of biological systems and phenomena.

Students should read the question carefully so that they understand the language of the question and the tasks they are being asked to perform. Teachers can assist their students with careful instruction in the meaning and application of the bolded task words in the questions. Task words such as "predict" are tied in with many Learning Objectives such as 3.4 and 4.16. Students need multiple opportunities to apply and practice the task words from the Learning Objectives if they are to be successful with the new curriculum framework.

Question 2

What was the intent of this question?

Question 2 asks students to work with scientific theory and evidence to explain how the processes of natural selection and evolution could have resulted in different photosynthetic organisms absorbing light within different ranges of the visible light spectrum. Students were asked to use experimental data (absorption spectra) to identify two different photosynthetic pigments and to explain how the data support their identification. Students were then presented with a description of an experiment for investigating how the wavelength of available light affects the rate of photosynthesis in autotrophic organisms. Students were

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asked to predict the relative rates of photosynthesis in three treatment groups, each exposed to a different wavelength of light, and to justify their prediction using their knowledge and understanding about the transfer of energy in photosynthesis. Finally, students were asked to propose a possible evolutionary history of plants by connecting differences in resource availability with different selective pressures that drive the process of evolution through natural selection.

How well did students perform on this question?

The mean score was 3.70 out of a possible 10 points.

In part (a), students were often able to correctly identify both pigments, and many students could explain that an organism containing chlorophyll *a* appears green because the pigment absorbs light in the red and blue ranges of the light spectrum and reflects green light, while an organism containing bacteriorhodopsin appears purple because the pigment absorbs green light and reflects red and blue light.

In part (b), many students were able to correctly predict that the relative rates of photosynthesis for the three groups of organisms. Some students were able to justify their predictions by explaining that absorbed light energy is used to drive photosynthesis.

In part (c), many students proposed that only some wavelengths of light were available to the ancestors of plants because other wavelengths were absorbed by their aquatic environment. Some students were able to support their proposals by reasoning that natural selection favored organisms that relied on pigments that absorb available wavelengths of light.

What were common student errors or omissions?

In part (a), students misidentified the two absorption spectra. Although the question asked students to identify **both** pigments, some only identified one pigment. Students often displayed a misunderstanding of light absorption vs. light transmission or reflection, e.g., many students erroneously claimed that chlorophyll *a* is green because it absorbs green light, or that bacteriorhodopsin is purple because it absorbs purple light. Some students referred to the absorption spectra as action spectra.

In part (b), many students were able to predict the photosynthetic rates of the three experimental groups by analyzing the absorption spectrum, but were unable to construct an explanation connecting the absorption of light to its role as an energy source in photosynthesis. In contrast, some students were unable to predict photosynthetic rates for the experimental groups, even though they were able to analyze the graphs in part (a) to identify the pigments and construct accurate explanations of the relationship of pigment color to light absorption. Although the question asked students to predict the relative rate of photosynthesis in each of the three groups, some students failed to distinguish between the 650 nm group and the 430 nm group. Some responses erroneously predicted that there would be *no* photosynthesis in green light. Other students claimed that because plants are green, green wavelengths allow for the most photosynthesis. Some responses predicted photosynthetic rates based on the numerical value of the wavelength, claiming that longer wavelengths of light result in higher rates of photosynthesis; predicted absorbance rates or growth rates rather than rates of photosynthesis; confused photosynthesis with respiration; and referred to pigments as "colors."

In part (c), students often did not demonstrate an understanding that photosynthesis first evolved in prokaryotic organisms. Many students proposed evolutionary histories of purple photosynthetic bacteria rather than plants. Students proposed that the purple photosynthetic bacteria evolved into green plants, or that bacteriorhodopsin evolved into chlorophyll. Some students erroneously referred to bacteriorhodopsin as an organism. Some responses made erroneous claims about the physics of light, e.g., students claimed that longer wavelengths of light can penetrate water to greater depths than can shorter wavelengths, or that blue light is reflected by water. Some students proposed that the light spectrum emitted by the sun

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has changed over time. Other responses claimed that the sun emits yellow light. Some responses proposed that plants evolved at the bottom of the ocean, and that chlorophyll evolved after plants moved onto land. A few responses claimed that water plants use bacteriorhodopsin while land plants use chlorophyll. Some responses erroneously referred to animals (e.g., corals, fish, and mammals) as plants. Many responses employed Lamarckian reasoning, e.g., plants want to change or choose to adapt. Some students reasoned that plant pigments evolved as a result of herbivory pressure, i.e., plants evolved green pigments as camouflage.

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?

Explain the meaning of terms, e.g., *explain*, *justify*, *predict.* Remind students to read the question carefully, answer the specific prompts in the question, and follow through with a complete answer to each prompt. Provide opportunities for students to practice reading and analyzing many different types of graphs, as well as allowing students to practice justifying claims using scientific evidence. Photosynthesis is a critical part of the curriculum and should not be neglected. Expose students to the absorption spectrum for chlorophyll and the simple physics of light. Make the distinction between light absorbance and transmission (or reflection), and emphasize the connection between light absorbance and energy for photosynthesis. Provide students with opportunities to explain how natural selection could have played a role in the evolution of various systems and emphasize that photosynthesis first evolved in prokaryotic organisms and that prokaryotic photosynthetic pathways were the foundation of eukaryotic photosynthesis.

Question 3

What was the intent of this question?

Question 3 asks students to apply strategies for collecting and analyzing data to a proposed investigation of the evolutionary histories of specific types of organisms. Students were presented with a hypothesis about the evolution of amphibians and with a description of different rock samples that might contain evidence for testing the hypothesis. Students were asked to select the most appropriate rock sample in which to search for evidence of a transitional species between lobe-finned fishes and amphibians. Students were also asked to justify their selection using their knowledge and understanding of paleontology, comparative anatomy, and molecular biology. Finally, students were asked to describe two pieces of evidence provided by fossils of a transitional species that would support the hypothesis that amphibians evolved from lobe-finned fishes.

How well did students perform on this question?

The mean score was 2.55 out of a possible 4 points.

What were common student errors or omissions?

Some students listed lungs as a fossil. Students confused lungfishes with lobe-finned fishes.

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 know the meaning of the bolded terms in the question. This question asked students to select, justify, and describe.

In discussions and investigations of evolutionary biology, be sure to include topics such as the fossil

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record, homologous structures, and molecular evidence. The BLAST lab investigation provides this exposure for the students.

Question 4

What was the intent of this question?

Question 4 asks students to use representations and models to explain how energy and matter move through ecosystems. Students were asked to identify the key metabolic processes (photosynthesis and cellular respiration) depicted in a visual representation of a carbon cycle and to explain the role of energy in both processes. Students were also asked to identify an organism that carries out both processes. Students could identify the organism by connecting concepts about energy flow with their general knowledge about organisms in different domains.

How well did students perform on this question?

The mean score was 1.64 out of a possible 4 points.

What were common student errors or omissions?

Students reversed the identification of the processes in Step I and Step II.

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 did not understand the bolded term "explain."

An understanding of the carbon cycle is essential for a biology student. Students should be able to differentiate between an element cycling through the ecosystem and energy flow. An energetics lab investigation would provide opportunities for the students to study these concepts.

Question 5

What was the intent of this question?

Question 5 asks students to use models of biological polymers to connect genetic variation with changes in protein structure and function. Students were presented with the amino acid sequences of a conserved polypeptide from four related species. Students were asked to explain how specific genetic changes could have produced the different amino acid sequences shown. Students were then asked to use a model of protein structure and function to predict how a change in the amino acid composition of a polypeptide might affect the structure and function of the resulting protein.

How well did students perform on this question?

The mean score was 1.18 out of a possible 4 points.

What were common student errors or omissions?

For part (a), the students were not very successful in explaining that a mutation would occur in the DNA of the species. In the case of species II, this would then cause a different codon to be introduced, which would result in Lys to be coded for instead of Val at position 4 in the polypeptide chain. In the case of species III, a mutation that introduces a STOP codon occurred after Val which would lead to termination of the polypeptide at position 8.

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Part (b) asked students to look at the effect of the mutation on the structure and function of the resulting protein, but many students tried to answer the question in the same way they answered part (a), by explaining the particular genetic change.

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 did not understand the meanings of the bolded terms: explain, predict, justify.

Information about how the information found in a gene is transferred to a functioning polypeptide (protein) is an essential part of the biology curriculum. Students should be able to explain how a change in DNA can result in a change in the polypeptide (protein) that is formed from that information.

Question 6

What was the intent of this question?

Question 6 asks students to work with data about the contribution of cellular structures to specialized cellular functions. Students were presented with experimental observations about the relative amounts of specific organelles in three different cell types and asked to identify a likely function of each cell type. Students were then asked to explain how the experimental observations support their conclusions about why each cell type is likely to have the primary function that they identified in their response.

How well did students perform on this question?

The mean score was 0.69 out of a possible 3 points.

What were common student errors or omissions?

Students often did not make the connection between the function of the cell and the organelles present. Rather, they identified a special type of cell (e.g., muscle cell with cilia, stem cell, neuron) instead of identifying the cell's function. Students often identified the function of Cell X as cellular respiration and did not link the ATP production by the mitochondria to provide energy to the cilia for movement.

Students were confused about the function of some organelles. They interchanged the functions of cilia (movement/transport along cell surface) with villi (increase surface area) in Cell X. They stated that ER makes ribosomes and the ribosomes get exported in Cell Y.

Students also had difficulty when presented with Cell Z that lacked the organelles listed. They named cell types (prokaryotes, stem cells, neurons, sex cells, viruses) rather than identifying the function of cells lacking the organelles listed.

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 be presented with situations that challenge them to think outside the box. They should be asked to practice "what if" scenarios related to cell organelles. Teachers should ask questions that require students to predict the outcome of a situation: "What would happen if this organelle was absent?" "What organelles would be necessary if the function of the cell was (blank)?"

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Students should practice using representations and models to analyze situations describing the interactions of subcellular structures. Encourage students to look at a cell as an interacting system of organelles, rather than merely a membrane holding discrete parts with unrelated functions.

Teachers should review organelle structure and function, and their interactions, but should avoid using analogies (stack of pita bread, powerhouse, UPS.) Many students thought neurons or stem cells have no organelles.

Teachers should emphasize, and students should practice, the reading skills needed to understand and interpret the intent of the question.

Question 7

What was the intent of this question?

Question 7 asks students to engage in scientific questioning about the complex properties of biological systems. Students were presented with a description of an experiment in which researchers measured the volume of urine excreted by rats that had been fed solutions containing different concentrations of ethyl alcohol. Students were asked to pose a scientific question that the researchers could have been investigating in the experiment. Students were then asked to state a testable hypothesis that would address the scientific question they posed. Finally, students were asked to use data from the experiment to describe the relationship between ethyl alcohol consumption and urine production.

How well did students perform on this question?

The mean score was 2.19 out of a possible 3 points.

What were common student errors or omissions?

In part (a), students based their question on the results of the experiment by looking ahead to the data table. In some cases, they were posing a question for a follow-up experiment. Students often posed their question based on alcohol as a nutrient or alcohol in the urine, and questions often did not directly relate to the description.

In part (b), students did not indicate a direction of alcohol's effect on urine output (increase, decrease, or no change.) Others did not relate their hypothesis to the question they posed in part (a). Some students gave an experimental design/plan rather than stating a hypothesis.

In part (c), students determined the sum of the urine output from the three groups and indicated the output was greater than the input in the description. Students have the misconception that kidneys expel alcohol as a waste, and focused on detoxification or elimination of the alcohol. Others focused on the effect of alcohol on ADH.

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?

Provide opportunities for students to practice posing scientific questions, and in turn, converting these questions to hypotheses. In addition, students need practice in formulating a null hypothesis.

Provide opportunities for students to practice analyzing and evaluating data from tables.

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Question 8

What was the intent of this question?

Question 8 asks students to use a model of a cell signaling pathway to explain how extracellular signals are converted to specific cellular responses. Students were presented with a visual representation of a generalized hormone-signaling pathway and asked to use the representation to explain the role of specific steps in the pathway, beginning with reception of a hormone signal and ending with changes in target gene expression.

How well did students perform on this question?

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

What were common student errors or omissions?

In Step 1, students confused the receptor with a channel protein or an enzyme's active site. They described the hormone/ligand going through the receptor as in facilitated diffusion rather than initiating signaling.

In Step 2, students described a single, signal protein changing shape, often several times, in order to morph into a shape that would fit through the nuclear membrane. Some students erroneously described an enzyme passing through the cell membrane and then changing its shape and activity as it made its way to the nucleus.

In Step 3, students were not specific as to the regulation of the target gene. They restated the question prompt by saying gene expression was regulated, but did not indicate the direction (stimulated or repressed.) Some indicated the DNA was mutated/altered/changed by the molecule that entered the nucleus. Students stated DNA was replicated or translated rather than transcribed. Many stated the original hormone entered the nucleus, after having been modified.

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 the opportunity to study and analyze diagrams and to practice interpretation.

Spend time teaching cell to cell communication (download the AP® Resource). Students should model (act out, use manipulatives) to emphasize that the molecule in signal reception activates different molecules during the signaling cascade to relay the signal to the nucleus/DNA for gene expression.

Teachers should emphasize the importance of using the correct terminology. The terms "hormone," "protein," "enzyme," and "substrate" cannot be used interchangeably.

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