CollegeBoard AP

Student Performance Q&A:

2010 AP® Biology Free-Response Questions

The following comments on the 2010 free-response questions for AP® Biology were edited by the Chief Reader, John J. Lepri of the University of North Carolina at Greensboro. 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 concerned the homeostatic maintenance of optimal levels of glucose in the blood of vertebrate organisms, and intercellular communication by hormones. In part (a) students were asked to identify two pancreatic hormones that regulate glucose levels and then to describe the specific effects of each hormone on blood glucose levels.

In part (b) students were asked to identify one target cell for either of the two pancreatic hormones identified in part (a). Students were then required to discuss the mechanism by which that pancreatic hormone alters activity in the identified target cell. They were prompted to include descriptions of reception of the hormone by the target cell, the transduction of the signal by the target cell, and the ultimate response of the target cell to the hormone.

Part (c) moved to broader considerations in cell signaling by asking students to compare the cell-signaling mechanisms of steroid hormones and protein hormones.

How well did students perform on this question?

The mean score for this question was 2.63 out of a possible 10 points. Some essays demonstrated abundant knowledge about counterregulatory hormonal mechanisms in glucose homeostasis, and others showed very little knowledge. The 2 points most often earned in part (a) were those for identifying the two pancreatic hormones, insulin and glucagon, that regulate blood glucose levels.

What were common student errors or omissions?

Many essays did not demonstrate familiarity with the pancreatic hormones involved in the counterregulatory homoestatic mechanisms underlying glucose levels in the blood. Less commonly, the effects of insulin and glucagon were reversed. Numerous essays omitted the identity of specific target cells, and some revealed confusion about the distinctions between molecules and cells. In some cases there appeared to be a blending of hormone–receptor interactions with enzyme–substrate interactions, neurotransmitter actions, or immune cell activation. The overall distinctions between the actions of steroid hormones and the actions of protein hormones were described poorly in many essays and were reversed in a few cases.

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?

The big picture concerning cell communication is an important basis for understanding cause and effect in biological systems. The teaching of cell-signaling mechanisms has been encouraged for several years. Exploring a topic in depth — for example, counterregulatory mechanisms in glucose homeostasis — must be accomplished with the big picture in mind. Every chance to connect different parts of the course can and should be exploited. For example, where does glucose come from? How does it enter cells? What happens to glucose inside an active cell?

Teachers should ask their administrators to allow them to attend AP workshops and AP Summer Institutes to stay current on these connections. They should visit AP Central® often for updates.

Teachers should also caution students to carefully read each free-response question and should encourage them to diagram the questions during the exam's 10-minute reading period.

Question 2

What was the intent of this question?

In this question data were provided resulting from an experiment on the reaction rate of the human salivary enzyme α-amylase. The amount of product (maltose) and the time intervals over which it was measured were given. In part (a) students were instructed to construct a graph and to calculate the reaction rate for the time period of 0 to 30 minutes. In the graph students were expected to include the correct placement of the dependent (*x*-axis) and independent (*y*-axis) variables, proper labeling and scaling of the axes, and the precise placement of the data points on the curve. The correct calculation of the reaction rate over 30 minutes demonstrated an understanding of how data are used to obtain a kinetic rate for enzymatic reactions. Use of correct units of measurement was expected.

Part (b) requested an explanation of the change in reaction rate after 30 minutes. Students were expected to demonstrate an ability to analyze data and make appropriate conclusions.

Part (c) instructed students to predict and label a line on the graph that represented a doubling of the amount of the enzyme (α-amylase). Students were asked to explain their predicted results. Students were expected to demonstrate an understanding of how enzymes function and to use that understanding to make an appropriate prediction based on increased availability of the enzyme.

Part (d) instructed students to list two environmental factors that can alter the rate of enzyme-mediated reactions. Students were asked to discuss how each of the two factors they selected would affect the reaction rate. Students were expected to demonstrate an understanding of how environmental variables control an enzyme's function.

How well did students perform on this question?

The mean score for this question was 6.12 out of a possible 10 points. Many students were able to earn points on the graphing part of the question. Four points were available for properly graphing and labeling the figure: 3 points from part (a) and 1 point from part (c) for adequately drawing and labeling a predicted line. A fifth point was earned for a rate calculation derived from the provided data. Essays with high scores typically earned 4 or 5 points from graphing and calculating and then successfully answering the remaining three parts.

Part (b) stressed an understanding of the relationship between the data in the table and the calculated rate. Many students were successful in the calculation and interpretation of the rate data, noting that the rate diminished after 30 minutes and that the likely reason was a depletion of the substrate from the solution as it was converted to product or that the enzyme was becoming inactive.

Part (c) was answered correctly in high-scoring essays, demonstrating an understanding that increased amounts of the enzyme result in an increase in the initial rate of the reaction, but that the rate would level off sooner than before as the substrate concentration had not also been increased. Furthermore, these students understood that the final concentration of product with double the enzyme concentration would be the same as in the initial curve. An alternate explanation, given by some students, was that the rate leveled off at about the same time as in the initial reaction because the enzyme became inactive, but that the total amount of product was higher because more enzyme was included in the reaction.

Part (d) requested identification and discussion of two environmental factors that can alter enzymatic reaction rates. Temperature and pH changes were frequently listed as relevant environmental factors, with higher-scoring essays explaining that increased thermal motion will increase substrate–enzyme collisions and, therefore, catalysis. High-scoring essays also discussed the denaturing effect of excessive heat on an enzyme and demonstrated an understanding of optimal temperature and pH.

What were common student errors or omissions?

A significant number of graphs misplaced dependent and independent variables. Similarly, faults on some of the graphs included missing units and zero points. There were also errors in calculating the reaction rate for the requested time interval.

Some essays included incorrect labels for the substrate (starch) and the product (maltose), often using them interchangeably. The substrate was described as having its own active site, and it, rather than the enzyme, underwent an induced fit. In such cases, the essays suggested that the enzyme bound to the active site of the substrate and stated that an enzyme is saturated or that the enzyme had reached its "carrying capacity" when it had depleted all of its substrate. The term "equilibrium" was confused with a constant reaction rate in some essays.

Some essays implied that a change in the reaction rate occurred at 30 minutes because the experiment was half done, instead of analyzing the data and noting how the rate had changed noticeably after the 30-minute measurement. Some essays predicted that a doubling of product would be observed when the enzyme availability was increased, even though the substrate concentration had not changed.

Student misconceptions about enzymes included thinking that once an enzyme catalyzes a reaction, it is inactivated or "used up," or that if the substrate was exhausted, the enzyme would be denatured. Students were confused as to how this enzymatic experiment was conducted, stating that the experiment was conducted "in a person," meaning in a person's body.

Students sometimes proposed that both high and low temperatures could denature enzymes. The fact that other environmental factors (e.g., salinity, pH) cause enzyme inhibition was often cited as being a result of denaturation rather than inhibiting the catalysis by making the active site less receptive for the substrate. The concept of denaturation was misunderstood and applied to the substrate instead of, or in addition to, the enzyme. When valid environmental factors were cited, an explanation of how these affect enzyme catalysis was sometimes lacking. Occasional misstatements of pH effects included the explanation that an increase in pH results in an increased activity, without regard to whether the optimal pH was surpassed.

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?

Graphs are tools for data presentation and analysis that students should use for deductive reasoning. This reasoning allows a student to understand and explain what has occurred during the course of the experiment: in this case, that the enzyme had exhausted its substrate and the reaction rate correspondingly diminished as the experiment progressed. A discussion or exercise centering on how a change in the experimental design and implementation would affect the data set would help hone students' reasoning skills. For this experiment, for instance, such a discussion could include what would be expected if the experiment was conducted at 10°C versus the stated 25°C.

Teachers should be clear in explaining enzymatic catalysis and how enzymes interact with their substrates to perform reactions. They should emphasize that enzymes are catalysts and explain that although an enzyme can consume the substrate to (near) completion, the enzyme is usually active during the course of an experiment and does not get consumed or, as many students expressed, "used up" during the experiment. Student misconceptions about enzyme–substrate interactions (e.g., a rate approaching zero does not mean that the enzyme is saturated) or enzyme inactivation (e.g., once an enzyme binds a substrate, that enzyme is done with catalysis) should be addressed. An in-depth discussion of factors that affect the activity of enzymes would help students to understand more clearly how enzymes are affected by the environment. Discussions concerning how environmental factors such as thermal motion and charge interactions (salinity, pH) affect enzyme shape, substrate binding and catalytic activity would engage a deeper understanding about how enzymes function.

Students should be encouraged to support statements they make. For example, a statement that increased temperature increases enzymatic activity is better when supported by the explanation that higher temperatures increase the movement of both the enzyme and the substrate, increasing the collisions and reactions between the two, but only to the point that the increased temperature does not begin to alter the enzyme's shape and lead to thermal denaturation.

Question 3

What was the intent of this question?

This question offered an opportunity to demonstrate fundamental knowledge about the Mendelian inheritance of single gene traits with complete dominance as well as the opportunity to recognize and explain the effects of gene linkage on phenotype. The question further provided an opportunity to project an understanding of genetics from the level of individual flies to the level of population genetics by discussing the effects of genetic change on Hardy-Weinberg equilibrium. Data tables containing the phenotypic results of three different fly crosses were provided. Cross I showed the F_2 data of a cross between two heterozygotes for eye color (bronze versus red). Cross II showed the

F_2 data of a cross between two heterozygotes for wing type (stunted versus normal wings). Both sets of data indicated a typical autosomal dominant form of inheritance. In part (a) students were asked to draw conclusions from the cross I and cross II data and then explain how the data supported their conclusions. Data from a third cross showed the results of crossing a heterozygote for both traits with a fly that was recessive for both. The data clearly indicated linkage between the genes for eye color and wing type.

In part (b) students were again asked to draw conclusions from the data and to explain how the data supported their conclusions. In part (c) students were asked to identify and discuss two factors that would affect the Hardy-Weinberg equilibrium of the fly population.

How well did students perform on this question?

The mean score for this question was 5.28 out of a possible 10 points. The majority of essays demonstrated a reasonably good knowledge of the basics of Mendelian crosses, earning 2 to 4 points in part (a).

Other frequently earned points were the 2 possible points for identifying the Hardy-Weinberg conditions in part (c). In fact, many essays included more than the requested two factors. Less frequently earned points in part (c) were the discussion points that were supposed to explain the identified Hardy-Weinberg conditions. For example, a response might list "large population" as an important factor in maintaining genetic equilibrium, but the explanation of how a large population ensures equilibrium was often incorrect.

The points earned least often were those available in part (b). Only a small percentage of essays demonstrated an understanding that the data indicate that the two genes/alleles are linked. Many essays expressed concern that something beyond normal Mendelian inheritance was taking place, noting the expected Mendelian ratio for nonlinked genes/alleles, but did not explain exactly what might have caused the presented data not to match the expected data.

What were common student errors or omissions?

Because the phenotype data for the crosses were broken down by number of males and females exhibiting each trait, many essays included an incorrect assumption that eye color and wing type are sex-linked traits. Two additional misconceptions about dominance and recessiveness were frequently expressed: One was the idea that the abnormal trait is the one that has to be the recessive trait. For example, stunted wings are abnormal so the condition must be recessive. Another misconception was that the recessive trait is always the trait that occurs less frequently, regardless of the cross.

There was some confusion about cross III. Because one of the parents was heterozygous for both traits, many essays included the expectation of seeing a 9:3:3:1 ratio from the cross even though the dihybrid was crossed with a fly that was recessive for both traits. The majority of responses in part (b) failed to recognize that the data indicated linkage of the alleles. Many responses did discuss linkage, but in an incorrect context. For example, some responses said the traits were linked on the same "gene." Some responses stated that because all four phenotypes were present, the genes were "not linked."

The correct identification and listing of Hardy-Weinberg conditions was reasonably widespread, but many of these essays failed to explain or discuss how those conditions affect the population. In part (c) there were several misconceptions about the Hardy-Weinberg principle. Many responses claimed that immigration brings new *species* into a population rather than new alleles or genes. Often responses equated gene flow to genetic drift.

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 covering the principles of classical genetics, it will be helpful to include problems in which it is not obvious if a cross is autosomal or sex-linked. Also, students might benefit from practicing more problems that allow them to work with gene linkage.

It is important and helpful to do all 12 of the recommended AP Biology labs. Question 3 covered concepts that students encounter in at least three of the labs: the *Sordaria* exercise in Lab 3, the fruit fly lab, and the population genetics lab.

It is helpful to emphasize connections between concepts and the big picture. Crosses may be taking place between individuals, but their alleles are part of a larger gene pool that may be shifting and evolving.

Question 4

What was the intent of this question?

The diagram and caption in this question showed the ecological succession of plant communities from annual plants to hardwood trees in a specific area over a period of time. In part (a) students were expected to demonstrate an explanation of changes in biodiversity as succession proceeds, based on the diagram given.

In part (b) students were asked to describe and explain three changes in abiotic conditions over time, also in reference to the succession shown in the diagram. Students were expected to describe directional changes — that is, increases or decreases — of abiotic conditions.

Part (c) provided students with the opportunity to discuss and compare the immediate and long-term effects on succession of two disturbances to a 10 km^2 mature forest: a volcano erupting and covering the forest with lava, and clear-cutting of the forest. In part (c) students were expected to demonstrate an understanding of the similarities and differences between primary succession and secondary succession.

How well did students perform on this question?

The mean score on this question was 2.72 out of a possible 10 points. For essays receiving scores near the mean, most earned their points primarily from parts (a) and (c).

Students generally wrote extensive essays. The most commonly earned point in this question was for the statement that biodiversity typically increases during ecological succession. Many essays included a valid biological explanation as to why biodiversity increased: For example, there was an increase in niches/habitats; the death and decomposition of initial organisms facilitated soil changes that allowed new populations to colonize; or as new plants established themselves, new animal species would soon follow.

Most essays demonstrated knowledge of the differences between abiotic and biotic conditions. Most of the points awarded in part (b) were for describing and explaining changes in soil quality or quantity over time, including the decomposition of plants. Many essays correctly stated that as organisms die, they enrich the soil with nutrients that other organisms can use.

Many essays successfully linked primary succession to the volcanic eruption covering a forest with lava and secondary succession to the clear-cutting of a forest. Other points were earned with statements describing the necessity for lava to be eroded into soil over time or how habitats were lost following clear-cutting of a forest.

What were common student errors or omissions?

Although the most commonly earned point for this question was for stating that biodiversity increases, many essays lacked evidence of a thorough understanding of biodiversity. Many described increased biodiversity as a simple increase in the number of organisms, that is, larger populations, rather than changes in the number of species. Some essays included simple descriptions of the labels in the diagram, as follows:

annual plants → perennial plants and grasses → shrubs → pine trees → hardwood trees

However, simply restating the information from the prompt did not earn points.

Some essays indicated confusion about the terms biotic and abiotic, including essays with descriptions of predator–prey relationships, seed dispersal, and animal migration as examples of abiotic factors.

Some essays merely listed abiotic factors, rather than describing and explaining three changes in abiotic conditions. Some stated that an abiotic factor or condition had changed but failed to designate the direction of the change. In some cases an essay would correctly designate a directional change of an abiotic factor but fail to earn an additional point by explaining either why the abiotic condition changed or why that abiotic change facilitated succession.

A surprising number of essays failed to demonstrate awareness of the destructive force of a lava flow from a volcano. Some of these essays, in fact, included information about the positive benefits for the ecosystem of a volcanic eruption, such as how fertile the soil would become. There might be some confusion among students about the differences between volcanic ash and lava, and the tremendous amount of time it takes to erode lava into soil. Possibly this confusion stems from the recent eruption of the Icelandic volcano Eyjafjallajökul or pictures of Mount St. Helens taken shortly after the eruption and then years later. Both of these volcanoes expelled plumes of ash, which can, indeed, add to soil fertility, but the ash can also be detrimental to the environment. A few essays wrongly suggested that the heat of the lava would cause pines to release their seeds, and the seedlings would then dominate the landscape.

Some essays failed to demonstrate an understanding of the forestry term “clear-cut,” often equating it with the removal of all vegetation. Ethical judgments distinguishing human and nonhuman forces possibly led some students to the argument that the clear-cutting of a mature forest is far more detrimental to the ecosystem than is a lava flow.

Many essays included information about evolution, and about organisms adapting to the environment. This effort did not earn points. Numerous essays errantly proclaimed that the diagram revealed a form of Lamarckian evolution, whereby the annual plants become perennial plants, which grow into shrubs. A number of evolution-oriented essays set forth the idea that plants that could survive the volcanic eruption were now better fitted for the environment. There were occasional scenarios in which the heartiest plants broke through the lava.

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 practice on deciphering instructions for questions so that students can distinguish between the information given in the question and the information sought in the answer.

The organizational distinctions in ecology need more exposure, along with the sequence of examining development of individual organisms → populations → communities → ecosystems → biomes. Unfortunately, some textbooks do not present the flow in this order.

Ecological succession is a key concept in biology and needs to be emphasized. Many students lacked understanding about the scale of time involved for primary and secondary succession. Teachers need to help students comprehend the difference between primary succession, where the soil is absent, and secondary succession, which begins with soil and some life forms intact. There is a dynamic interchange between the biotic and abiotic conditions in all ecosystems that needs to be grasped as well. Teachers should encourage explorations of biodiversity and species interactions.

The teaching of ecology should be included as part of the course. Too many courses, it appears, simply give the ecology unit as a precourse summer reading assignment or intend to teach it at the end of the year and fail to accomplish that. Maybe teachers assume that students understand ecology from an earlier biology course. Understanding the interrelationships between organisms is one of the eight themes in AP Biology (VII: Interdependence in Nature) and needs to be effectively taught.