Student Performance Q&A:

2003 AP® Biology Free-Response Questions

The following comments on the 2003 free-response questions for AP® Biology were written by the Chief Reader, Dwayne Wise of Mississippi State University in Mississippi State, Mississippi. 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?

The intent of this question was to test the students' knowledge of classical genetics and mutation. Part (a) tested whether students could reason that the first set of data (F1) was explained by a gene that is sex-linked and shows classical dominance. Students were expected to determine parental genotypes and to discuss how these explained the data. Part (b), reflecting two objectives from Laboratory #7 in the AP Biology laboratory manual, asked students to use a chi-square statistical test to support the hypothesis formulated for the data in the F2 generation. This required a correct hypothesis, use of the formula, calculation, and interpretation. Part (c) asked students to discuss mutations that could have resulted in the one individual in the F1 generation whose phenotype was not predicted by the hypothesis. This required an understanding of mutation and, specifically, of those types of mutation that might yield a particular type of phenotypic result. Students were also able, in some cases, to demonstrate their ability to relate the classical genetics of the problem to some biochemical and/or molecular mechanism.

How well did students perform on this question?

Students varied widely in their overall ability to handle this question. While Part (a) involved skills that are typically acquired in a beginning biology class (ninth or tenth grade), a surprising number of students could not earn any points for this section. Either they left it blank, failed to recognize that the gene was sex-linked, or could not reason from progeny to parental types. A very large percentage of students did not even approach Part (b) on statistical analysis. Many students could set up the problem according to the given formula but could not do the calculation correctly or interpret the result. Students were able to earn some points on Part (c). They could frequently define mutation and give an example of a type of mutation that could have provided the result described.

The mean score was 2.93 out of a possible 10 points. Overall, the number of students leaving the answer blank or scoring a 0, despite the basic nature of the first part of the question, was 27 percent. Many students, however, earned the full 10 points.

What were common student errors or omissions?

There were a number of common errors in each of the three sections. In Part (a) there were many students who did not recognize that the gene was sex-linked. There were also a significant number who indicated that there is an allele for eye color on the *Y* chromosome. Few students explained which eye color is dominant.

In Part (b) the most frequent problem was students not attempting the statistical analysis at all or trying to analyze only one number. The most surprising result was the number of students who took the square root of the chi-square number they had calculated. Not many students used the correct degrees of freedom and very few understood the significance of the *p* value. Responses to Part (b) were the weakest of the three sections.

In Part (c) most students gave a reasonable definition of mutation, but some incorrectly said that it is a change in the RNA, a change in the genotype (which could occur from recombination without mutation), or an error in transcription or translation. Many also said, incorrectly, that this particular mutation could be due to a chromosomal error such as translocation or nondisjunction. Others named appropriate types of mutations but failed to give even minimal explanation or description.

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?

- Although classical genetics is frequently taught early in the year, it probably needs to be reviewed just prior to the exam, especially in conjunction with molecular genetics, which the students may have learned in a separate section.

- The chi-square analysis represents two of the objectives of the genetics lab and should be considered basic to the course.

- Students may need more practice distinguishing events of mutation and replication from transcription and translation.

Question 2

What was the intent of this question?

This question asked students to explain the regulation of four biological processes, three of which were classic examples of homeostatic loops, and one (flowering) that exemplified a response to an external stimulus, in this case, change in length of day and night.

Part (i) required students to explain how flowering is regulated. Successful answers described how changes in photoperiod, temperature pattern, or nutrition/growth link to a plant's signaling mechanisms involved in the conversion of shoot meristem to floral meristem. Each of the major areas for points in Part (i) was scored as being independent.

Part (ii) required students to explain how water balance in plants is regulated. The term "balance" focused attention on water input versus water loss and how these are adjusted to achieve regulation. Scoring well on this part required the explanation of adjustments in water balance; a simple description of unregulated water transport was not the intended answer and did not earn points.

Answers that listed several mechanisms that influence water balance, without explaining how any of the mechanisms alter water input or output, received only a single point. To receive a second point on this question students had to correctly "explain how" a mechanism assists water balance. Once an "explanation point" had been awarded, a third point became available for the elaboration of details of the first mechanism and/or the identification of a second mechanism.

Part (iii) required students to explain how water balance in terrestrial vertebrates is regulated. Answers that listed several mechanisms that influence water balance, without explaining *how* any of the mechanisms alter water input or output, received only a single point. To receive a second point on this question students had to correctly "explain how" a mechanism assists water balance. Once an "explanation point" had been awarded, a third point became available for the elaboration of details of the first mechanism and/or for the identification of a second mechanism.

Part (iv) required students to explain how body temperature in terrestrial vertebrates is regulated. An essential component of a successful answer directly addressed this question: "How is heat transferred or produced?" A list of the diverse mechanisms that regulate body temperature, without any explanation of *how* a mechanism alters heat transfer, received only a single point. Thus, the second point was awarded only for a correct explanation of how a mechanism alters heat transfer or production. Once an "explanation point" had been awarded, a third point became available for the elaboration of details of the first mechanism and/or for the identification of a second mechanism.

How well did students perform on this question?

The mean score for this essay was 3.58 out of a possible 10 points.

In Part (i) students were asked to address three of the four options listed, and the "flowering" option was the one they most often omitted. It seems likely that many students were not comfortable with the regulation of flowering. However, those students who did remember this material often achieved at least three of the four points, typically by noting photoperiod changes, critical night length, phytochromes, and/or "florigen."

In Part (ii) many students showed familiarity with the linkage between gas exchange and water loss via the stomates, and this was probably the most commonly awarded point in this section. The majority of those students correctly explained the effects of open or closed stomates on water balance, and a number of them went on to gain elaboration points on the operation of guard cells.

In Part (iii) general knowledge of the kidneys' "effector" role in the regulation of the ionic composition and volume of the extracellular fluid was apparent in many answers, and many students correctly noted that activity in its functional units, the nephrons, is hormonally regulated. The most common hormone mechanism that was described was that of antidiuretic hormone (ADH, or vasopressin). The role of the hypothalamic-posterior pituitary axis in the regulation of ADH secretion was often reported. The role of increased aldosterone secretion in dealing with water shortage was less commonly described, and Angiotensin II was only rarely mentioned, as was the role of atrial natriuretic peptide in the response to excessive blood volume.

Evolutionary descriptions of specializations that promote water balance were found in many answers. One of the more frequently mentioned specializations was the increased length of the loop of Henle that accomplishes the increased osmolarity of animals with adaptations to arid environments. A number of students communicated their awareness of the utility of having a water-resistant body surface. A few noted that regulated water-absorption mechanisms in the colon are of importance.

In Part (iv) identification of the sweating/perspiring response when hot was the most widely awarded point in the entire question, though its explanation (evaporative cooling) was much less commonly stated. Also frequently identified was shivering when cold. Movement to alternative locations was commonly described, but the details of explaining how this transfers heat were not often stated.

What were common student errors or omissions?

With only 3 percent leaving the answer blank and 13 percent scoring a 0, most students found an area they knew at least a little bit about. In Part (i) some answers suggested that flowering is regulated by pollination, which, of course, occurs after the plant has already flowered. Other answers suggested that students thought the question called for a description of floral adaptations that serve to increase the probability of pollinator visits. Some answers described the types of environmental exposures that influence seed germination. These errors suggest difficulty in distinguishing flowering, fertilization, and germination.

In Part (ii) a substantial proportion of answers suggested that stomates open when the plant "has too much water," as if water balance, and not gas exchange, was the sole function of stomatal opening and closing. A number of students reversed the relationship and suggested that flaccid guard cells result in open stomata. Many students had factual material describing the routine details of water transport but without describing any active regulatory mechanisms. These descriptions were not awarded points. Confusion was apparent on the distinctions between C_4 and CAM plants, and their adaptations to aridity, including stomate operation details. Regulated aspects of root function were rarely covered in the answers.

In Part (iii) knowledge of the similarities and differences in osmotic homeostasis and volume homeostasis was rarely apparent. Statements that sweating is a means of excreting excessive water and wastes and is therefore a central player in the regulation of water balance were frequent. Many students simply stated that animals facing dehydration feel the "need to drink." Only a few students described the renin-angiotensin activating system.

In Part (iv) some students, in attempting to describe peripheral vasodilation, stated that the blood vessels move closer to the skin in an overheated organism. Simple descriptions of endo- and ectothermy were not adequate to identify mechanisms or explain how they function to transfer heat.

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?

- Whenever possible, include in the classroom or lab plants that will flower during the school year. Even casual observations and questions to students can inspire them to investigate the field of plant physiology.
- Discussion of water balance in plants should focus attention on the interaction of water input versus water loss and the ways that plants adjust input and loss to achieve regulation. This helps students grasp the fundamental concepts of diffusion and osmosis at the cellular level while providing an organismal perspective.
- Although the linkage between osmotic pressure and cell volume is prominently covered at the level of the individual cell, this relationship should be reiterated at the organismal level.
- It can be challenging to take single-cell scenarios and extend them to whole organisms. Temperature regulation is a topic with which students have lots of experience and intuition about how it works. Asking them to make a list of heat sources and heat sinks would prove a useful exercise.

Question 3

What was the intent of this question?

This population question was centered on the basic concepts of life history strategies. Students were asked to describe what was occurring in Phase A of the graph where the population moved from establishment phase to exponential growth and then slowed in growth rate as it reached the environmental carrying capacity. In the second part of the question students were asked to discuss three factors that might have caused the fluctuations around the carrying capacity in the section of the graph labeled Phase B. The third part of the question asked for an explanation of exponential (*r*) and logistic (*K*) reproductive strategies and then for a discussion of how they affect the population over time.

How well did students perform on this question?

The mean score for this question was 3.17 out of a possible 10 points. The most commonly earned point on the question was the exponential growth point in Part (a). Few students addressed the establishment period or the deceleration of the population. The carrying capacity point was generally awarded in this section.

Part (b) had a maximum of four points. Many students were prepared to offer ecologically sound, density-dependent factors that are widely attributed to *K*-strategy variation around the carrying capacity. Many students also noted the vacillations of Phase B and attempted convoluted explanations of the graph's undulation. These attempts often did not earn points.

Part (c) had a maximum of four points: two points for the explanation of *r* and *K* strategies and two points for the discussion of how these strategies affect population size over time. These points were not linked, so it was possible to earn points on one section even if the other section was not addressed.

What were common student errors or omissions?

When some students looked at the graph included with this question they thought Phase A represented the growth curve of one species, such as a rabbit, while Phase B showed the growth curve of a different species, such as a wolf. It seems that many students simply were not familiar enough with the material to provide a strong answer.

In Part (a) the majority of students received only one point by noting the exponential nature of the graph in Phase A, omitting discussion of establishment phase and deceleration.

In Part (b) many answers included fanciful attempts to explain the fluctuations around the carrying capacity. However, as the curve in Phase B clearly shows, the graph has a definite cyclical nature and the vacillations are small compared to the total population size. Acceptable answers had to meet the criteria established by the graph.

Part (c) was omitted by many students. Those who did address the question frequently did not answer both sections. It was common for answers to address the characteristics of exponential or logistic growth curves but to omit information about the reproductive strategies that were asked for in the question.

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

- Many teachers will assign the ecology chapters as summer reading. Teachers may want to be sure that students have a clear understanding of the concepts involved in population change over time, the effect of limiting factors, and the concept of carrying capacity.
- Teachers may want to spend some time on reproductive strategies. Having students identify examples of *r* and *K* strategy organisms, and the characteristics of the reproductive strategies may clear up their confusion.
- Students' knowledge in this area was not strong. Even when they understood some of the concepts, their inability to express ideas in a clear and understandable way may have caused them to miss potential points. Teachers may wish to reflect on their depth of coverage of ecological topics.

Question 4

What was the intent of this question?

The intent of this question was to have students show an understanding of the consequences that death has on any level of organization within a multicellular organism, and its significance in evolution. This was a very open-ended question. Students were being asked to apply various areas of biology to the topic of death.

In Part (a) two examples of cell death were to be discussed to show how development changed in the multicellular organism and to show how cell death changed the function of the affected area. Since development of an organism is the sum of the processes that occur in the life cycle of an organism, any type of developmental change was accepted from embryonic stages through senescence. Examples of how cell death could occur include elimination of certain cells, tissues, and organs during larval development or embryonic development, tissue remodeling or reconstruction, threat to the survival of the organism, exposure to toxins or an altered chemical balance, aging, and severe injury.

In Part (b) degradation and reuseability of a substance were to be discussed. It was unclear whether or not degradation meant intracellular or extracellular breakdown. Therefore, any example of degradation was considered as long as the degraded product was being reused in a cell. Students could pull from various areas of biochemistry, cell biology, or anatomy and physiology to answer this area of the question.

In Part (c) the evolutionary significance of death was to be discussed. Relationships between death and the concepts of evolution were expected.

How well did students perform on this question?

The mean score was 1.72 out of a possible 10 points, with approximately 30 percent of the students scoring a 0 or leaving the answer blank.

In Part (a) two examples were expected in a discussion of how cell death affected development and functioning of a multicellular organism. Generalized statements without a discussion on how cell death affected development and/or function did not earn points for this section. Most of the examples given by those who were awarded points applied cell death to the development and function of xylem, white blood cells, loss of the tadpole tail, or limb development in amphibians or humans.

In Part (b) a typical answer was written with nonspecific information, such as “ATP is broken down and recycled for reuse in the cell” or “substances degrade to small pieces then sent to other parts of the cell where they are used for other jobs that the cell needs to perform.” Examples that described how the degradation and reuse occurred were awarded two points. Many students used ATP, NADH, H^+, and proteins for their discussion.

In Part (c) students discussed evolution but not the evolutionary significance of death. Students who earned one or two points in this area mainly addressed removal of individuals from a population based on having a particular gene that was not suitable for survival and passing the trait onto offspring.

What were common student errors or omissions?

Overall, responses typically lacked depth due to the broadness of this question. A high level of analysis was needed to answer this question on a “cutting edge” topic. Most students could not look across the biology curriculum and pull from what they had learned.

Students made many generalizations on all parts of this question. They carried over their thoughts from genetics, homeostasis, flowering, water regulation in plants, and carrying capacity, as these topics were all used in answering Questions 1, 2, and 3 on the 2003 AP Exam.

In Part (a) the most common omission was not giving a concrete example of how cell death affects development and function in an organism. If students did begin with a good example, they often did not follow through on what the question asked. It was clear to readers that a question on development was difficult for students to answer.

In Part (b) many students used the term “degrade” in their answer to explain *how* a substance was being broken down. Students did not use a specific example of a substance to discuss how a product was reused in cells. In the case of how ATP is broken down into ADP, students rarely identified the loss of a phosphate group from ATP to turn into ADP, nor was it mentioned that this breakdown is a result of enzyme activity

In Part (c) students did not relate the concepts of evolution to death but rather related evolution to ecological principles. Evolution terms were used but not explained. Survival of the fittest, the weak die, and the strong survive were common responses. Often, comparisons were made between evolution and recycling of nutrients or evolution and overcrowding.

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?

- This question was extremely broad. Cell biology, evolution, developmental biology, and organismal biology had to be quickly analyzed for topics that related to the question. Teachers can prepare students for these types of questions by using similarly broad questions from past AP Exams. Having students develop answers that pull from various areas of the curriculum is challenging enough, but also developing an answer that focuses on a higher level of thinking is most important for our AP students.

- Teachers should continue to design essay questions that are divided into sections. Examples should be required. When examples are being considered in an answer, determine if it is a specific example. Is the example clear? Is it being used in a meaningful discussion? Caution students to write only on what the question is asking and not on unrelated topics. On the AP Exam students need to demonstrate their knowledge of what they know but they must answer the question they have been given, not the one they wish had been asked. Irrelevent information only interferes with the limited time students have to synthesize a pertinent answer.

- Ask students to begin writing an answer to the question immediately without an introductory paragraph.