Student Performance Q&A:

2012 AP® Biology Free-Response Questions

The following comments on the 2012 free-response questions for AP® Biology were written by the Chief Reader, Domenic Castignetti of Loyola University–Chicago. 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 focused on reproduction and examined students' knowledge of the embryological development aspect of the reproductive process. Part (a) asked students to describe the processes involved in the embryological development of a typical vertebrate embryo as it develops from a fertilized egg to the stage where the three embryonic tissue layers are formed. Part (b) asked them to identify, from a list of three tissues, the developmental origins of two of those tissues. In part (c) students were required to identify and explain three differences between the embryological development of protostomes and the embryological development of deuterostomes. In part (d) they had to explain two unique properties of human embryonic stem cells that distinguish them from other human cell types. Students were also asked to describe a current medical application of human stem cell research (not just human *embryonic* stem cell research).

How well did students perform on this question?

The mean score for this question was 3.81 out of a possible 10 points.

In part (a) many students earned points for correctly describing the processes of fertilization, cleavage, and gastrulation. However, correct descriptions of blastulation were less frequent.

In part (b) many students earned 2 points for correctly identifying the developmental origins of the central nervous system, digestive system, or muscle.

In part (c) four possible major differences between the two groups of vertebrates gave students many opportunities to earn points.

In part (d) students often noted that stem cells have the ability to develop into many different types of cells. Many correct examples of stem cell applications were also cited, including nervous system regeneration, treatments for cystic fibrosis, Alzheimer's, and Parkinson's therapy .

What were common student errors or omissions?

In part (a) the question addressed human embryological development, but many students described fetal development and pregnancy. Students often incorrectly attributed the events of a particular stage of embryological development to a different stage. Meiosis and oogenesis were confused with mitosis that occurs during embryonic cleavage. The distinction between the morula (solid ball of cells) and the blastula (hollow ball of cells) was another common student error. Students often incorrectly used terms such as blastopore, blastocoels, blastocyst, and blastula.

In part (b) students were challenged by the term "developmental origin." Many students interpreted this as the evolutionary origins of the structure and not the embryological origins. Others described how the components of each system related to the others (e.g., brain to spine to sensory neurons) rather than describing the developmental origin of the tissue. Students often listed correct characteristics of the central nervous system, the digestive system, or the muscles rather than describing their developmental origin. Many students described the origin of the notochord rather than of the tissue for the central nervous system.

In part (c) students made many incorrect comparisons when discussing protostomes and deuterostomes and were not clear about the differences. Students commonly confused which organisms are protostomes and which are deuterostomes. There was also confusion about the differences between spiral and radial symmetry. Students also struggled with embryological terms (e.g., diploblastic, triploblastic, acoelemate, coelomate, prokaryotic, eukaryotic). Many students incorrectly stated that protostomes have a single opening but deuterostomes have two openings.

In part (d) students did not make the distinction between embryonic stem cells and other human stem cells. Students demonstrated misconceptions that stem cells can be cultured to cure anything, that they do not replicate, that they have more or less DNA than normal cells, that they can grow replacement limbs or become any organ in the body, or that they are cancer cells.

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 read the question carefully and reread it to ensure that they understand what is being asked. They should also focus on the bold printed terms, which give direction on how to answer each part of the question.

Question 2

What was the intent of this question?

This question examined students' ability to apply mathematics to a biological process. Parts (a) and (b) focused on analyzing and interpreting graphs, with appropriate calculations. In part (a) students were asked to use the data in a graph to calculate the rate of oxygen consumption in two different varieties of wheat at two different temperatures. Part (b) asked them to demonstrate knowledge and understanding of the relationship between metabolism and oxygen consumption and to discuss the effect of temperature on metabolism. In part (c) students were expected to use a knowledge of intermediary metabolism to make and support a prediction about how the metabolism would be affected when a metabolic inhibitor that prevents the oxidation of NADH was present.

How well did students perform on this question?

The mean score was 4.88 out of a possible 10 points.

In part (a) many students earned a point for using the appropriate data to calculate the rate of oxygen consumption. Fewer students earned the point for correctly setting up the rise over run equation ($\Delta y/\Delta x$). Students tended to leave their answers as fractions instead of converting them to decimal format as specified in the question.

In part (b) many students earned points for identifying the direct relationship between metabolism and oxygen consumption and could often state that increasing temperature increases metabolic rate/oxygen consumption. Fewer students provided correct comparisons of metabolic rate/oxygen consumption within each variety of wheat at different temperatures or between the varieties of wheat.

In part (c) students often correctly predicted that metabolism, rate of respiration, or oxygen consumption would stop, decline, decrease, or slow down in the presence of the chemical. However, explanations for these predictions were frequently omitted or lacked sufficient detail.

What were common student errors or omissions?

In part (a) students often did not show the rate formula as the difference in oxygen concentration over the difference in time ($\Delta y/\Delta x$), and answers were frequently presented as fractions rather than in decimal format.

In part (b) students often confused cellular metabolism with digestion. Students did not always remember to compare within and between the varieties of plants.

In part (c) students often confused photosynthesis and respiration or provided incorrect or irrelevant details, such as describing the reactions of photosynthesis instead of respiration.

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 use and practice the proper construction of graphs, data analysis, and calculations and should practice clearly showing their work. Students should become familiar with using decimals rather than fractions and should practice completing calculations rather than simply setting up the equations. Teachers should emphasize the differences between photosynthesis and respiration, and how the pathways function together in photosynthetic organisms. The distinction between photosynthesis and respiration should also be emphasized. Teachers should emphasize that the students read each question carefully and completely so that they understand the specific tasks.

Question 3

What was the intent of this question?

This question asked students to describe information flow within cells and organisms — specifically, the regulation of, and the effects of mutations on, protein synthesis. Part (a) required students to describe the role of three normal cellular processes or factors in the regulation of protein synthesis, and part (b) asked for a description of three different types of mutations and the effect of the mutations on protein synthesis. In part (c) students needed to identify environmental factors that could increase the mutation rate and to describe the effect of these mutations on the genome of an organism. Lastly, part (d) provided information about how the emerging field of epigenetics studies heritable changes in an organism's phenotype that are caused by mechanisms other than changes in the DNA sequence and then asked students to describe an example of epigenetic inheritance.

How well did students perform on this question?

The mean score was 3.26 out of a possible 10 points.

In part (a) most students earned a point for describing RNA splicing as the removal of sections of RNA. Students less frequently mentioned the involvement of snRNPs/spliceosomes in splicing. Another point was earned by most for describing that repressor proteins inhibit transcription and translation or silence genes. Few responses discussed DNA methylation or siRNA.

In part (b) students frequently described how nucleotide substitutions can affect protein production, but they often did not correctly explain how nucleotide insertions and deletions affect protein production.

In part (c) many students earned points for stating that factors such as cigarette smoke, pollution, or radiation can increase the mutation rate. However, students often did not provide sufficient detail about how the mutagens alter or damage DNA. Few responses gave an example of epigenetic inheritance for part (d).

What were common student errors or omissions?

In part (a) students often stated that RNA splicing cut up the RNA into the three different types of RNA: mRNA, tRNA, and rRNA. DNA methylation and siRNA were much less frequently mentioned, and when they were mentioned students incorrectly stated that methylation produces methane or is associated with the first amino acid (methionine) during translation. Many students incorrectly stated that siRNA is a signaling RNA that directs different molecules to their destinations in the cell.

In part (b) students often used the terms "nucleotide," "nucleic acid," "amino acid," and "codon" interchangeably. Many students identified RNA or amino acids instead of DNA as the source of a mutation. Students did not clearly understand the difference between nonsense and missense mutations. Finally, various diseases and disorders were randomly listed without identifying the molecular cause.

In part (c) many students stated either that the Sun causes mutations in the skin or that evolutionary mechanisms like natural selection cause mutations. Students also stated that inbreeding causes mutation and that mutagens cause sequence changes rather than DNA damage. Students also stated that cancer is a mutation rather than that mutations can cause cancer.

In part (d) students did not provide examples of epigenetics. When students attempted this part of the question, they often chose incorrect examples, such as epistasis, polygenic inheritance (skin color), Lamarck's giraffes, Down syndrome, or natural selection in pepper moths.

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 be aware of current, important trends in biology and incorporate them into their course. Teaching that genetic regulation occurs at many levels and that all levels of regulation are extremely important in producing an organism's phenotype is critical for students' understanding of molecular genetics. Teachers should clearly state that mutations are heritable changes at the DNA level that affect the phenotype of the organism. As a general strategy, students should be encouraged to pay close attention to boldfaced terms such as "describe," "discuss," and "identify." Teachers should encourage students to provide sufficient detail to demonstrate an understanding of the biology and not to merely restate the question. Students should provide only the number of examples asked for in the question and put their best examples first.

Question 4

What was the intent of this question?

This question allowed students to demonstrate an understanding of the global carbon cycle and to discuss human impacts on the carbon cycle. In part (a) they were asked to discuss the role of photosynthesis and cellular respiration in carbon cycling. In part (b) students chose three out of four given perturbations and were required to predict and explain the effects of each perturbation on the carbon cycle. Part (c) asked students to explain how increased atmospheric CO_2 results in greater acidification of the oceans and to describe the effect of acidification on marine organisms. Students were also asked to include two examples of how human activity can increase atmospheric CO_2.

How well did students perform on this question?

The mean score was 3.91 out of a possible 10 points.

In part (a) most students earned points for correctly describing the processes of photosynthesis and cellular respiration.

In part (b) students demonstrated good understanding of the effect of deforestation on the carbon cycle. Some students correctly explained that the solubility of gases decreases in warm water compared with cold water and could predict that O_2 and CO_2 will have decreased solubility in warmer oceans. A few students also connected a decrease in the oxygen concentration with a predicted decrease in the overall amount of respiration.

In part (c) students often included combustion of fossil fuels and deforestation as examples of human activities that increase atmospheric CO_2. Some students applied their understanding of the bicarbonate buffer system in the blood to ocean acidification.

What were common student errors or omissions?

In general, responses often discussed carbon cycling in vague terms (e.g., photosynthesis absorbs *carbon*) without specifying specific molecules involved (CO_2, glucose, organic molecules). Also, carbon was often incorrectly used interchangeably with CO_2.

In part (a) many students confused the carbon cycle with oxygen cycling and indicated that the purpose of photosynthesis is to make O_2 for animals to breathe. Students included unnecessary details about the biochemical pathways involved in photosynthesis and cellular respiration. They also described photosynthesis as the conversion or breakdown of CO_2 into O_2 or cellular respiration as the conversion of O_2 into CO_2. Many students described an indirect proportion between CO_2 and O_2 in the atmosphere because of the misconception that the air can hold only a finite number of molecules.

In part (b) it was often difficult to distinguish the predictions from the explanations in the responses, and many students did not correctly state a prediction. Many indicated that changes to the carbon cycle (absence of decomposers, deforestation, etc.) result in, and require, either increasing production of carbon or the slowing or stopping of the entire cycle. Students did not have a clear understanding of the process of decomposition. Many students confused decomposition with nitrogen fixation, and some focused on nitrogen rather than carbon in discussing the effects of decomposition. Students also indicated that decomposers return carbon dioxide to the soil, and plants then acquire carbon from the soil. Students also described how a lack of decomposition causes rotting of dead organisms. They also indicated that volcanic dust contains large amounts of carbon, and that the dust clogs the pores of the plants so they cannot absorb CO_2. Finally, many students did not grasp the degree of anticipated increase in ocean temperatures and stated that warming of oceans will result in protein denaturation.

In part (c) students had difficulty understanding the process of acidification. Students described CO_2 itself as acidic and explained how increased acidity causes an increase in pH. Students claimed that acid rain causes ocean acidification, which in turn denatures enzymes and causes mutations. Many students described how an increased atmospheric CO_2 leads to destruction of the ozone layer. Students could not specifically describe how atmospheric CO_2 levels fluctuate, writing that the use of aerosol sprays, unspecified "pollution," people exercising, and breathing all increase atmospheric CO_2 levels. Students also claimed that cows produce large amounts of CO_2 (as opposed to methane). Students generally described fossil fuel emissions with no mention of combustion.

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 opportunities for students to practice making predictions and explaining the rationale for their predictions. Teachers should explain how different molecules cycle and are converted in the environment. Finally, teachers should make the distinction between global warming as a result of atmospheric accumulation of greenhouse gases and ozone depletion as a result of chlorofluorocarbon emissions.