CollegeBoard
Advanced Placement Program

# Student Performance Q&A:

## 2004 AP® Biology Free-Response Questions

The following comments on the 2004 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 students' knowledge of specific events occurring in meiosis in diploid organisms that are responsible for the reduction of chromosome number from diploid (2n) to haploid (n) and the creation of genetic variation produced by the recombination of chromosomes during meiosis. In addition, this question tested students on their ability (1) to name one example of a human condition resulting from either an abnormal number of chromosomes or a structural abnormality in a chromosome due to a malfunction in meiosis, (2) to describe the resulting phenotype for that disorder, and (3) to identify the meiotic anomaly responsible for that condition. Finally, students were required to describe either parthenogenesis or cloning and to compare the degree of genetic diversity expected in the genomes of an offspring and its parent based on the occurrence of either parthenogenesis or cloning.

***How well did students perform on this question?***

The mean score was 4.2 out of a possible 10 points.

Most students knew that meiosis was a two-step division that involved one replication, but they were less likely to write much about rearrangement other than mentioning crossing over.

Many students earned points for the chromosomal abnormality question, often choosing Down syndrome as their example. In general, students were able to explain nondisjunction as an error in meiosis. They rarely cited other errors linked to chromosomal anomalies.

Most students understood that the end result of cloning is genetically identical organisms, although the process was not clearly presented. Overall, few students appeared to be able to give a response beyond what might be known from the common media or offhand usage of the word "cloning." A small percentage showed evidence of having learned about somatic nuclear transfer in a structured way. A disappointingly small percentage knew anything about other types of asexual reproduction. Some students confused cloning with in-vitro fertilization. A minority addressed parthenogenesis, and most who did were confused. Some students wrote off the subject (e.g., about the moral issues involved in cloning).

***What were common student errors or omissions?***

Based on their answers, many students continue to struggle with the details and outcome of meiosis. Many students were mistaken about when synthesis of DNA occurs and when the reduction of ploidy occurs. Many students confused the terms "chromosome," "chromatid," and "gene." Some students attributed Down syndrome to a missing copy of chromosome 21, and some thought that single-gene defects like sickle cell result from nondisjunction. Students sometimes stated that bacterial plasmids were used in reproductive cloning. Many students stated that any form of asexual reproduction could be called cloning.

Some students interpreted the questions as calling for a complete discussion of all the stages of meiosis, and these students did not focus on the processes that reduced chromosome number or resulted in rearrangement of chromosomes. A small percentage of students addressed the concept of independent assortment.

In the cloning portion, many students did not indicate that the process would yield an entire organism. Very few students demonstrated an understanding of the concept of parthenogenesis.

***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?***

Coverage of meiosis needs to include much more than the names and descriptions of the phases. Teachers are encouraged to emphasize the relationship between chromosome behavior during meiosis and the major outcomes of meiosis, namely the reduction of ploidy from diploid to haploid and the production of genetically variable products. It would be helpful to focus on how the steps of meiosis lead to the outcomes of reduction and rearrangement, with the use of drawings, models, and manipulatives. It would be helpful to stress that reductional division occurs during meiosis I. Emphasize to students that diploid chromosome pairs (tetrads) separate during meiosis I, and haploid sister chromatids separate during meiosis II.

Teachers are also encouraged to emphasize the process of independent assortment, reinforcing the fact that, due to the random alignment of tetrads during metaphase I, the 23 pairs of human chromosomes can assort in $2^{23}$ ways *without* crossing over.

Teachers can help students by advising them to read the question, read it again, answer it, then read it again. Emphasize to students that they should respond to the specific details of the question rather than spending a lot of time writing about the general concept. Too many students seemed to miss "easy" points because they did not address chromosome rearrangement or did not give a phenotype for a chromosomal disorder. Likewise, students should not spend time on information not required by the question; many students provided accurate comparisons between mitosis and meiosis, but this was not part of the question and did not earn points.

## Question 2

***What was the intent of this question?***

The first part of this question, Part (a), was designed to test students' knowledge of basic Darwinian evolution. Four fundamental concepts of evolution were given for students to discuss and support by example in Part (a). Part (b) asked students to discuss how more recent discoveries in evolutionary biology have modified or enhanced our understanding of Darwin's original contributions. This necessitated an understanding of two of the three contributions offered, Darwin's original ideas on the subject, and how those ideas have been modified. In general, students have a good understanding of Darwinian evolution and scored well in Part (a). In Part (b) a number of students could define or express an understanding of the concepts given but found it difficult to relate these discoveries to changes in evolutionary theory.

***How well did students perform on this question?***

The mean score was 4.7 out of a possible 10 points. The scoring rubric contained 14 opportunities to earn a maximum of 10 points. Many students were able to earn points in Part (a), where discussing the basic tenets of evolution was required. It is possible that the regular inclusion of evolution questions on the essay portion of the exam is resulting in increased classroom emphasis on evolution. Most students were also able to accumulate points in Part (b), but overall they seemed to find this section more difficult.

***What were common student errors or omissions?***

The most common error students committed involved explaining evolution in Lamarckian terms. Students frequently used phrases like "the animals needed to develop lungs because the sea was drying and if they did not the animals would become extinct." It would be a rare teacher who did not occasionally lapse into a Lamarckian version of evolution, but teachers are encouraged to be as careful as possible in their choice of words when explaining evolution to students. A serious misconception that appeared in many essays was the idea that evolutionary change in a population can be a change in the size or location of the population, rather than a change in the genetic make-up of the population. This misunderstanding can also extend to the Hardy-Weinberg equilibrium, where students think the five conditions keep the population number stable.

***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?***

It is important for students to be trained during the year to give time to all parts of the essay. It was not unusual for students to answer only portions of what was asked. Obviously, if half of the points are not attempted, students miss an opportunity to demonstrate knowledge and understanding.

Finally, students may use phrases they have heard, like "survival of the fittest" or "struggle for survival," and have no real understanding of their meanings. These types of "buzz words" seldom gain points on the AP Exam and are not a substitute for the explanation of an idea. Teachers are encouraged to advise their students that terms used should be defined.

## Question 3

***What was the intent of this question?***

Students were provided with data from an experiment on photosynthesis. They were asked to present the data as a graph, to analyze the experimental design that was used to produce the data, and to interpret the data in the context of demonstrating their knowledge of the light reactions of photosynthesis. Lab 4 in the *AP Biology Lab Manual* describes an experiment that uses similar techniques and produces similar data.

***How well did students perform on this question?***

The mean score was 5.0 out of a possible 10 points. Most students easily drew the graph and quickly chalked up three points. Students who did well on this question understood experimental design and many of the details of energy transfer in plants.

***What were common student errors or omissions?***

Most respondents did well on the graphing portion of the question. Occasional errors included reversed independent ($x$) and dependent ($y$) axes, omitted labels, or scale errors.

When asked to "*Identify* and *explain* the control or controls," students generally recognized and cited the need to make comparisons, but some responses showed confusion between the independent variables and the controls, stating that light/dark is a control and that boiled/unboiled is another control. The unboiled sample held in the dark (Sample 2) was wrongly identified by some students as the control, because "nothing had been done to it." Additional errors included the labeling of the things held constant (e.g., identical chloroplasts, identical amounts of reagents, identical reaction temperatures and time points, using the same spectrophotometer, etc.). Students who identified at least two such experimental constants received a point for good experimental methodology.

Many students recognized the similarity of the stated procedure to the recommended Lab Number 4 (photosynthesis lab) they experienced during the school year. Unfortunately, some of these students then answered the questions based on their memories of the recommended lab rather than on the data provided. This is a common error that has been made by students when the lab question is reminiscent of 1 of the 12 recommended labs in the *AP Biology Lab Manual.*

Many students failed to identify chlorophyll as the molecular link between light energy and free electrons. Hydrolysis was wrongly substituted for photolysis in many responses. The role of free electrons was not always clear. Students did not earn credit for simply saying "sunlight is needed for photosynthesis" or for writing the overall equation of photosynthesis.

A few students were unclear about the effects of boiling, failing to identify denaturation of proteins/enzymes as crucial to the disruption of photosynthesis.

***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 generally did well on the graphing part of this question, and teachers should be congratulated for emphasizing this in their classrooms. Teachers are encouraged to continue working with students to design, carry out, and interpret lab experiments. An emphasis on the identification of the various characteristics of a controlled experiment would benefit many of the students.

## Question 4

***What was the intent of this question?***

This question connected topics in ecology, anatomy, evolution, immunology, and microbiology to the theme of interdependence in nature. The intent of the question was to have students show an understanding of symbiosis and to apply this concept to various areas of the AP curriculum. The question asked students to identify, describe, and discuss the symbiotic relationship that exists in plant root nodules, the digestion of cellulose, epiphytic plants, AIDS, and anthrax.

***How well did students perform on this question?***

The mean score was 3.3 out of a possible 10 points. Students had general knowledge about symbiosis and were able to describe the symbiotic relationship that existed in the examples given.

For plant root nodules, most students related bacteria in the plant nodule to nitrogen fixation and clearly saw this relationship as mutualism. Of the five examples given, this one was chosen most often.

In the digestion of cellulose, most students commented on the fact that cellulose is not digested by animals without the help of another organism. Bacteria were the common organisms identified in cows to aid in cellulose digestion. Other paired relationships, such as termites/protozoans and insects/bacteria, were cited in the discussion as well.

Many students adequately described a commensal relationship involving epiphytes. A few students wrote on symbiotic relationships that showed mutualism or parasitism. Although these were few in number, students who clearly discussed the relationship and specifically named organisms as participants were able to earn points.

Students who selected AIDS knew that the disease called AIDS is caused by a virus, and many applied the concept of symbiosis to demonstrate understanding that HIV must replicate in a host cell and that harm/death will eventually occur to the host organism.

Students who selected the anthrax example often were too vague about the participants in the relationship to earn points.

***What were common student errors or omissions?***

With regard to plant root nodules, most errors were made in trying to identify specific participants of the symbiotic relationship. These errors included plants and mycorrhizae or fungus, plants and soil, and plant roots and the root nodule. In many cases, the root nodule was treated as an organism separate from the plant. Also, students identified "nitrifying bacteria" as a participant for fixing nitrogen for the plant, rather than nitrogen-fixing bacteria, and they substituted nitrification for nitrogen fixation.

Examples of errors made in identifying participant pairs in the digestion of cellulose include *E. coli* in the gut of humans or cows and naming cellulose/plants as one of the participants being paired with enzymes or cows. Some students named the intestine or stomach as the organism and did not earn points for the participants.

Fewer students chose the epiphyte example. Some students described epiphytes as carnivorous, lichen, or ivy and showed confusion over whether the plants exhibit commensalism or parasitism. Many wrote about plants growing on nonliving structures.

Many students who chose the AIDS example wrote about the disease, not the virus associated with the disease. The other participant identified was often a host cell or blood cell, which did not earn a point. Many students stated that HIV is a DNA virus, rather than a retrovirus. A common omission throughout the student essays was the benefit that this virus has in the host. Students knew of the detriment to the host but did not mention the benefit to the virus.

For anthrax, the most common misconception was that anthrax is caused by a virus. Students who did know that the disease is bacterial often stated that anthrax will kill the host but never mentioned the benefit to the bacteria.

***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?***

Because this was the last question, many students ran out of time before finishing their answer. Teachers are encouraged to continue to teach in themes that cut across the curriculum and to practice testing under timed conditions. Essays that stimulate students to look into other areas of the curriculum should be used to help them think and see relationships within the themes of the curriculum.

Teachers are also encouraged to bring current world issues into the classroom for discussion of the appropriate biology. Many students knew that anthrax was a white powder that would lead to death, but they could not describe it in biological terms.

This question had a category involving viruses. Many students described how bacteriophages replicate in the lytic cycle, not retroviruses. A distinction between these two different types of viruses should be emphasized in the classroom.