2021

AP® CollegeBoard

# AP® Biology

## Sample Student Responses and Scoring Commentary

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**Free Response Question 2**

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## Question 2: Interpreting and Evaluating Experimental Results with Graphing

**8 points**

Geneticists investigated the mode of inheritance of a rare disorder that alters glucose metabolism and first shows symptoms in adulthood. The geneticists studied a family in which some individuals of generations II and III are known to have the disorder. Based on the pedigree (Figure 1), the geneticists concluded that the disorder arose in individual II-2 and was caused by a mutation in mitochondrial DNA.

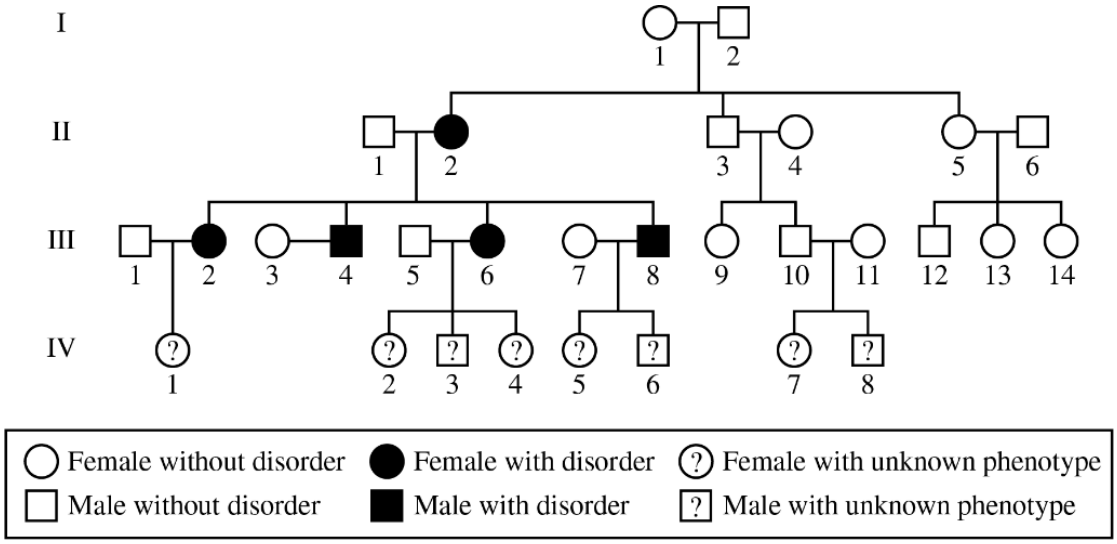



Figure 1. Pedigree of a family showing individuals with the glucose metabolism disorder. A question mark indicates that the phenotype is unknown.

TABLE 1. AVERAGE BLOOD GLUCOSE LEVELS OF INDIVIDUALS IN GENERATION IV

| Individual | Average Blood Glucose Level ( mg/dL $\pm$ $2SE_{\bar{X}}$ ) |
|---|---|
| IV − 1 | $170 \pm 15$ |
| IV − 2 | $190 \pm 10$ |
| IV − 3 | $145 \pm 5$ |
| IV − 4 | $165 \pm 15$ |
| IV − 5 | $110 \pm 15$ |
| IV − 6 | $125 \pm 5$ |
| IV − 7 | $105 \pm 15$ |
| IV − 8 | $120 \pm 10$ |

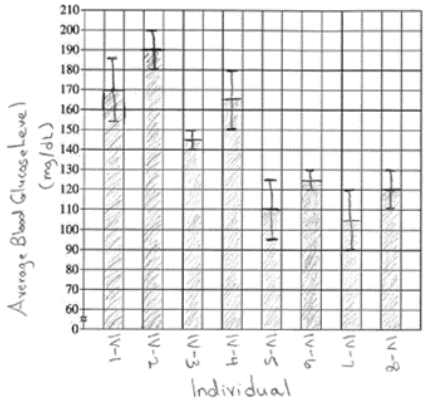
TABLE 2. PHENOTYPIC CLASSIFICATIONS BASED ON BLOOD GLUCOSE LEVELS

| Phenotype | Blood Glucose Level ( mg/dL ) |
|---|---|
| Normal | $<$ 140 mg/dL |
| At risk | 140 − 199 mg/dL |
| Affected | $\geq$ 200 mg/dL |

**(a)** The disorder alters glucose metabolism. **Describe** the atoms AND types of bonds in a glucose molecule. **1 point**

- The atoms are carbon, hydrogen, and oxygen (C, H, and O) and are held together by covalent bonds.

**(b)** Use the template provided to **construct** an appropriately labeled graph based on the data in Table 1. **3 points**




- Point distribution: Axis labels; plotting in a bar graph or modified bar graph; error bars

**Determine** one individual who is both at risk of developing the disorder and has a significantly different blood glucose level from that of individual IV-1. **1 point**

- IV-3

**Total for part (b)** **4 points**

**(c)** Based on the pedigree, **identify** all individuals in generation IV who can pass on the mutation to their children. **1 point**

- IV-1, IV-2, IV-4

**(d)** Based on the fact that individual II-2 is affected, a student claims that the disorder is inherited in an X-linked recessive pattern. Based on the student's claim, **predict** which individuals of generation III will be affected by the disorder. **1 point**

- III-4 and III-8

Based on the pedigree, **justify** why the data do NOT support the student's claim. **1 point**

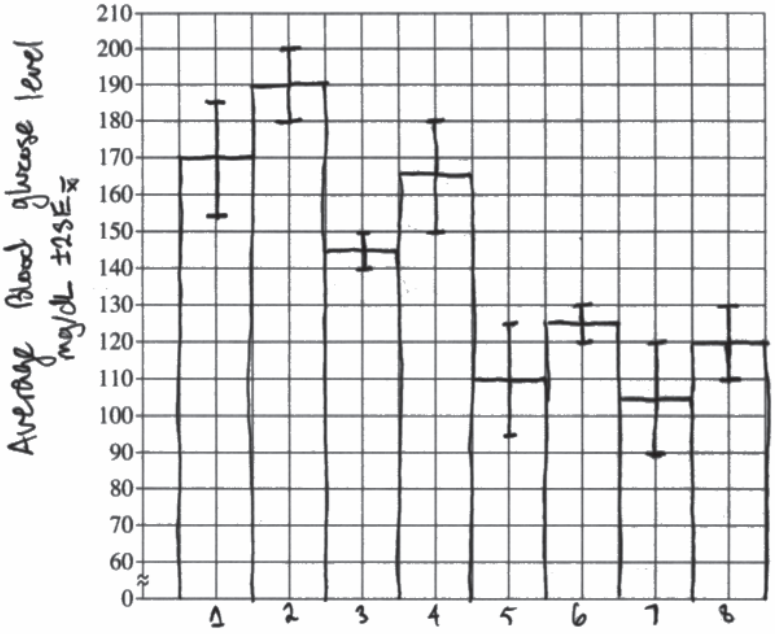
Accept one of the following:

- The data do not support the claim because females III-2 and III-6 have the disorder and, if inheritance is X-linked recessive, they could only do so if their father II-1 had the disorder, which he does not.
- The data instead support mitochondrial inheritance, because all of the offspring of individual II-2 , not only the sons, have the disorder.

**Total for part (d)** **2 points**

**Total for question 2** **8 points**

Begin your response to **QUESTION 2** on this page. Do not skip lines.




a) Glucose is made of carbon, hydrogen, and oxygen its formula is $C_6H_{12}O_6$, the bonds found between these atoms in a glucose molecule are covalent bonds.

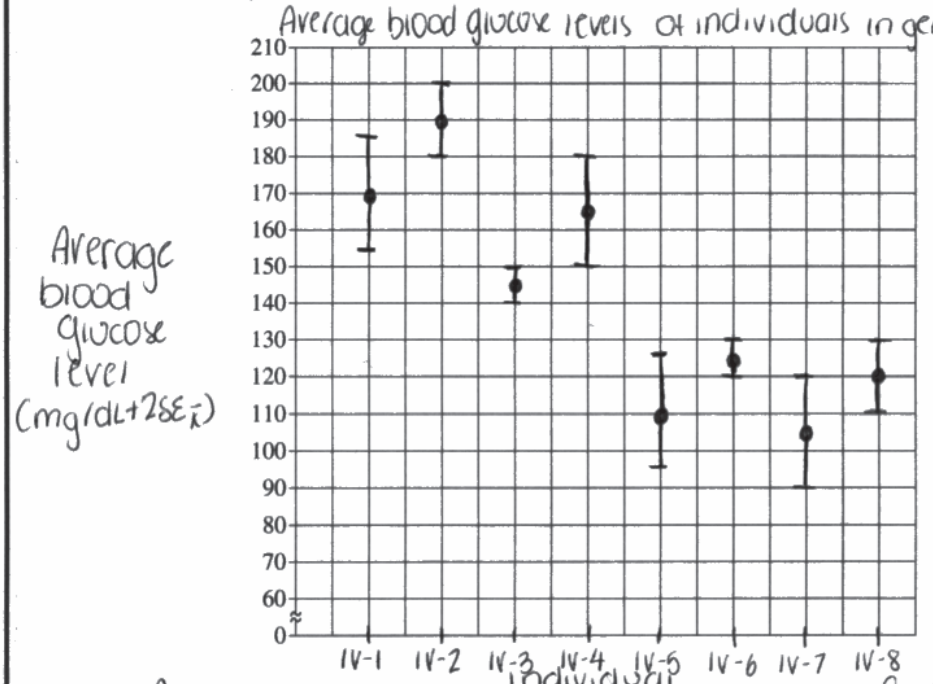
b) One individual who is at risk of developing the disorder with a significantly different blood glucose level than IV-1 is IV-3. We know this because the error bars on the graph do not overlap making the difference in blood glucose level for IV-1 and IV-3 significantly different.

Continue your response to **QUESTION 2** on this page. Do not skip lines.

c) the individuals that can pass on the mutation are individuals III-1, III-2, III-4. this trait is found in mitochondrial ~~sex-linked~~ DNA so it is only passed down by females with the trait. since in generation III only individuals 1, 2, and 4 ~~have~~ are female and have parents with the trait and show at risk blood glucose levels they can pass the mutation to their children.

d) Based on the students claim all of the ~~male~~ offspring of II-2 will have the trait although no ~~some~~ females will have it ~~some~~ because it is a recessive disorder and their father has the dominant trait which will be expressed. The individuals predicted to have it based on the students claim are 4, 8 in generation III. the data does not support the students claim because the trait is found in mitochondrial DNA which is passed down by the mothers and not autosomal DNA which is from both parents. For this reason, all of II-2 offspring will have the mutation.

Begin your response to **QUESTION 2** on this page. Do not skip lines.

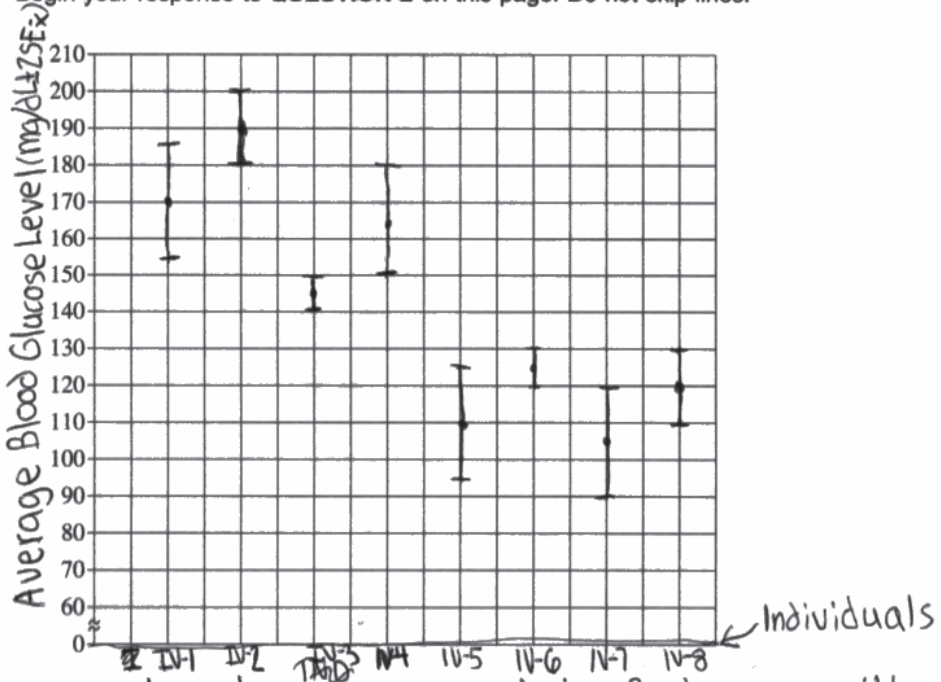



A glucose molecule is a carbohydrate with Carbon, hydrogen and oxygen atoms ($C_6H_{12}O_6$) covalently bonded. One individual who is both at risk of developing the disorder and has a significantly different blood glucose level from that of individual IV-1 is individual IV-2. The individuals in generation IV who can pass on the mutation to their children are IV-1, IV-2, and IV-4. Based on the student's claim, the individuals ~~not~~ of generation III who would be affected by the disorder are III-1, III-4, III-5, ~~III-7~~ and III-8. The data does not support the student's claim because in order for it to have been X-linked recessive,

Continue your response to **QUESTION 2** on this page. Do not skip lines.

All the sons of II-2 would have been affected by the ~~disorder. However, III-3 and III-5 are not affected~~ disorder since they only need one X chromosome from their mother to be affected with the recessive disorder. However, III-3 and III-5 are not affected.

Begin your response to **QUESTION 2** on this page. Do not skip lines.




Glucose molecules ~~are~~ consist of atoms with NADPH formulas with bonds that share molecules. Individual 3 has a chance and is signifigantly different in levels. Individuals 1-4 are capable of passing the disease to their children. The student's prediction states that only females can have the disease, but since III-4 and III-8 have the disorder the claim is not supported.

# Question 2

**Note:** Student samples are quoted verbatim and may contain spelling and grammatical errors.

## Overview

This question presented a pedigree of a family in which some individuals are affected by a "rare disorder that alters glucose metabolism and first shows symptoms in adulthood." Data on average blood glucose levels of individuals in one generation of the pedigree were presented in a table. A second table provided phenotypic classifications based on blood glucose levels.

In part (a) students were asked to describe the atoms and types of bonds in a glucose molecule. Responses were expected to demonstrate an understanding of the structure of carbohydrates (SYI-1.B.2.c in Topic 1.4).

In part (b) students were asked to construct a graph based on the blood glucose data. Responses were expected to demonstrate proficiency in constructing a bar graph (Science Practice 4.A). Students were asked to determine one individual both at risk of developing the disorder and with a significantly different blood glucose level from a specified individual. Responses were expected to demonstrate proficiency in describing data from a table or graph (Science Practice 4.B) and using error bars to determine whether means are statistically different (Science Practice 5.B).

In part (c) students were asked to identify all individuals in generation IV of the pedigree who can pass on the mutation to their offspring. Responses were expected to demonstrate proficiency in analyzing a visual representation of biological concepts and processes (Science Practice 2) and an understanding of a mitochondrial inheritance pattern (IST-1.J.4 in Topic 5.4).

Part (d) presented a claim that the inheritance pattern is X-linked recessive. Students were asked to predict which individuals of generation III would be affected by the disorder, based on the claim, and to justify why the data do not support the claim. Responses were expected to demonstrate an understanding of X-linked and mitochondrial inheritance patterns (IST-1.J.2 and IST-1.J.4 in Topic 5.4) and proficiency in argumentation (Science Practice 6).

## Sample: 2A
## Score: 8

The response earned 1 point in part (a) for describing that a glucose molecule contains atoms of carbon, hydrogen, and oxygen that are covalently bonded. The response earned 1 point in part (b) for constructing a graph labeled with correct y-axis (average blood glucose level ( mg/dL )) and x-axis ( IV-1 through IV-8 ) labels. The response earned 1 point in part (b) for constructing a bar graph representing accurate data points from Table 1. The response earned 1 point in part (b) for including correct error bars. The response earned 1 point in part (b) for determining individual IV-3 . The response earned 1 point in part (c) for identifying individuals IV-1 , IV-2 , and IV-4 . The response earned 1 point in part (d) for predicting that III-4 and III-8 are the individuals of generation III who will be affected by the disorder. The response earned 1 point in part (d) for providing accurate evidence and reasoning to refute the claim that the disorder is inherited in an X-linked recessive pattern.

## Question 2 (continued)

**Sample: 2B**
**Score: 5**

The response earned 1 point in part (a) for describing that a glucose molecule contains atoms of carbon, hydrogen, and oxygen that are covalently bonded. The response earned 1 point in part (b) for constructing a graph labeled with correct y-axis (average blood glucose level ( mg/dL )) and x-axis ( IV-1 through IV-8 ) labels. The response earned 1 point in part (b) for constructing a modified bar graph representing accurate data points from Table 1. The response earned 1 point in part (b) for constructing a graph with correct error bars. The response did not earn a point in part (b) because IV-2 is incorrectly identified as having significantly different blood glucose levels from IV-1 . The response earned 1 point in part (c) for identifying individuals IV-1 , IV-2 , and IV-4 . The response did not earn a point in part (d) because the response predicts individuals in addition to III-4 and III-8 who will be affected by the disorder. The response did not earn points in part (d) because the response provides inaccurate evidence and reasoning to refute the claim that the disorder is inherited in an X-linked recessive pattern.

**Sample: 2C**
**Score: 3**

The response did not earn a point in part (a) because it does not describe the atoms that make up a glucose molecule, and it misidentifies the bond type. The response earned 1 point in part (b) for constructing a graph labeled with correct y-axis (average blood glucose level ( mg/dL )) and x-axis ( IV-1 through IV-8 ) labels. The response earned 1 point in part (b) for constructing a modified bar graph representing accurate data points from Table 1. The response earned 1 point in part (b) for including appropriate error bars. The response did not earn a point in part (b) because it does not include the generation of "Individual 3." The response did not earn a point in part (c) for identifying "individuals 1-4" because individual IV-3 should not be included. The response did not earn a point in part (d) because it does not predict individuals III-4 and III-8 . The response did not earn a point in part (d) because it provides inaccurate evidence and reasoning to refute the claim that the disorder is inherited in an X-linked recessive pattern.