

**Ohio Graduation Test for Science– March 2005
Annotated Item 12**

Standard and Benchmark Assessed:

Standard: Life Sciences
 Benchmark: C. Explain the genetic mechanisms and molecular basis of inheritance.

Extended Response Question:

Sickle cell Disease

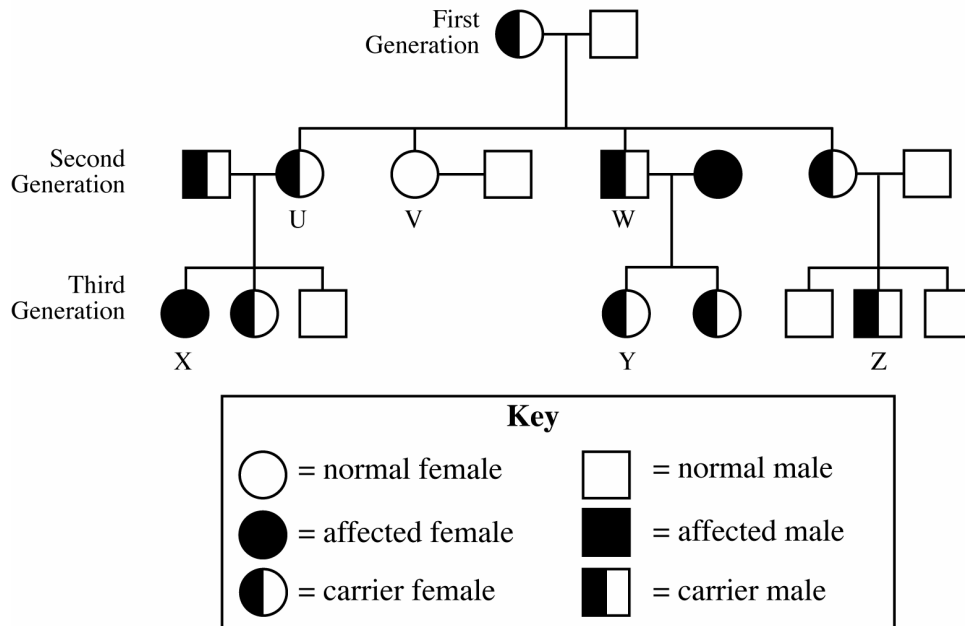
Sickle cell disease is a group of inherited disorders in which deoxygenated red blood cells become distorted and take on a shape like a sickle. There are two common alleles for this gene. One causes normally shaped red blood cells and the other allele causes the red blood cells to have a sickle shape. The sickled cells can lodge in the smallest blood vessels and reduce the circulation of blood to tissues.

The sickle cell allele is most common in areas where the disease malaria is a significant problem, and among people whose ancestors are from those areas. Evidence shows that having just one sickle cell allele makes a person resistant to malaria.

This genetic condition is a recessive trait. When an individual has only one allele for the sickle cell trait, the person is a carrier.

The pedigree below represents a family in which some members have the sickle cell allele.

Genetic Pedigree



12. Draw a Punnett square or comparable diagram for the couple in the first generation of the pedigree. Use **B** to represent the allele for normal red blood cells and **b** to represent the allele for sickle cell disease. How do the couple's actual children compare to the expected

**Ohio Graduation Test for Science– March 2005
Annotated Item 12**

results shown in your Punnett square? Respond in the space provided in your **Answer Document**. (4 points)

Commentary:

This extended response question asks students to provide a Punnett square and to compare, children predicted, with the actual children shown in the pedigree based on a given scenario about sickle cell disease. Traditionally, the sickle cell trait was considered dominant or recessive but research has shown that the trait is a case of incomplete dominance. The blending of traits allows those who live in areas affected by malaria to have a survival advantage. The sickle cell disease is displayed in those who are homozygous for the trait. The interpretation of the Punnett square and the pedigree may be based on dominant versus recessive traits or incomplete dominance. Credit is awarded for both interpretations.

The question provides the alleles that are to be used and the student must infer from the pedigree the genotype of the parents to set up the Punnett square or diagram. Using information from the key in the pedigree, the student can determine that one parent is heterozygous, **Bb**, for the sickle cell trait and the other parent is homozygous, **BB**, and does not carry the trait. The student must use the completed Punnett square to accurately predict that 50% of the offspring are expected to carry the trait for sickle cell. None of the offspring will be affected by the disease. The response must correctly analyze the pedigree by showing that three of the offspring carry the trait and one does not. The response must correctly compare the Punnett square and the pedigree. Seventy-five percent of the couple's actual offspring carry the trait. This is higher than the 50% probability that is illustrated by the Punnett square.

The response that earns 4 points must provide a Punnett square or comparable diagram to illustrate the offspring that can be produced by the first generation of the genetic pedigree provided in the passage. The 4-point response demonstrates an understanding that the Punnett square represents the probability of the distribution of alleles for each offspring that is produced by a couple. It is not an indicator of the actual number of offspring that will carry each allele.

This question is classified as Demonstrating Investigation Processes of Science because the task requires students to make a prediction, a Punnett square, and compare this information to actual observations, the pedigree, based on an experimental context.

Performance Data:

The percent of public school students earning each score point for question 12 on the March 2005 Ohio Graduation Test:

Percent at Each Score Point								
0	0.5	1	1.5	2	2.5	3	3.5	4
20%	4%	12%	5%	11%	4%	11%	3%	24%

**Ohio Graduation Test for Science– March 2005
Annotated Item 12**

Sample Response for Item 12 (Extended Response):

The accurate Punnett square has two characteristics (2 points).

- Genotypes **BB** and **Bb** are shown for parents (top row and left column).
- Genotypes **BB** and **Bb** are in proper squares representing offspring.

	B	b
B	BB	Bb
B	BB	Bb

Notes:

- The response may not have the last row on the Punnett square complete and it would still be correct. The response could show the cross.
- The response does not necessarily have to label the genotypes “male parent” and “female parent” as long as the contents of the chart are correct.

The comparison of actual results to the expected results described by the response includes two parts (1 point each).

- A Punnett square that shows half (50%) of the expected offspring being carriers (Bb).
OR
- An accurate interpretation of their Punnett square.
AND
- The pedigree shows three out of four of the offspring (75%) being carriers.
OR
- The Punnett square ratio gives the chance for each offspring having the allele for sickle-cell.
AND
- The results of a small population may deviate from the predicted ratios. The predicted ratios would be more observable in larger populations.

Example: “The Punnett square only shows half of the children being carriers, but actually three out of four are carriers as read from the pedigree.”

Notes:

- The response may also interpret the Punnett square and pedigree based on incomplete dominance. In this case, three out of four offspring may exhibit symptoms of the disease due to incomplete dominance.
- The response may compare non-carriers instead, i.e., the Punnett square shows half of the offspring without the sickle-cell gene, but only one of four actual offspring lacks the gene.

Ohio Graduation Test for Science— March 2005
Annotated Item 12

Scoring Guidelines:

Score point	Description
4 points	The response shows a correctly drawn Punnett square or a diagram of the cross. The response includes an accurate interpretation of the Punnett square. The comparison is completed by including a statement that the couple's children, based upon the given pedigree, do not match the numbers expected from the Punnett square.
3 points	The response shows a correctly drawn Punnett square or a diagram of the cross. The response interprets the pedigree or makes an accurate comparison between the Punnett square and the pedigree. OR The response shows a single error in the Punnett square but follows through by correctly interpreting the pedigree and makes an accurate comparison between the student's Punnett square and the pedigree.
2 points	The response shows a correctly drawn Punnett square or diagram of the cross. OR The response shows a single error in the Punnett square but follows through by correctly interpreting the Punnett square. OR The response fails to show a Punnett square but provides a correct interpretation and comparison with the results of the pedigree. For example: "The pedigree shows three out of the four children as carriers. In a cross between a male BB parent and a female Bb parent, however, only 50% of the offspring would be expected to carry the gene."
1 point	The response shows a single error in the Punnett square or other diagram of the cross. OR The response gives a correct interpretation of the Punnett square without attempting to draw one. OR The response gives a correct interpretation of the pedigree.
0 points	The student response does not meet the criteria to earn one point. The response indicates inadequate or no understanding of the task. It may only repeat information from the passage or prompt or provide incorrect or irrelevant information. The student may have written on a different topic or written, "I don't know."

Keywords: genetics, Punnett square, pedigree, sickle cell disease, malaria