Sickle Cell Inheritance MiniLab
Student FRQs

Cat# M3050

Version 073126

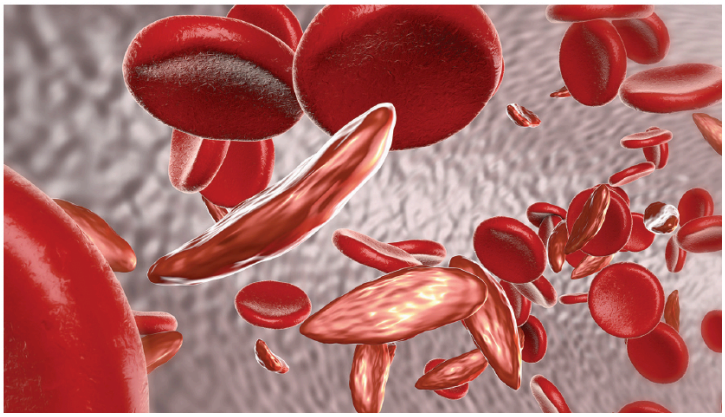


Table of Contents

Q2 2

Q3 4

Q4 5

This resource provides 3 total FRQs of the following types:

- Question 2: Interpreting and Evaluating Experimental Results with Graphing (9 pts)
- Question 3: Scientific Investigation (4 pts)
- Question 4: Conceptual Analysis (4 pts)

Q2. Sickle cell disease is caused by the inheritance of two mutated, recessive alleles for a gene responsible for hemoglobin production. When a person is homozygous for the recessive allele (*HbS*), the hemoglobin is abnormal and can cause the red blood cells to form a sickle shape. The sickled cells tend to adhere to each other and to capillary walls restricting oxygen flow and causing fatigue and pain. Heterozygotes for sickle cell will produce sickle shaped red blood cells under extreme conditions such as intense exercise. Individuals with two dominant (*HbA)* alleles always create typical shaped red blood cells.

The presence of the sickle hemoglobin allele in homozygotes (*HbS*) and heterozygotes (*HbA/HbS*) provides strong protection against symptomatic malaria caused by Plasmodium parasites carried by mosquitos.

Part A

Describe the advantage of phenotypic variation in a population where malaria is present.

Although scientists have long agreed that the presence of *HbS* provides protection against symptomatic malaria, not many studies have been completed to determine the effect of the allele's presence on asymptomatic malaria. To determine if *HbS* also protects against asymptomatic malaria, researchers collected blood samples from 2,685 children aged 3–17 from 11 villages in Cameroon during three high malaria transmission seasons. Children appeared healthy and without a fever and reported no antimalarial treatment or malaria symptoms for the past month. DNA from the blood samples was sequenced to determine the HbS genotypes and whether *Plasmodium falciparum* gametocytes, the stage of the parasite responsible for spreading infection, were present.

Genotype	Infection Rate (%) when *P. falciparum* gametocytes were absent $\pm SE_{\bar{x}}$	Infection Rate (%) when *P. falciparum* gametocytes were present $\pm SE_{\bar{x}}$
Homozygous Dominant (HbA/HbA)	60 ± 5	16 ± 2
Heterozygous (HbA/HbS)	54 ± 3	19 ± 4

Table 1. Asymptomatic Malaria Infection Rates of Homozygous and Heterozygous individuals in the presence and absence of *P. falciparum* gametocytes

Part B

i. Using the template in the space provided for your response, **construct** a bar graph that represents the data in the table. Your graph should be appropriately plotted and labeled.

ii. Based on the data in Table 1, **determine** if *HbS* provides protection against asymptomatic malaria.

Researchers found the following genotypic frequencies in the children they tested:

Homozygous Dominant Individuals (*HbA/HbA*)	Heterozygous Individuals (*HbA/HbS*)	Homozygous Recessive Individuals (*HbS/HbS*)
0.8281	0.1638	0.0081

Part C

i. Assuming the population is in Hardy-Weinberg equilibrium, **calculate** the frequency of the *HbS* allele.

ii. **Predict** the effect on the frequency of heterozygous individuals if *Plasmodium falciparum* becomes more prevalent in the mosquito population.

Part D

i. Researchers claim that the *HbS* allele is under balancing selection where multiple alleles are maintained even though individuals who are recessive have a lower life expectancy. Use reasoning to **support** the researchers' claim.

ii. CRISPR-based gene therapy has been used to reactivate fetal hemoglobin production preventing adult red blood cells from sickling in patients 12 and older. **Predict** what will happen to these patients' defenses against malaria.

Q3. Malaria is a life-threatening infectious disease transmitted by mosquitoes and caused by the Plasmodium parasite. Before the 1990s it was treated with chloroquine, but the parasite grew resistant to the medicine.

Part A

Describe how a mutation that gives resistance to chloroquine became common in the Plasmodium population.

After resistance to chloroquine, malarial infection was commonly treated with ACT (Artemisinin-based Combination Therapy). Recent evidence shows that the parasites are now showing signs of resistance to ACT, as well as chloroquine. Scientists are testing a new medication called KLU156 to treat malaria. Patients were given a dose of KLU156 or ACT every day for three days. They were then tested 29 days later to determine if they were free from symptoms and parasites.

Part B

Identify the dependent variable in the experiment.

Part C

State the null hypothesis for the experiment.

Part D

KLU156 disrupts the rough endoplasmic reticulum of the parasite. **Predict** the effect on protein secretion when parasites are treated with KLU156.

Q4. Hemoglobin, a protein containing two alpha chains and two beta chains, carries oxygen in red blood cells. Alpha Thalassemia is an autosomal recessive disorder caused by a deletion mutation of the genes *HBA1* and *HBA2* on chromosome 16 that affects the alpha chains of the hemoglobin protein in red blood cells. Patients with three of four mutated *HBA1* and *HBA2* alleles can experience jaundice, iron overload, a shortage of red blood cells and must receive routine blood transfusions to stay alive.

Part A

Describe how a deletion mutation can affect the function of a protein.

Part B

Researchers would predict that individuals with the dominant phenotype would not experience the symptoms of Alpha Thalassemia. However, patients who are heterozygous for both genes can exhibit a bit of fatigue due to having smaller than average sized red blood cells. **Explain how** this condition can occur even though the individual is heterozygous for both the HBA1 and HBA2 genes.

Doctors have been using hematopoietic cell transplantation to treat Alpha Thalassemia. This treatment consists of collecting blood stem cells from patients with three mutated alleles, adding the missing alpha-globin gene, and then using viral transduction to return the corrected cells back to the patient.

Part C

Predict the effect on the number of blood transfusions needed for a patient who undergoes this procedure.

Part D

Justify your prediction.

miniOne® SYSTEMS

theminione.com (858) 684-3190 info@theminione.com

FastTaq, GreenGel, gloTray, PrepOne, spiniOne and The Winston are trademarks of Embi Tec.
GelGreen is a trademark of Biotium. MiniOne is a registered trademark of C.C. IMEX.
Patents issued: US 10,641,731 B2, US 20110253541 A1, US 11879118-B2, US 12,384,994,
US 11,879,117, US 11,879,118