

Activity 3.4.3: World Distribution of Sickle Cell Disease – Optional

Introduction

Sometimes having a certain trait or genotype can actually be protective against disease. You have learned that sickle cell disease is a very serious disease. People who are carriers, although they do not have the disease themselves, can pass the gene on to their children. This is often thought of as a very negative thing, because no parent would want their child to suffer from this disease. However, being a carrier for sickle cell disease can actually offer people protection from malaria.

Malaria is a life-threatening disease caused by parasites that are transmitted to people through the bites of infected mosquitoes. The infection causes recurrent attacks of chills and fever and kills about 1 million people each year worldwide. It is prevalent in tropical and subtropical countries around the world, predominantly in sub-Saharan Africa. In the middle 1940s in Africa, doctors began noticing that patients who had sickle cell anemia were more likely to survive malaria. It was learned that carriers of sickle cell disease experience a survival advantage over people with normal hemoglobin in regions where malaria is prevalent. People infected with the malaria are more likely to survive the illness if they have the sickle cell trait. When malarial parasites invade the bloodstream, the red blood cells that contain defective hemoglobin become sickled and die, trapping the parasites inside them and reducing infection. Therefore, over generations, carriers for sickle cell disease become more prevalent in the population. Researchers have found that in areas of Africa hard-hit by malaria, as much as 40 percent of the population carries at least one mutated hemoglobin gene. In this activity you will simulate the effects of a high frequency of malaria on the allele frequencies of a population.

Equipment

* Computer with Internet access
* Laboratory journal
* (5) Plastic cups
* Permanent marker
* (1) Coin
* (75) Red beans
* (25) White beans

Procedure

Part I:

1. Examine the map of the Global Distribution of Hemoglobin Disorders provided by the World Health Organization’s Genomic Resource Center at <http://www.who.int/genomics/public/Maphaemoglobin.pdf>. In your laboratory journal, write your observations of where these diseases occur and where they do not.
2. Answer Conclusion question 1.
3. Watch the video clip “Accidents of Creation” from the PBS’s *Secret of Life,* available from*:* <http://www.pbs.org/wgbh/evolution/library/01/2/quicktime/l_012_02.html>.
4. In your laboratory journal, predict what will happen to the frequencies of the normal and sickle alleles as a result of malaria? Will the frequency of the normal allele increase or decrease? Will the frequency of the sickle allele increase or decrease? Explain your reasoning.
5. Work with a partner to obtain 5 plastic cups, 75 red beans, 25 white beans, and 1 coin.
6. Label the five cups as follows: *Normal (SS), Carrier (Ss), Sickle (ss), Non-Surviving Alleles, and Gene Pool*.
7. Place all of the red and white beans in the cup labeled *Gene Pool* and mix them up.
8. Simulate fertilization by picking out two beans (alleles) WITHOUT looking.
9. Flip a coin to determine whether that individual is infected with malaria.
10. Put the beans in the proper cup using the table below.

|  |  |  |  |
| --- | --- | --- | --- |
| **Genotypes**  **(The genes/alleles present for a trait)** | **Phenotype**  **(The traits shown based on the genotype)** | **Malaria**  **(Heads)** | **Non infected**  **(Tails)** |
| SS  (Red/Red) | No sickle cell disease,  Malaria susceptibility | Die: Place in Non-surviving cup | Live: Place in SS |
| Ss  (Red/White) | No sickle cell disease,  Malaria resistance | Live: Place in Ss cup | Live: Place in Ss |
| ss  (White/White) | Sickle cell disease | Die: Place in Non-surviving | Live for a brief time: Place in ss cup |

1. Continue picking out two beans (alleles) at a time without looking and placing them in the proper cups until all of the beans in the Gene Pool are used up.
2. Count the number of individual red beans (S alleles) and white beans (s alleles) in the cups labeled SS and Ss. All individuals in the SS and Ss cups survive to reproduce. Record these numbers in the table below.

**2nd Generation - Total Surviving Alleles:**

|  |  |
| --- | --- |
| Number of S (RED) alleles surviving. (All red beans in SS and Ss cups) |  |
| Number of s (WHITE) alleles surviving.  (All white beans in Ss cup) |  |

1. Put all of the SS and Ss beans back in the gene pool cup. These represent all of the individuals who survive to reproduce.
2. Move all of the beans from the ss cup into the Non-surviving alleles cup. These represent all of the individuals who do NOT survive to reproduce.
3. Repeat the procedure for the next generation, using up all of the beans in your gene pool. Record the results in the table below.

**3rd Generation - Total Surviving Alleles:**

|  |  |
| --- | --- |
| Number of S (RED) alleles surviving. (All red beans in SS and Ss cups) |  |
| Number of s (WHITE) alleles surviving.  (All white beans in Ss cup) |  |

1. Record all of your results on the class board, which will look like the chart below. Note that the number of parent alleles should be **75 S** and **25 s** for each group.

|  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- |
|  | Parents | | 2nd Generation | | 3rd Generation | |
| S | s | S | s | S | s |
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| Totals |  |  |  |  |  |  |

1. Calculate the frequencies of S and s alleles for each generation using the following formulas. Show your work below.

1. Answer the remaining Conclusion questions.

Conclusion

1. What does the map of the prevalence of hemoglobin disorders worldwide indicate about the disease?
2. What do the red and white beans represent in this simulation? What does the coin represent?
3. What do you think “allele frequency” means?
4. How are allele frequencies related to how a population changes over time?
5. Since few people with sickle cell anemia (ss) are likely to survive to have children of their own, why hasn’t the recessive allele been eliminated?
6. Why is the frequency of the sickle cell allele so much lower in the United States than in Africa?