Name:\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_

Names of any students you completed assignment with:

**Instructions**

For this assignment, you will use the *evolfoRces* application to answer the questions below. When applicable, include figure(s) in the space provided for each question. Each question should be answered in complete sentences. You are strongly encouraged to work with one another but you must submit your own assignment in your own words. **Please answer all questions in a different color (Like red! Or blue! But definitely not yellow.).**

Note: When using evolfoRces, you may see that the screen goes grey and gives an error such as “Disconnected from server” – simply refresh the webpage and you’ll be back online!

**Consider the following scenario for this assignment:**

Sickle cell anemia is a genetic disease which occurs when individuals are homozygous for a recessive allele, "a", and hence have the genotype "aa". Heterozygous (Aa) individuals exhibit resistance to malaria, and AA individuals are free from sickle cell anemia but are susceptible to malaria. Assume that, in a town in Ghana (a country in Africa where malaria is present), the relative fitnesses for these genotypes are AA=0.88; Aa=1.0; aa=0.14. This represents an extreme case of balancing selection, but one where "aa" homozygotes (sickle cell anemia phenotype) have substantially lower fitness than "AA" homozygotes (no sickle cell anemia, but susceptible to malaria).

For this assignment, you will be examining how effective evolution is at ridding the population of the genetic disease sickle cell malaria. (BIG hint: In order for sickle cell malaria to be fully eradicated, the “a” allele must be lost from the population entirely). *For all questions, assume there is NO genetic drift unless otherwise stated.*

1. Based on the fitnesses of each genotype, which individually is *more likely* to survive: An "aa" individual with sickle cell anemia but no malaria, or an "AA" individual with malaria but no sickle cell anemia? Answer this question in one complete sentence.

1. Use the evolfoRces application to determine whether sickle cell anemia (the aa genotype) can be entirely eradicated in 50 generations. Assume the following:
   * Allele "A" has a frequency of 70% in the population to begin
   * There is no mutation
   * There is no migration

Explain your findings in 2—4 sentences, and *include the final figure from evolfoRces showing the allele A frequency over time in your answer, and state the final fitness for the population in your answer.*

1. Based on your results for #2, does it appear that percentage of individuals who are susceptible to malaria (genotype "AA") increased or decreased over the fifty generations? Explain your reasoning in 1-2 sentences.
2. Assume a new vaccine has been developed that protects all individuals from malaria. Once individuals are protected from malaria, the relative fitnesses for genotypes become AA=1.0; Aa=1.0; aa=0.14. Based on this updated information, will it be possible to fully eradicate sickle cell anemia within 50 generations. Use the same initial assumptions as given in #2. Explain your findings in 2—4 sentences, and *include the final figure from evolfoRces showing the allele A frequency over time in your answer, and state the final fitness for the population in your answer.*
   * Note: For question #6 you will be comparing results from #4 and #5, so you may wish to “store” your results for this question in evolfoRces for easier comparison!
3. Assume again that a vaccine has been introduced (so fitnesses are AA=1.0; Aa=1.0; aa=0.14), but in this scenario there is also mutation between alleles. At every generation, 5% of "A" alleles mutate to "a" (mutation rate 0.05), and 10% of "a" alleles mutate to "A" (mutation rate 0.1). Given this new information, will it be possible eradicate sickle cell anemia within 50 generations? Explain your findings in 2—4 sentences, and *include the final figure from evolfoRces showing the allele A frequency over time in your answer, and state the final fitness for the population in your answer.*
4. Compare your results for questions #4 and #5: Does mutation reduce, increase, or not affect the percentage of *heterozygotes* in the population after 50 generations of evolution? Answer this question by precisely indicating the percentage of heterozygotes from each question and comparing the results.
5. Based on your answer to #6, for which scenario (#4 or #5) does the population contain more *variation* after 50 generations of evolution? What do you therefore conclude is the overall effect of mutation on population variation?
6. In certain region of Ghana, there are many tiny villages each with a population size of roughly 500 individuals (this means there is *genetic drift*). Assume all people have been vaccinated (fitnesses are AA=1.0; Aa=1.0; aa=0.14), and there is no migration and no mutation. Assuming a starting “A” frequency of 0.7, again test whether sickle cell anemia can be eradicated within 50 generations. *Hint: To answer this question, assume the probability of eradicating sickle cell anemia is equal to the percentage of* ***50 replicate simulations*** *for which allele “a” is lost*. Explain your findings in 2—4 sentences and *include the final figure from evolfoRces showing the allele A frequency over time in your answer, and state the final fitness for the population in your answer.* Based on your results, does it appear that the combined effects of natural selection and drift can fully rid the population of sickle cell anemia?
7. Consider a different situation where individuals from villages in Ghana are moving to Accra, the capital city of Ghana, representing a scenario of migration. In this situation, “Accra” represents the “island” and the villages represent the “continent”. After 100 generations of migration, will the proportion of fully healthy individuals who neither have malaria nor sickle cell anemia (i.e. the heterozygotes) increase, decrease, or remain unchanged in Accra? Explain your findings in 1—2 sentences, indicating which specific quantities (and their values!) you used to answer this question. Also include the final figure from evolfoRces showing the allele A frequency over time in your answer, and indicate the final population fitness in Accra.

You can assume the following:

* + There is no vaccination, so fitnesses are AA=0.88; Aa=1.0; aa=0.14.
  + In villages, the percentage of "A" allele is 0.7, but in Accra, the percentage of allele "A" before migration began was 0.5. *This means the starting heterozygosity in Accra is also 0.5.*
  + Each generation, 4% of all Accra individuals are new arrivals from villages (i.e., migration rate = 0.04).

1. Considering all of your findings from this assignment, make an overall conclusion whether it is possible for evolution to cure sickle cell anemia. Based on this conclusion, is evolution perfect at increasing fitness and helping populations adapt, or does evolution only sometimes "succeed" at helping populations adapt? In this case, full adaptation means the population achieves an average fitness of 1.0.