

TESTING A HYPOTHESIS

OVERVIEW

This worksheet serves as a guide to the short film *The Making of the Fittest: Natural Selection in Humans* (<http://www.hhmi.org/biointeractive/making-fittest-natural-selection-humans>) by asking questions about the information provided in the film. It engages students in answering questions about how Dr. Tony Allison discovered the link between sickle cell disease and resistance to malaria.

KEY CONCEPTS AND LEARNING OBJECTIVES

Students will be able to

- explain how natural selection preserves favorable traits;
- describe why a harmful trait, such as sickle cell disease, can be preserved in a population;
- explain how natural selection causes changes in allele frequencies in a population;
- describe how disease can act as a selective pressure in evolution; and
- understand the scientific process of asking questions, formulating hypotheses, doing experiments, and drawing conclusions based on evidence.

CURRICULUM CONNECTIONS

Curriculum	Standards
NGSS (April 2013)	MS-LS1-5, MS-LS4-4 MS-LS1.A, MS-LS2.A, MS-LS3.B, MS-LS4.B, MS-LS4.C HS-LS4-2, HS-LS4-4 HS-LS1.A, HS-LS3.B, HS-LS4.B, HS-LS4.C
Common Core (2010)	CCSS.ELA-Literacy.RH.9-10.3, CCSS.ELA-Literacy.RH.9-10.4, CCSS.ELA-Literacy.RH.11-12.2, CCSS.ELA-Literacy.RST.11-12.4, CCSS.ELA-Literacy.WHST.9-12.2, CCSS.ELA-Literacy.W.9-10.2
AP Biology (2012–13)	1.A.1, 1.A.2, 1.A.4, 1.C.3, 3.A.3, 3.C.1, 3.C.2, 4.C.1
IB Biology (2009)	4.1, 4.3, 5.4, D.2

KEY TERMS

alleles, evolution, hemoglobin, heterozygous, homozygous, malaria, mutation, natural selection, sickle cell anemia, sickle cell character, sickle cell disease

TIME REQUIREMENTS

This worksheet was designed to be completed within one 50-minute class period.

SUGGESTED AUDIENCE

This lesson is appropriate for middle school life science and high school biology (all levels including AP and IB).

PRIOR KNOWLEDGE

Students should know how traits are inherited and that some traits provide organisms with a greater chance to survive and reproduce. A basic understanding of genetics would be helpful.



*The Making of the Fittest:
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WORKSHEET
TEACHER MATERIALS

TEACHING TIPS

- Before viewing the short film, provide students with some information about malaria. Include its mode of transmission, symptoms, and severity. You may also want to show the following animations: *Malaria: Mosquito Host* (www.biointeractive.org/malaria-mosquito-host) and *Malaria: Human Host* (www.biointeractive.org/malaria-human-host).
- You may wish to have your students read the questions in the chart (see the answer key) before watching the film and underline some key points. You can also have students work in groups and assign different parts of the chart to each group. After the film, have students discuss and fill out the chart as a class.

SUGGESTED DISCUSSION QUESTIONS

You might discuss the following questions with your students *before* they watch the film.

1. *What do you know about sickle cell anemia?*
It is not necessary for students to be familiar with the disease, as the film provides an adequate amount of background information. This question and the others that follow serve as a formative assessment piece and provide an opportunity for students to share prior knowledge, misconceptions, or both.
2. *Was, or is, malaria a problem in the United States?*
Malaria was a problem in the United States until fairly recently and was only eradicated in the 1950s. For more information, check the Centers for Disease Control and Prevention link on the history of malaria: <http://www.cdc.gov/malaria/about/history/>.
3. *What are some things you already know about human evolution?*
You can use this as a formative question to assess students' prior knowledge and preconceptions about human evolution.
4. *How might a disease such as malaria play a role in human evolution?*
Students might speculate that some individuals possess genetic variations that provide them with some resistance to malaria. These individuals would be selected for, while those lacking the variation would be selected against.

ANSWER KEY

Possible answers include but are not limited to the following.

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**WORKSHEET
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Film Information Chart

Sickle Cell	Malaria	Process of Discovery
<p><i>What is sickle cell disease (or sickle cell anemia)?</i></p> <ul style="list-style-type: none"> • A genetic disease • A painful, potentially fatal disease • A disease that prevents oxygen from getting to all parts of the body • A disease caused by a mutation in the hemoglobin gene <p><i>Where is the sickle cell allele, or “character,” most common in East Africa?</i></p> <ul style="list-style-type: none"> • In the coastal areas and around Lake Victoria <p><i>What happens in a blood sample of individuals who carry the sickle cell allele when the blood is deprived of oxygen?</i></p> <ul style="list-style-type: none"> • Some red blood cells change shape, or sickle, when deprived of oxygen. 	<p><i>How is malaria transmitted?</i></p> <ul style="list-style-type: none"> • It is transmitted by mosquitoes. • When mosquitoes carrying the parasite (<i>Plasmodium falciparum</i>) bite an uninfected person, they can transmit malaria. • Mosquitoes become infected with malaria when they bite a person infected with malaria (not shown in the film). <p><i>Where is malaria most prevalent in East Africa?</i></p> <ul style="list-style-type: none"> • In the coastal areas and around Lake Victoria <p><i>What types of human cells does the malaria parasite, Plasmodium falciparum, infect?</i></p> <ul style="list-style-type: none"> • Red blood cells • Liver cells (not shown in the film) <p><i>How does the sickle cell allele protect against malaria?</i></p> <ul style="list-style-type: none"> • The allele compromises the ability of the parasite to reproduce. 	<p><i>What were Dr. Allison’s initial questions when he went to East Africa in 1949?</i></p> <ul style="list-style-type: none"> • He wanted to know the distribution of the ABO blood groups and other inherited characteristics, including the sickle cell allele, in East African tribes. <p><i>What were Dr. Allison’s initial observations?</i></p> <ul style="list-style-type: none"> • That there was a high frequency of people carrying the sickle cell allele, or character, in the coastal areas and near Lake Victoria but a lower frequency in the highlands <p><i>What did Dr. Allison hypothesize after his 1949 expedition?</i></p> <ul style="list-style-type: none"> • There is a connection between sickle cell anemia and malaria. • The sickle cell allele (or character) protects against malaria. <p><i>What data did Dr. Allison collect to test his hypothesis?</i></p> <ul style="list-style-type: none"> • He collected blood samples from 5,000 children in all parts of East Africa. • From the blood samples, he looked at the malaria parasite load and tested whether the children had the sickle cell character.

QUESTIONS

1. *Explain how Dr. Allison’s hypothesis was supported by the data he collected.*
 - **There were many more children with the sickle cell allele in regions of East Africa where malaria was endemic than there were in the arid and highland areas.**
 - **The parasite load was lower in the red blood cells of children with the sickle cell allele than in those without it.**

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**WORKSHEET
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- In arid and highland areas of East Africa, the frequency of children with the sickle cell allele was much lower than in coastal and wetland regions.
- Other areas of the world where malaria is endemic also show an elevated frequency of the sickle cell allele.

2. *Why are there higher frequencies of the sickle cell allele in areas where malaria is more prevalent?*

In areas where malaria is endemic, the presence of the sickle cell allele in the heterozygous state improves the fitness of individuals. These individuals are provided some protection from malaria and are therefore more likely to survive and reproduce than those who do not carry the sickle cell allele.

3. *Define “natural selection” and explain how Dr. Allison’s work provides an example of natural selection in humans.*

Natural selection is a process by which organisms most suited to their environment survive and reproduce at higher rates. Dr. Allison provides evidence that shows that, while the sickle cell allele is advantageous in one environment, it is not in another. In an environment where malaria is endemic, individuals who carry the sickle cell allele have a selective advantage because they are protected against malaria. In an environment like the coastal regions of East Africa or near Lake Victoria, Dr. Allison shows that natural selection favors an increased frequency of the sickle cell allele. However, in an environment where malaria is not endemic, like in the East African highlands, the sickle cell allele is disadvantageous. Individuals who are heterozygous (AS) for the sickle cell allele have no selective advantage in this environment, and two heterozygous individuals can pass on their sickle cell allele to their offspring, who inherit sickle cell anemia. Since sickle cell anemia can be a lethal disease, for every child with sickle cell disease, two sickle cell alleles are eliminated from the population.

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