ScienceNews

EDUCATOR GUIDE

COURTESY OF MUSEUM OF LONDON ARCHAEOLOGY

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Plague Immunity Left a Lasting Mark

SOCIETY FOR SCIENCE

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About this Guide

Traces of one of history's most infamous pandemics may linger in our genes. In this Guide, students will learn about a genetic link between the Black Death and a modern-day disease and discuss basic genetics concepts at the individual and population levels.

This Guide includes:

Article-based Comprehension Q&A — Students will read and answer questions about the online *Science News* article "Black Death immunity came at a cost to modern-day health." A version of the article, "Plague immunity left a lasting mark," appears in the November 19, 2022 issue of *Science News*. Related standards include NGSS-DCI: HS-LS4; HS-LS3.

Student Comprehension Worksheet — These questions are formatted so it's easy to print them out as a worksheet.

Cross-curricular Discussion Q&A — Population genetics bridges the basic concepts of genes and inheritance, often studied at the individual level, with the larger concept of how a species evolves. In this discussion, students will review basic genetics concepts and investigate an example of evolution within the human population. Learning Outcomes: Population genetics, human evolution. Related standards include NGSS-DCI: HS-LS4; HS-LS3.

Student Discussion Worksheet — These questions are formatted so it's easy to print them out as a worksheet.

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Article-based Comprehension, Q&A

Directions for teachers: Ask students to read the online *Science News* article "Black Death immunity came at a cost to modern-day health" and answer the following questions. A version of the article, "Plague immunity left a lasting mark," appears in the November 19, 2022 issue of *Science News*.

1. What is bubonic plague? What germ causes this plague?

Bubonic plague is a highly infectious and deadly infection caused by the bacterium *Yersinia pestis*.

2. What was the Black Death? How was it related to bubonic plague?

The Black Death was a wave of bubonic plague that lasted from 1346 to 1350 and wiped out roughly a third of the human population in Europe.

3. What gene did researchers in the article study? In what bodily system does the gene play a role?

Researchers studied the gene *ERAP2*, which plays a role in the human immune system.

4. What do the researchers claim about the gene and its relationship to the Black Death?

Researchers claim that having a specific version of the gene improved the odds of surviving the Black Death by as much as 40 percent.

5. What evidence do the researchers use to support their claim? Explain how the researchers gathered their evidence.

Researchers compared the genetic information of people who died before, during and after the Black Death and found that the frequency of this variant drastically increased in the population after the Black Death. In follow-up experiments with human immune cells, cells from people that have the variant and that were infected with *Y. pestis* fought off the bacteria better than cells from people without the variant.

6. Why did the frequency of the gene variant increase after the Black Death?

People with the variant had better odds of surviving the Black Death and passing on their genes than people without the variant. Therefore, more people with the variant survived and passed on the variant, than people without the variant.

7. What implications does the gene variant have for modern-day health?

The variant has been linked with an increased risk of developing Crohn's disease.

8. What broader hypothesis does the new finding support?

It supports a hypothesis that genetic changes that helped our ancestors better fight off ancient infections can have costs for people's health today.

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Cross-curricular Discussion, Q&A

Directions for teachers:
Ask students to read the *Science News Explores* article "Explainer: What are genes?" and use the first set of questions to review some basic genetics concepts.

Then ask students to read the online *Science News* article "Black Death immunity came at a cost to modern-day health" and work with partners or in small groups to answer the second set of questions, which connect those basic concepts to how species evolve. A version of the *Science News* article, "Plague immunity left a lasting mark," appears in the November 19, 2022 issue.

Want to make it a virtual lesson? Post the online *Science News* article to your virtual classroom. Discuss the article and questions with your class on your virtual platform.

An individual's genes
When we talk about genes and inheritance, we often focus on the individual. These questions will get us started by reviewing some basic concepts.

1. What is DNA and how is it organized? Where did you get your DNA?

DNA is short for deoxyribonucleic acid. It's a double-helix molecule that carries genetic information from one generation to another. Packaged into chromosomes within cell nuclei, DNA gives cells instructions for building and maintaining life, including making proteins. We get our DNA from our biological parents.

2. What are genes? What are alleles?

Genes are the segments of DNA that provide instructions for making proteins. Alleles are different versions of the same gene, also called variants. We get a version of a gene, called an allele, from each of our biological parents. The alleles can be the same or different, and the allele pairs determine our observable traits.

3. Define the terms genotype and phenotype. How are they related?

A genotype is an organism's complete set of genes. Phenotype refers to an organism's observable traits. Phenotype is determined by genotype as well as environmental factors.

4. With a partner, use the *Science News Explores* article "Explainer: What are genes?" to create a diagram that shows the relationships among the following terms: DNA, nucleotide, gene, allele, chromosome, nucleus and cell. Note: Some of the terms are linked to *Science News Explores* "Scientists Say" articles that will give you more information.

Student answers will vary. Here is an example from the National Institutes of Health.

Zooming out to species evolution
When we talk about evolution, we often zoom out from the individual to the species level. These questions will introduce the study of population genetics as a way of bridging the two.

1. Give an example of a population, then come up with a biological definition for population that includes the terms "individual" and "species."

Student answers will vary. All the people within a city or all the trout in a lake are examples of populations. A population is a group of individuals of the same species that live among each other and interbreed.

2. Based on your understanding of genetics, your definition of population and the story you read, how would you define population genetics? What do population geneticists try to understand?

Population genetics is the study of what genes and gene variants, or alleles, are present in a population and how they and their distributions change over time.

3. What factors could change what gene variants, or alleles, are present within a population and their frequency?

Student answers should touch on topics that relate to natural selection (factors that make individual more fit based on environmental factors, food supply, predators, parasites, disease, etc.), sexual selection (non-random mating), mutation (changes in alleles due to random changes in DNA), genetic drift (natural disasters or other random events that affect the population) and gene flow (the introduction of new individuals with different genes into the population).

4. What was the Black Death? According to the article, how did it influence the frequency of alleles within the human population in Europe? How does the change relate to a factor you listed in your answer to the previous question?

From 1346 to 1350, the bacterium Yersinia pestis *killed roughly one-third of the human population in Europe — a wave of bubonic plague known as the Black Death. After the Black Death, the frequency of an allele of the immune-related gene* ERAP2 *increased drastically. People with that allele were more likely to survive and so pass it on to their offspring, increasing its frequency in the population. It's an example of natural selection, since people with the allele were more fit to survive the disease.*

5. Define adaptation and evolution in the context of the article. How are they related?

Adaptation refers to a trait that helps an organism or a group of organisms survive in its environment. In this case, in the context of disease, the beneficial allele became an adaptation that spread through the population. When the frequency of the allele in the population changed over time through natural selection, the population was evolving.

6. Draw a diagram that represents the change in relative frequency of the standard *ERAP2* gene and its variant (the beneficial allele) in the European population before and after the Black Death.

Student answers will vary. Generally, before the Black Death, the frequency of the standard ERAP2 *gene should be higher than the frequency of the beneficial allele within the population. After the Black Death, the allele frequency should be higher than the frequency of the standard* ERAP2 *gene.*

7. What are the advantages to this adaptation? Are there disadvantages? How could the disadvantages cause the population to evolve in a different direction, and what would that look like for allele frequency?

Advantages include more individuals who are less likely to die from infections of the bacterium Yersinia pestis*. Disadvantages include possible increased risk for developing immune-related conditions or diseases. In the absence of disease risk from* Y. pestis*, if the immune-related diseases make people less fit for survival or affect their ability to mate, the standard gene (or another variant) could become a beneficial adaptation, decreasing the frequency of the once-beneficial allele.*

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Student Discussion Worksheet

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