WHAT CAN ZEBRAFISH TELL US ABOUT HUMAN SKIN COLOR?

OVERVIEW

In the film *The Biology of Skin Color*, Dr. Nina Jablonski proposed an explanation for why humans living in different parts of the world have different natural skin colors. Specifically, students learned how patterns in variation for the *MC1R* gene provide evidence that dark skin is favored in environments that experience intense UV radiation. This activity focuses on a different gene, *SLC24A5*, which plays a large role in the expression of lighter skin tones common in people of European descent. Students explore data generated from genetic studies in fish to help them understand the function and evolution of *SLC24A5*.

KEY CONCEPTS AND LEARNING OBJECTIVES

- Studies of model organisms can provide valuable information about gene function in humans.
- Changes to a gene's DNA sequence can affect the translation of the gene into amino acids, and ultimately, the function of a protein and the expression of a trait.
- Genetics and the environment can affect expression of a trait. Experiments suggest the degree to which differences in traits are inherited. Differences in human skin color are mostly controlled by genetics.
- By comparing genes and proteins among species, scientists can infer common ancestry and when a given trait evolved.
- Patterns in allele frequencies among populations can indicate adaptation and whether a trait has evolved more than once.

Students will be able to

- construct explanations, make predictions, and propose hypotheses based on available information; and
- use real data presented in scientific figures and information from the film to make evidence-based claims.

SUGGESTED AUDIENCE

- This lesson is appropriate for all levels of high school biology, including AP and IB, as well as introductory college biology.

CURRICULUM CONNECTIONS

Curriculum	Standards
NGSS (April 2013)	Practices 2, 4, 7; HS-LS1-1, HS-LS3-3, HS-LS4-1
AP Biology (2012–2013)	Science Practices 1, 5; 1.A.2, 1.A.4, 3.A.1, 3.C.1, 4.C.2
IB Biology (2016)	3.1, 5.1, 5.2, 7.2

KEY TERMS

adaptation, allele, allele frequency, gene, melanin, melanosome, phenotype

TIME REQUIREMENTS

This lesson was designed to be completed within a single 50-minute class period but may take longer depending on the amount of class discussion. This does not include the necessary time to watch the short film.

PRIOR KNOWLEDGE

- Students should have a basic understanding of Mendelian genetics, including the terms DNA, gene, and allele, and know that variations in some traits are inherited.
- It would be helpful for students to have prior knowledge of the terms *genotype* and *phenotype* and how to apply the terms to specific examples.
- Students need a basic understanding of how adaptations arise through evolution by natural selection.

TEACHING TIPS

- Have students watch the short (19-minute) film *The Biology of Skin Color* before completing this activity. If you don't have sufficient in-class time, consider assigning it for homework. Have students write down any questions they have while they watch. Run through some of these questions as a warm-up or as a concluding discussion.
- Before beginning the lesson, consider reviewing genes and alleles with students. One way to accomplish this is to ask them in an open-ended class discussion to elicit everything they know about genes and alleles. Write everything students say so all can see the list. At the end of the brainstorming session, highlight the following overarching concepts.

- *Genes are inherited.* Genes are located on chromosomes. Chromosomes are inherited in pairs, one from each parent. Different versions of genes are called alleles. A single gene can have many alleles.
- *Genes affect phenotypes.* Genes code for proteins, which are critical for thousands of functions within cells. The expression and action of proteins result in the distinguishable traits of an organism: its phenotypes.

- The activity has been constructed to minimize copies and to promote active learning. For implementation, consider an interrupted approach of instruction or small team-based learning groups. For a discussion-based approach, figures could be projected and students could be given time to look at the data individually, then pair with another student, and then share out via whole-group discussion. Another approach could be to provide small groups of two to four students a single set of reference figures (recommend using card stock and laminating if possible so the reference sets can be reused) and allow them to have team-based discussions about the data.
- Some of the data considered in this activity is taken from zebrafish. For example, students are presented results from a study that transplanted a human skin-color gene into a zebrafish. Take the opportunity to reinforce the universality of the genetic code as evidence for common descent.
- Make sure to emphasize the critical point that while much of the data for skin color presented in this activity focuses on differences among people, most of the other genetic data show how closely related all humans are to each other and how much people have in common.
- Question 4 has students reflecting on whether allele frequency data is evidence of selection, specifically, that 96 percent of indigenous Europeans have one allele for the skin-color gene *SLC24A5*, while only 9 percent of West Africans do. If your students are familiar with genetics, you may tell them that simulations using mathematical models show that it is highly improbable (less than a 0.01 percent chance) that these differences in allele frequency could have arisen by genetic drift alone.
- Figure 4, referenced in question 8, indicates that chimpanzees and other animals all have the G allele of the *SLC24A5* gene, which would suggest that they have highly melanized skin—but certainly not all of them do (for example, chimpanzees have pale skin underneath their dark fur). If it comes up, point out to students that only a small portion of the protein is shown and other variations may exist. Further, skin color is polygenic, so variations in many other genes may be causing the difference in skin color, and there could be environmental effects as well.
- Questions 11 through 13 are about data contained in two different maps. In question 13, students are asked to synthesize the two maps to evaluate the claim that light-skinned phenotypes evolved

only once in human history. Students should conclude that the claim is not supported by the data, but that light-skinned phenotypes evolved at least twice, once among Europeans and once among Asians.

Various human populations dispersed from Africa in waves. For example, some humans migrated out of Africa and went to Asia about 35,000 years ago and evolved less melanized skin in response to lower levels of UV radiation. A different group of humans settled in Europe about 40,000 years ago and also evolved less melanized skin. Thus, both populations evolved similar traits (less melanized skin) in response to a similar environmental influence.

Both the European and Asian dispersals took place less than 50,000 years ago. Both populations came from ancestors in Africa. Thus, the move north influenced natural selection on both European and Asian populations in a relatively short amount of time. In the European population, the G allele of *SLC24A5* was strongly selected against, resulting in selection of the A allele and less pigment in skin. Because this allele remains in high frequency in Asian populations, some other gene or genes must be responsible for the lower melanin content in Asian skin. Evidence from the *OCA2* G allele frequency supports this claim because it is associated with lighter skin but is essentially restricted to individuals indigenous to East Asia, or of East Asian ancestry.

ANSWER KEY

1. The cells (melanophores) in the wild-type zebrafish are larger and contain larger and more abundant melanosomes and much more melanin compared to the melanophores of the *golden* zebrafish.
2. Answers may vary. An acceptable answer would be that the melanin color in the *golden* zebrafish melanosomes looks like the melanin from the woman with light skin.
3. The images in Figure 2 show that the size and number of melanosomes, and the amount of melanin, are different in people with different skin colors. Remind students that the film mentioned that a person's skin color is determined by the type and amount of melanin in their skin. "The reddish-yellow pheomelanin is more abundant in lightly pigmented people. More darkly pigmented people have more of the brown-black eumelanin, and the more eumelanin, the darker the skin."
4. DNA codes for a messenger RNA (mRNA), which can be translated into a protein. The mRNA is read in groups of three to code for a specific amino acid. A change in a DNA sequence will change the mRNA that gets formed, which could result in a code for a different amino acid and ultimately a different protein.

5. Yes. The differences in allele frequency for the *SLC24A5* A allele are so dramatic between West Africans (0.09) and Europeans (0.96) that selection must be at play. Almost all Europeans have the A allele, while it is extremely rare among West Africans. This is very similar to the *MC1R* variation seen (or not seen!) among individuals in these populations, which was caused by selection.
6. *Sample answer:* Not really; although people who are homozygous for the G allele have the highest amount of melanin and the darkest skin color and people who are homozygous for the A allele have the lowest amount of melanin and the lightest skin color, there is a large amount of overlap among the groups. Someone with a Δ melanin index value of 0, for example, could belong to any of the three genotypes.
7. a. other genes and environmental factors

   b. There is significant overlap among the groups. If it accounted for all of the differences, then there would be no overlap at all; each genotype would result in a unique phenotype.
8. The high degree of similarity in sequences suggests that the proteins have a similar function across the different species, and this function is critical for survival and/or reproduction. The simplest explanation for the similarity in the sequences is that the gene was inherited from a common ancestor in all the species.
9. The fact that the messenger RNA (mRNA) from the human *SLC24A5* gene restored the high melanin levels (and dark color) in the zebrafish larvae strongly suggests that the proteins have a similar function in the different species.
10. The gene must have evolved in the most recent common ancestor of all the groups on the tree, which existed at least 400 million years ago. As a result, the gene must have been present at least 400 million years ago (though it may be much older).
11. Asia, Northern North America, Australia, Europe, Southern South America. These are the areas with the lightest native skin tones.
12. Answers will vary, but most students will notice that Europe has a high frequency of the A allele but Asia does not; this will not match their predictions.
13. The data contradict the claim because clearly there is more than one "way" to get light skin. The A allele evolved and spread among European populations, but not in Asian populations, so some other genetic pathway for forming light skin must have evolved.
14. Answers will vary, but students should mention for example that Figure 4 shows that zebrafish and humans share a common genetic code and are made up of the same conserved amino acid sequences. In Figure 5, scientists were able to take a messenger RNA (mRNA) fragment from the human DNA sequence for the *SLC24A5* G allele and inject it into golden zebrafish embryos

and the zebrafish was able to translate the human mRNA into a protein. The cladogram in Figure 6 shows that zebrafish and humans share a common ancestry.

REFERENCES

This activity is adapted from an activity in the *Evolution of Human Skin Color* curriculum unit for AP Biology that is a part of the Smithsonian Institution's National Science Foundation-funded Teaching Evolution through Human Examples project (Grant No. 1119468). See http://humanorigins.si.edu/education/teaching-evolution-through-human-examples to explore the full curriculum unit.

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