



Human Skin Color: Evidence for Selection

OVERVIEW

This activity supports the viewing of the short film [The Biology of Skin Color](#). Students watch the film in segments and use real data to propose hypotheses, make predictions, and justify claims with evidence.

KEY CONCEPTS

- Within a population, heritable traits that provide a survival and reproductive advantage in a particular environment are more likely than other traits to be passed on to the next generation and thus tend to become more common over time. These traits are known as adaptations.
- Human populations living in different parts of the world have different sets of evolutionary adaptations. These include wide-ranging variations in the way people look, especially with respect to skin color.
- Evidence from different disciplines can inform what makes a human trait beneficial or harmful in a particular environment.
- Evolution involves tradeoffs; a change in a gene that results in an adaptation to one aspect of the environment may be linked to a disadvantage with respect to another aspect of that same environment.

STUDENT LEARNING TARGETS

- 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.

CURRICULUM CONNECTIONS

Standards	Curriculum Connection
NGSS (2013)	HS-LS1-1, HS-LS4-1, HS-LS4-2, HS-LS4-4
AP Bio (2015)	1.A.1, 1.A.2, 1.A.4, 1.C.3, 3.C.1, 4.C.2, SP1, SP5, SP6
IB Bio (2016)	5.1, 5.2, D.1
AP Env Sci (2013)	II.C, III.B.1
IB Env Systems and Societies (2017)	8.1
Common Core (2010)	ELA.RST.9-12.4, WHST.9-12.9
Vision and Change (2009)	CC1, CC2

KEY TERMS

evolution, folate, human evolution, melanin, natural selection, skin, ultraviolet (UV) radiation, vitamin D

TIME REQUIREMENTS

- Two 50-minute class periods or one 90-min block period.

SUGGESTED AUDIENCE

- High School Biology (General, AP/IB)
- College-level introductory biology, human biogeography, genetics and anatomy and physiology.

PRIOR KNOWLEDGE

Students should have a basic understanding of evolution and natural selection.

TEACHING TIPS

- You may want to watch each clip of the short film as a class and address any questions students might have after each viewing. Students can then work independently or in small groups to examine the figures and answer the associated questions.

- Alternatively, you may want to project the figures and examine them together as a class and then let students answer the questions independently.

ANSWER KEY

PART 1: Is There a Connection Between UV Radiation and Skin Color?

- Describe the relationship between the UV Index (the colored bar in Figure 1) and latitude (y-axis).
UV radiation is most intense near the equator and least intense toward the poles. Students may also say it is most intense at lower latitudes and increasingly intense as latitude increases.
- How do you explain the relationship between the UV Index and latitude? (In other words, why does UV intensity change with latitude?)
The answer has to do with the angle of Earth relative to the sun. Latitudes at the equator receive direct sunlight year-round. Latitudes toward the poles receive sunlight at an oblique angle, which means that the same amount of radiation is spread out over a larger area than at the equator.
- Find your approximate location on the map. What is the primary UV Index value of your state on this particular day in September?
Answers will vary depending on location. Most states in the U.S. have a UV index between 4 and 6.
- Look at the regions that receive the most-intense UV (light pink). Site a specific piece of evidence from the map that a factor other than latitude was contributing to UV intensity on this day.
The Andes and Himalayas have higher UV Index values than you'd expect, which is evidence that UV intensity increases with higher altitude. Students may also say that there might be decreased cloud cover or greater humidity. All these answers would be acceptable.
- In the film, Dr. Jablonski explains that melanin, located in the top layer of human skin, absorbs UV radiation, protecting cells from the damaging effects of UV. Genetics determines the type of melanin (i.e., brown/black eumelanin or red/brown pheomelanin) and the amount of melanin present in an individual's cells. Based on this information, write a hypothesis for where in the world you would expect to find human populations with darker or lighter skin pigmentation (i.e., different amounts of melanin).
Answers will vary, but students may predict that populations with darker skin color (or more eumelanin) would be found in regions with more intense UV radiation. Thus, populations found in equatorial areas will have the darkest skin (most eumelanin) and populations at higher latitudes will have lighter skin (least eumelanin).
- Explain how scientists could test this hypothesis.
Scientists could measure the average skin color of people at different locations throughout the world and compare that to average annual UV intensity.
- Why do you think that reflectance data are collected from a subject's inner arm?
The inner arm is not usually affected by environmental factors (e.g., it doesn't tan).
- Describe the relationship between skin reflectance (y-axis) and latitude (x-axis). Consider both the direction and steepness of the lines' slopes.
Skin reflectance increases as you move north and south from the equator. That means that skin is darker near the equator and lighter as you move north or south.
- Do these data support your hypothesis from Question 5? Justify your answer.
This graph indicates that darker-skinned individuals (individuals with more eumelanin in their skin that reflects less visible light) tend to live around the equator, where UV intensity is highest. Student responses may vary about whether the findings support their hypothesis from question 5.

10. Based on what you know about skin pigmentation so far, suggest a mechanism by which UV intensity could provide a selective pressure on the evolution of human skin color. In other words, propose a hypothesis that links skin color to evolutionary fitness.

Students may propose that melanin protects an individual from skin cancer. While this is true, it may not account for the selection for dark skin, as they will learn in the upcoming film segment. Melanin also protects circulating folate from being broken down by UV radiation.

PART 2: What Was the Selective Pressure?

11. What does it mean for a trait, such as light skin coloration, to be under negative selection in equatorial Africa? Relate negative selective pressure to what we know about MC1R allele diversity among African populations.

It means that there is selection against that trait. Researchers found that among people of African ethnicity, there is very little variation in MC1R alleles; almost everyone has the allele associated with the darker skin trait. There is selection against any MC1R alleles that do not code for darker skin.

12. Why does Dr. Jablonski dismiss the hypothesis that protection from skin cancer provided selection for the evolution of darker skin in our human ancestors?

Because skin cancer does not usually arise until after an individual's peak reproductive years. To be affected by natural selection, a trait must have an effect on an individual's ability to survive and pass on its genes.

13. Revisit your hypothesis from Question 10. Based on the information you have now, does this seem like a more or less probable hypothesis than when you first proposed it? Provide evidence to support your reasoning.

Answers will vary. If the student had hypothesized that protection from skin cancer provided the selective pressure, based on this information they might want to revisit their hypothesis.

14. Describe the relationship between folate levels and UV exposure. Use specific data from the graph to support your answer.

The group exposed to UV radiation has less serum folate. The mean concentration for the "normal" group was about 7 ng/mL and the mean concentration for the "patient" group was about 4 ng/mL.

15. Dr. Jablonski describes learning that low folate levels are linked to severe birth defects as a "eureka moment." Explain what she means by this.

Dr. Jablonski saw a connection between phenotype (skin color), environment (UV intensity), and fitness (folate levels and the risk of severe birth defects and low sperm counts). This connection provides an alternative hypothesis for the selective pressure that drove the evolution of darker skin.

16. Based on this new information, revise your hypothesis to explain the selective pressure on the evolution of human skin color.

The greater amount of eumelanin in darker skin protects folate from being broken down by UV radiation and thus increases fitness among populations in high-intensity UV areas.

17. Can the effects of UV light on folate explain the full variation of human skin color that exists among human populations today? Explain your reasoning.

Protection of folate from destruction can explain the selective pressure for the evolution of darker skin. However, it does not explain why there is variation in human skin color. What is the selection for the evolution of lighter skin?

PART 3: Why Aren't We All Dark Skinned?

18. Based on these data, describe the populations least likely to synthesize sufficient levels of vitamin D. Explain your answer with data from the figure.

Dark-skinned people are least likely to have sufficient vitamin D. They cannot produce enough vitamin D regardless of where they live. Moderately dark-skinned people can synthesize enough vitamin D if they live near the equator.

19. How do these data support the hypothesis that the evolution of lighter skin colors was driven by selection for vitamin D production?

Light-skinned individuals are better able to synthesize sufficient vitamin D, especially at higher latitudes. That means that light skin increases fitness away from the equator.

20. For a person living farther away from the equator, would the risk of vitamin D deficiency be uniform or vary throughout the year? If it would vary, how would it vary? Explain your reasoning.

UV intensity varies with the seasons. A person would be at a higher risk for vitamin D deficiency in the winter, when UV radiation is less intense.

21. Vitamin D and folate levels in the blood are both affected by UV light. Describe the predicted effects of using a tanning booth (which exposes skin to UV light) on the blood levels of these two vitamins.

Being in a tanning booth would increase the amount of circulating vitamin D and decrease the levels of folate. It can also put the individual at greater risk of developing skin cancer.

22. Based on everything that you have learned so far, provide an explanation for how the different shades of skin color from pinkish white to dark brown evolved throughout human history.

Darker skin colors evolved because they provided increased fitness in early human populations living in equatorial Africa. Darker skin protects circulating folate from being broken down. Some human populations migrated out of Africa to places where UV radiation was less intense. Here there was selection for lighter skin which let more UV radiation through for vitamin D synthesis. Thus the evolution of variation in human skin color is due to the balance between needing protection from UV to maintain circulating folate levels and needing some UV to prevent vitamin D deficiency.

PART 4: How Does Recent Migration Affect Our Health?

23. Describe the trends visible in the data. Which subpopulation (gender, race/ethnicity) is at the greatest risk for vitamin D deficiency? Which subpopulation is at the least risk for vitamin D deficiency?

Non-Hispanic blacks have the lowest mean vitamin D levels overall and among males and females living in the United States. Non-Hispanic whites have highest mean vitamin D levels overall and among males and females. The subpopulation at the greatest risk for vitamin D deficiency is non-Hispanic black females. The subpopulation at the least risk for vitamin D deficiency is non-Hispanic white males.

24. What is one of the consequences of recent human migrations on human health?

One consequence is that people's skin color may not be a good match for the UV radiation intensity where they live.

REFERENCE

This lesson was adapted from the case study "The Evolution of Human Skin Color" by Dr. Annie Prud'homme-Généreux published by the National Center for Case Study Teaching in Science. http://sciencecases.lib.buffalo.edu/cs/collection/detail.asp?case_id=584&id=584

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