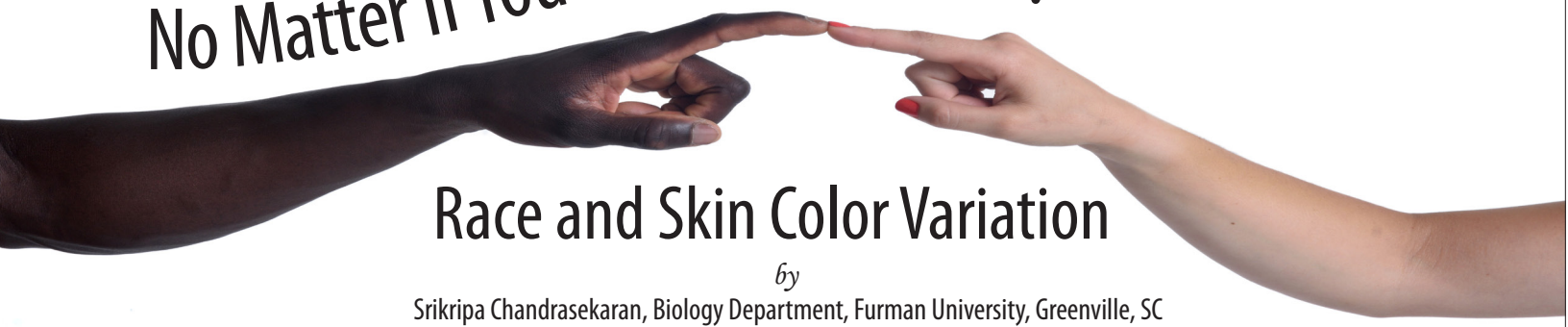
NATIONAL CENTER FOR CASE STUDY
TEACHING IN SCIENCE

No Matter If You're Black or *White*:



Race and Skin Color Variation

by
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Part I – Perceptions of Race

This case study will take you through a narrative between a father and a son as they discuss the genetic basis of skin color evolution. While the focus of the case is on skin color variation, we will also discuss other features commonly associated with race. Please take about 5–10 minutes to answer the following questions. We will revisit these questions once we have discussed and completed all other parts of the case.

Questions

1. How would you define race?

2. List as many racial groups as you can. Then choose three of them and write the names of those racial groups in the table below. Now brainstorm all characteristics that are usually attributed to those racial groups and write them in the table. At this point don't evaluate whether you think they are accurate or fair, just list what comes to mind. Mark characteristics that are external or visual traits with an *E* and any internal or non-visual characters with an *I*.

   Note: Please be respectful as you complete this task. Be aware that any intentional shaming of a race or targeted bullying of a person will not be tolerated and appropriate measures will be taken.

Racial Group	*Distinguishing Feature*	*External Trait (E) or Internal Trait (I)?*

Part II – Skin Color

Jake stared at the rows and rows of fish in his father's laboratory. Looking at the multiple tanks of zebrafish and wondering about the differences between them was Jake's favorite pastime when he was at work with his dad. Today Jake was particularly excited to see a whole section in the lab devoted to a new type of fish. They looked very different from the ones he had seen before. While fish in the other tanks had black stripes on a translucent body, these fish were all golden, with no trace of black pigmentation. *Perhaps they're a different species*? was Jake's first thought. He was learning the meaning of the word "species" in school and knew that there could be many related species of animals that might still share common physical features. Excited, he went off in search of his dad, who was in a different room, hunched over a microscope observing some fish larvae.

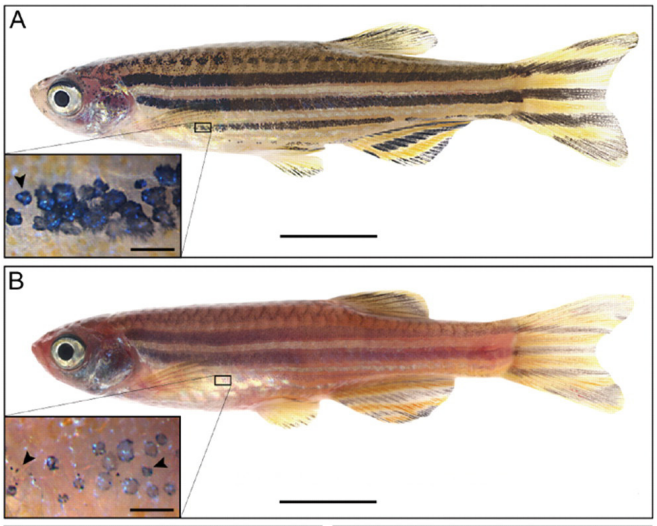

Figure 1. Panel A is a picture of a black-striped zebrafish with more melanocytes. Panel B shows a golden zebrafish with fewer melanocytes. *From:* Lamason, R.L., *et al.* 2005. SLC24A5, a putative cation exchanger, affects pigmentation in zebrafish and humans. *Science* 310(5755): 1782–6. Reprinted with permission from AAAS.

"Dad, what are the golden fish? What are they called?"

"They're zebrafish, just like the others," said his father with an amused smile.

Jake was confused. "How is that possible, Dad? They look different; not just a little bit, but *really* different from the normal zebrafish."

His father stepped away from his microscope, took off his lab coat, and sat down next to his son. "Why do you think these aren't normal?"

"Well, for one thing, they don't have the dark stripes like the others," said Jake. But even as he said this, he was already thinking about other aspects of the fish, not just the color. "Where did you get these fish from? What part of the world do they come from?"

His father replied, "These fish are not found in nature; instead they were created in the lab by scientists. But they are no different from the zebrafish with the black stripes in their ability to breed, swim, or forage for food. Nor do they differ in the type of organs that they have within them and in the way these organs function."

"But they are golden; they *have* to be different in some way," persisted Jake.

Questions

1. What do you think is the difference between the golden and black-striped zebrafish?

2. Can you think of any other species in the animal kingdom that exhibit variations in coat color or skin color? List examples.

3. In Part I of the case study, was skin color one of the characteristics important in characterizing different racial groups? List all the differences that you discussed in the species *Homo sapiens.*

4. Name factors that you think account for skin color differences between human beings.

Part III – Skin Color and Sunlight

Jake and his father looked back to the fish for a moment, watching them dart about the tank, before they resumed the conversation. "What's your skin color, Jake?"

Jake's father was African-American and Jake's mother was white-American, and while Jake was darker than his mother, he was a little lighter than his dad.

"It's somewhat brown; it gets darker in the summer," said Jake.

"What about me and your mom?" asked Dad.

Jake took a moment before he answered this one. "Well, you both have different skin colors," he said slowly, as if this was the first time he was really paying attention to this fact.

"But do you think me and your mom are different, as people, because of that?" asked Dad.

"Well, you like science, but Mom's a singer," said Jake.

"Hmm—my brother, your Uncle Roger, has my skin color, but he likes to sing, and he's good at it—just like your mom."

Jake fidgeted a little, and then brightened. "I know of a difference—Mom gets all red and freckly when we go to the beach, but you don't—neither does Uncle Roger."

"Now we're getting somewhere," chuckled Dad.

"You see, having a certain shade or type of skin color really doesn't have anything to do with personality, or likes and dislikes, or abilities. Mom can sing well, not because of her skin color, it's just her talent; some people are good at singing, and some people are better off being scientists," said Dad, with a hint of pride in his voice.

Questions

1. Humans tend to link skin color with race. What do you think accounts for differences in skin color between different races?

2. Why do you think Jake's mom got freckles and red skin at the beach, and Jake's dad did not?

3. Is there a particular trait or characteristic that you would expect Jake's dad to have that Jake's mom lacks, simply based on their skin color? If so, what would that be? Why would you make such an assumption? What other characteristics do you associate with race?

Part IV – Melanin and Vitamin Synthesis

Jake's father was also very proud of his son's analytical skills. Since he was a research geneticist, he wanted to educate his son about what was known about the genetics of skin color, and Jake's incessant curiosity made that a lot easier.

"I get that skin color isn't connected with singing," said Jake. "But why does Mom get freckles and you don't? How is it that at the beach my skin gets darker?"

"It's because of a pigment called melanin that I happen to have more of; that's what makes me darker. Your mom happens to have less of it, making her skin lighter."

"Why do you have more melanin than Mom?" asked Jake.

"The *real* question is not so much why I have more melanin, but why my *ancestors* needed more melanin, and why your mom's ancestors didn't. By now you've probably realized it must have something to do with the sun. You see, modern humans, *Homo sapiens,* first evolved in sub-Saharan Africa, a land with savannahs or open grasslands, right on the equator, which gets lots of direct sunlight, extremely bright and very hot. We all evolved from creatures that had plenty of hair protecting them from the harsh sunlight. Do you know why we needed to protect ourselves from sunlight?"

Jake had heard of ultraviolet (UV) radiation from the sunlight being harmful, and which could cause skin cancer. "I know all about UV and sunlight and skin cancer."

His dad smiled. "True, we need to protect ourselves from UV radiation from the sun, but not just for preventing skin cancer, but also to retain a particular vitamin called folic acid, or vitamin B9, in our body. When the first human beings emerged in sub-Saharan Africa, shedding off all hair, they needed a way to protect them from harsh UV from the sunlight, which was breaking down all their folic acid. Having the pigment melanin helped them, as it can prevent or block excess UV from being absorbed by our skin. That way our early ancestors could survive. Our first ancestors all adapted to be darker than apes. Devoid of all the hair, apes are actually quite fair, you know."

"Since the sunblock you and Mom make me spray on at the beach actually protects me from UV radiation, why don't you make me wear it all the time, like constantly, even when I'm at home? That way I won't get any UV radiation from any sun, anywhere."

"Well, it's not that simple, Jake. While we need to protect ourselves from excess UV, we actually need sunlight to make another vitamin, called vitamin D. Vitamin D is needed to absorb calcium, which makes strong bones and teeth."

Jake was now puzzled. "So what did our ancestors do? Their melanin made them dark, so did they all have weak bones?"

"No Jake, the key is location. Our ancestors in Africa had enough sunlight to allow for vitamin D synthesis, but they also had enough melanin to block too much UV so that they could retain their folic acid. That's how they could survive as populations and a race could be established."

This was the coolest story ever, thought Jake. But it only seemed to make things more complicated. "So those were your ancestors, people living in Africa, since you have dark skin. What about Mom's ancestors, where did they come from?"

"Ah, well the story doesn't just end there in Africa. When populations of people started inhabiting sub-Saharan Africa, their curiosity, desires, and need for more space drove them to migrate to other lands. They started drifting further away from the African equator in groups. After thousands of years, a subset of those populations made their way to Europe, some to the Middle East, and some to Australia."

Jake had a mental image of dark-skinned people moving in groups to different places, scouring various lands, just like a classic adventure. "So, if they were all dark-skinned, how come the people in Europe and Australia are light-skinned?"

Dad smiled; his son was asking all the right questions.

"First, let's correct your misunderstanding about Australian inhabitants. One tends to forget that the original inhabitants of Australia are the Aborigines, who have very dark skin tones and migrated to Australia about 60,000 years ago.

Australia gets lots of sunlight and UV radiation. The light-skinned Australians you are talking about are Europeans who landed there just a few centuries ago. But evolution of skin color happened over several thousands of years."

"Let's talk about your mom next. Her ancestors reached Europe, and judging by her skin color, freckles and the red hair and all, they probably landed up in Northern Europe."

"Grandma said her folks were from Ireland."

"There you go," said Dad, "a place quite different from Africa. When early humans reached Europe, their bodies had to change to absorb enough sunlight. They were not getting enough sunlight away from the Equator, so they needed to get rid of all that extra melanin so they could absorb most of the sunlight that Northern Europe received."

"How did they do that?" wondered Jake. "I mean, have scientists figured out how melanin decreased in migrants from Africa to Europe?"

"Well Jake, they're working on that question. A group of scientist used zebrafish to identify a gene that is involved. You know that I use zebrafish to study things that happen in humans because they are easier to work with while still being very similar to humans at the cell level. That's why scientists are creating and studying zebrafish that have different levels of melanin in them."

Questions

1. Why would a lighter-skinned person have lower tolerance to excess sunlight than a darker-skinned person?

2. Would a darker-skinned person have a harder or an easier time making vitamin D? What about folic acid?

3. How do you think early humans in sub-Saharan Africa "adapted" to have darker skin color?

4. How do you think African immigrants to Europe and Australia tackled sunlight by "gaining a lighter skin tone"? Make a scientific guess.

5. What is the similarity between the black-striped zebrafish and early Africans, and the golden zebrafish and Northern Europeans?

6. How would you define a "gene"? Do you think genes played a role in transitioning from a darker to a lighter skin color? If yes, explain how.

7. How do you think scientists created "golden zebrafish" from the original "black-striped zebrafish"?

Part V – Genetics and Skin Color

Dad was pleased with Jake's curiosity, and had to make a conscious effort to stop getting ahead of himself while unfolding this story.

"You're on the right track, Jake, but remember that such a change can't happen overnight. For instance, I can't move to Iceland and decide to get rid of melanin to become lighter."

"Then does this happen without one's knowledge, some kind of an adaptation to a new environment?" Jake had been imagining his glorious ancestors as superheroes who could change their skin color in a flash.

"Yes, it's an adaptation facilitated by changes in DNA. What do you know about DNA, Jake?"

Jake had learned in school that the nucleus in the cell contains the blueprint of life, or DNA. He was also familiar with "genes" as stretches of DNA constituting a code, which determined the traits of an organism.

"It's the genetic material I have that governs my features and characteristics. I got it from you and from Mom—which is why I'm neither as dark as you are, nor as light as Mom," Jake finished slowly.

"That's right, Jake. The populations which migrated to Europe from Africa, and even the early humans in Africa, all had to have changes selected for in their genetic code. Populations who survived in Africa were selected because of changes in codes within their genes responsible for making more melanin, called DNA mutations. Among the populations that migrated North, mutations in genes, which allowed less melanin to be produced, survived.

"So the pattern of the genetic code making melanin had to be altered or mutated to accommodate the change in skin color," reasoned Jake. "But does the same gene make melanin in zebrafish and humans?"

"Not quite. But we share an *early* ancestor with zebrafish, an ancestor that existed even before our pre-human ancestors appeared. They lived in the water and developed a backbone, which set them apart from other sea creatures at the time and was one of the things that allowed some of their descendants to eventually migrate to land. That is why we share similarity, or homology, in parts of different genes with these organisms," explained Dad patiently.

"So, these genes look similar and make melanin the same way in fish and humans?"

"Yes, they have a similar arrangement of the chemicals that make up the code I was telling you about, and the way melanin is made is also similar in fish and humans," Dad explained.

Questions

1. What is a DNA mutation?

2. How do you think DNA mutations would have regulated skin color in different populations? Compare sub-Saharan Africans and Northern Europeans.

3. How can scientists employ organisms like zebrafish to unearth the mystery of skin color variations in humans?

Part VI – Simple vs. Complex Traits

"So, what is this gene that codes for skin color? Is it the same gene that when mutated was responsible for creating the golden zebrafish?"

Dad had been waiting for this question to come along. "A ground-breaking study from a few years ago identified a gene involved in skin color regulation to be *SLC24A5*, which goes by the same name in fish and humans, and shares homology between fish and humans.

"So that's the gene that controls skin color?" asked Jake.

"Not *the* gene, but *one* of the genes involved. There are multiple biochemical reactions responsible for producing melanin, and several enzymes participate in this process. Each of these enzymes has a unique gene coding for them. In addition to melanin formation, other genes govern distribution of melanin. Hence, we require multiple genes governing melanin synthesis and distribution. More genes are involved in regulating more complex traits."

"So what is an example of an even more complex trait than skin color?" asked Jake.

"Do you remember what we were talking about that your mom and Uncle Roger had in common?"

Jake thought a second and then announced, "Musical talent!"

"Yes, musical talent is a very complex characteristic that involves physical, mental and emotional skills. In the realm of genetics there are traits that are influenced by a small number of genes that have very large contributions, like skin color. True, the adaptation to have different skin tones is a result of exposure to sunlight, an environmental factor. With skin color, you have an example of a single environmental factor that influences a subset of genes. However, it has been estimated that there are way more genes that are associated with intelligence, athletic ability and other complex behaviors, including musical abilities. Plus the contribution of environment to more complex traits is also varied. For instance, a culture that promotes musical skills may encourage more people to become musicians, or a very likeable music teacher may inspire young students to pursue music. However, not everyone exposed to the same environment will become musicians. So we are talking about several genes and many complex environmental factors. Hence there is a great diversity of different traits that may never be subject to evolutionary changes.

"Remember that all humans came out of populations in Africa and moved away and formed smaller populations. So while there has been the need and also enough time for skin color to change during that movement, the more complex behaviors may simply not have been subject to the same level of selective pressure for survival. Hence, as a species, we may not have found the need to be selected for musical abilities with changing environment. To complicate the situation even more, do people stay in the same place as they were born today compared to hundreds of years ago?"

"I think I understand," said Jake. "While characteristics like skin color can be associated with race, more complex characteristics such as musical ability, intelligence or athletic performance cannot. There just hasn't been a need for races to have fixed complex traits or not enough time has passed for us to know."

Questions

1. Several genes are responsible for regulating melanin synthesis. Scientifically reason as to why multiple genes might be involved in a single ultimate outcome, i.e., regulating skin color.

2. Based on what you have understood about skin color from this case study, draw some conclusions as to how DNA mutations could benefit the establishment of races across the globe. Focus on skin color adaptations.

3. Explain the science behind Jake's final statement. Make an argument for or against this statement.

Concluding Activity

1. Go back to the table in Part I that you filled in and for each of the traits you identified consider whether it would be influenced by genetics; if so, would it most likely be influened by a few genes or by many? Then consider how much environment or culture would play a role in the trait. Finally choose one visual external trait and one nonvisual internal trait. For homework investigate the genetics of each of these and be prepared to discuss them at our next class meeting.

2. How could you determine whether skin color is correlated with one of the traits that you associated with a particular racial group? What evidence would you look for?

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