WHY HUMAN SKIN COMES IN COLORS

by Nina G. Jablonski

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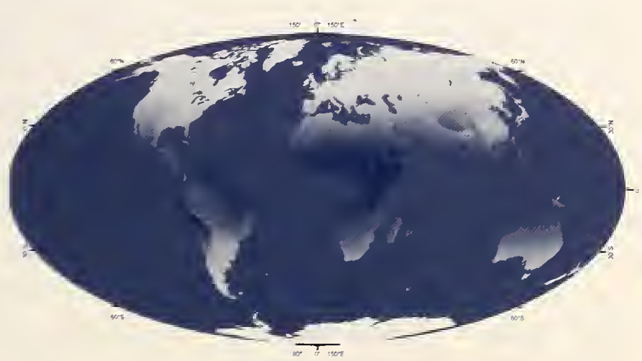
Skin pigmentation provides one of the best examples of evolution by natural selection acting on the human body. The fact that skin color has been so responsive to evolutionary forces is fascinating, and one that is important for modern human societies to understand. Similar skin colors – both dark and light – have evolved independently multiple times in human history. When we think of how races have been defined in the past using skin color, we can immediately see the problem. When the same skin color has evolved many times independently in different places, its value as a unique maker of identity is eliminated and the race so defined is rendered nonsensical. We are all "hue-mans"!

As modern humans moved around the world in greater numbers and over longer distances in the time between 50,000 and 10,000 years ago, a lot of "fine tuning" occurred in the evolution of skin pigmentation. As populations moved to parts of the world with different UVR levels, they underwent genetic changes that modified their skin pigmentation. As people moved into the Americas from Asia, for instance, we see evidence that some populations entering high UVR environments underwent genetic changes which made it possible for them to tan easily. Tanning is the ability to develop temporary melanin pigmentation in the skin in response to UVR and has evolved numerous times in peoples living under highly seasonal patterns of sunshine (Jablonski and Chaplin 2010). When we look at a map of predicted human skin pigmentation, we find that all people are varying shades of brown. The intensity of their brownness and their ability to tan is related to the UVR in the place where their ancestors came from.



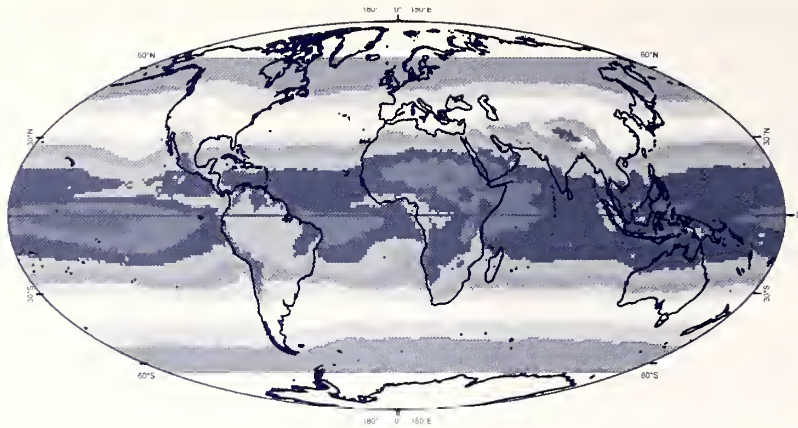
Map of human skin color predicted by multiple regression model. Map by George Chaplin.

In the last 10,000 years, we have gotten better and better at protecting ourselves against the extremes of UVR by cultural means. Sewn clothing and constructed shelters now protect us from strong sunlight and augment the protection afforded by natural melanin pigmentation. In far northern environments, diets composed of vitamin D-rich foods like oily fish and marine mammals supplement the vitamin D we can make in our skin under low UVR conditions. The major problem we face today is that we are able to travel so far so fast. Many people today live or take vacations far away from the lands of their ancestors. This means that, often, our skin color is mismatched to the UVR levels we are experiencing. Darkly pigmented people living in low UVR environments and people working indoors all of the time are at high risk of developing vitamin D deficiencies. Lightly pigmented people living in high UVR environments are at high risk of developing skin cancers. We must recognize these issues in order to avoid major health problems today.

Ultraviolet Radiation and Skin Color

Human skin is mostly hairless and comes in a range of colors. Some people have very dark skin that is almost black, while others have very pale skin that is nearly white. Most other people have skin that has a color somewhere in between. Skin color is remarkably variable in people from place to place, and differences in skin color began to be noticed thousands of years ago when people started traveling widely and engaging in long-distance trade. Observers noted that people who lived under intense sun close to the equator had dark skin and those who lived under weaker sun away from the equator had light skin. But why?

Many centuries ago, some early Greek and Roman philosophers speculated that skin color and other features were associated with climate. According to them, dark skin tones were produced by excessive heat and light



Annual average ultraviolet radiation at the earth's surface, based on data from the NASA Total Ozone Mapping Spectrometer 7 Satellite. Map by George Chaplin.

tones by excessive cold. By the mid-1700s naturalists like the American Samuel Stanhope Smith observed that skin pigmentation showed a pronounced gradient according to latitude, from dark near the equator to light toward the poles. He related this mainly to differences in sunshine experienced by people at different latitudes: "This general uniformity in the effect," Smith wrote, "indicates an influence in climate, that, under the same circumstances, will always operate in the same manner." But was it the heat caused by the sun or something else in the sunshine that skin was responding to?

By the middle of the 20th century, observers determined that skin color was most strongly correlated with ultraviolet radiation (UVR) from the sun. UVR, in fact, accounts for over 87% of the variation in human skin color. So how can it be shown that human skin pigmentation is an actual evolutionary adaptation to UVR? In evolutionary terms, an adaptation is a characteristic of an organism that allows it to reproduce more successfully under certain environmental conditions than other organisms, which do not have the characteristic. We first need to understand exactly what UVR is and what it does.

UVR's Harmful Effects

UVR is a highly energetic and invisible form of solar radiation that is capable of causing a lot of damage to living organisms. Life on earth is mostly protected from damaging UV rays by our atmosphere, but some UVR still gets through and has powerful biological effects. UVR damages DNA, and this activity can eventually cause skin cancer. Skin cancer is bad, but it is rarely fatal and it mostly affects people after their child-bearing years.

Other harmful effects of UVR have potentially much greater effects on reproductive success. Some wavelengths of UVR break down other important biological molecules, such as some forms of folate in the body. Folate is a B vitamin, which is needed to produce DNA and support cell metabolism. We normally get folate from green leafy vegetables, citrus fruits, and whole grains in our diet. Without adequate folate, we can't make sufficient amounts of DNA to maintain normal levels of cell division in our body. Cell division is needed to maintain the function of organs and tissues in our body and is especially important in tissues with a high turnover, like the lining of the gut and the lining of the mouth. Cell division also occurs rapidly in the early embryo and in the production of sperm. During the first few weeks of embryonic development, rapid and precise cell division leads to the establishment of the basic body plan of the body and the development of the early nervous system and circulation. If cell division is slowed or inhibited at this critical time, serious or even fatal birth defects can occur. Protection of the body's folate supplies is therefore important for successful reproduction (Lucock 2000). And successful reproduction is what evolution is all about. How then, was this ensured?

Natural Sunscreens

When it comes to protection against harmful UVR, many biological systems have evolved natural sunscreens. Most natural sunscreens are special molecules which reduce UVR damage by absorbing or scattering UV rays. The pigment called melanin – and especially the most common type in human skin called eumelanin – is one of the most effective natural sunscreens. Eumelanin is intensely dark and has the ability to absorb potentially damaging UVR as well as neutralize harmful chemical byproducts caused by UVR exposure.

Evolution often works by modifying biochemical pathways or structures that are already in existence. Ancestors of the human lineage had the ability to produce eumelanin in the naked skin on their faces and hands when they were exposed to UVR. When our ancestors lost most of their body hair, there was evolutionary pressure to protect exposed skin from the harmful effects of UVR (Jablonski 2004). The solution to this problem was to make dark pigmentation permanent. This was accomplished by natural selection. Individuals who carried the genetic changes or mutations leading to the production of more protective eumelanin pigment left more offspring behind than those who didn't. Genetic studies have shown that some of the most important changes occurred in a gene called *MC1R*. This gene regulates the production of a protein called the melanocortin-1 receptor that plays an important role in normal pigmentation. All modern humans originated from darkly pigmented ancestors who evolved permanent eumelanin pigmentation in their skin to protect them from the UVR-rich sunshine of equatorial Africa.

Vitamin D Benefits

When some of our modern human ancestors moved away from the most intensely sunny parts of Africa into southern Africa, Asia, and Europe, they encountered lower levels of UVR. This meant that they faced less potential damage to their bodies from harmful radiation, but there was also a downside. UVR is not a universally bad thing: The one important good thing it does is to initiate the process of making vitamin D in the skin. Vitamin D helps us to build and maintain a strong skeleton by regulating the absorption of calcium from the foods that we eat. Without enough vitamin D, bones don't develop properly and are weak. Vitamin D also helps to maintain the health of our immune systems. If we don't get enough vitamin D, our bodies can become physically weak and susceptible to disease. Only certain wavelengths of UVR are capable of starting the process of making vitamin D in the skin, and these are in the UVB range. The equator receives a lot of UVB year round, but north and south of the tropics (23.5° N and 23.5°S) there is much less and it falls in a highly seasonal pattern. And dark skin with lots of sun-protective melanin slows down the process of making vitamin D in the skin. So these circumstances posed another challenge to our ancestors. How could vitamin D production be maintained in people who were living under low UVB conditions? The answer is – with lighter skin (Jablonski and Chaplin 2000; Chaplin 2004).

The Role of Depigmentation

Light skin is actually depigmented skin. When people started moving away from very sunny places with high levels of UVB to less sunny places with lower levels of UVB, those individuals who had lighter skin were able to stay healthier and leave more offspring. Evolution was at work again. The individuals with lighter skin had specific genetic mutations that resulted in their producing less eumelanin and so having less natural sunscreen in their skin. These new patterns of genetic variation were very successful. We see evidence, in fact, that "selective sweeps" – greatly accelerated periods of evolution by natural selection – led to genes for lighter skin becoming fixed in the population over the course of just a few thousand years.

One of the most interesting and important things about the depigmentation process is that it didn't happen just once. Genetic evidence shows that the ancestors of modern western Europeans and the ancestors of modern eastern Asians underwent independent genetic changes leading to the evolution of lighter skin (Norton, Kittles et al. 2007). These changes involved different genetic mutations, which then were favored by natural selection. In other words, depigmentation evolved independently in both of the lineages of modern humans that began to inhabit higher latitudes of the Northern Hemisphere. We also know from the examination of ancient DNA that loss of skin pigmentation as a result of natural selection occurred in our distant, extinct cousins, the Neanderthals (*Homo neanderthalensis*), who inhabited much of eastern Europe and the region around the Mediterranean during the last ice age (Lalueza-Fox, Rompler et al. 2007).

Study of the evolution of skin pigmentation is an important part of the study of human diversity. Different degrees of skin darkness and lightness evolved multiple times in humans as we have dispersed to different places and adapted to local environmental conditions. Today, people are moving over much greater distances, much faster than ever before, and our adaptations are mostly cultural and social, not biological. These cultural and social adaptations have been imperfect, and we still have much to learn about how we as individuals and as human societies can stay healthy in environments far distant from our ancestral homelands.

Further Reading

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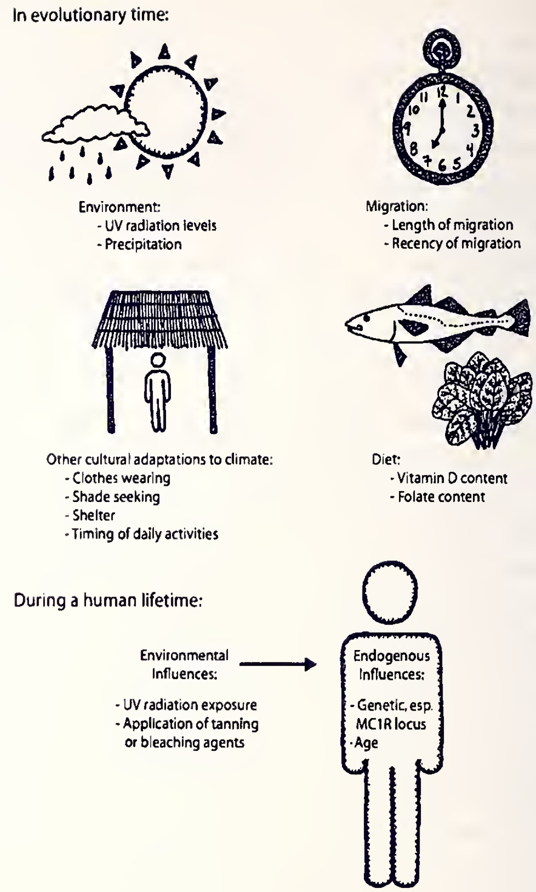

Many factors affect human skin pigmentation and operate over different time scales. As people move around more rapidly today, our adaptations to different environments are mostly cultural, not biological. Figure by Jennifer Kane.

[This article is based on an essay written for a forthcoming book *RACE: Are We So Different?* to be published by the American Anthropological Association as a companion volume to the *RACE* exhibit.]

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