Differences in skin color are intriguing, but few of us have a clear idea what causes the variations. Scientists have long known that human skin color varies with the amount of exposure to the sun's ultraviolet (UV) radiation, but until recently they had not identified the process of natural selection that actually influences this phenomenon. Now the work of scientists Nina Jablonski and George Chaplin, of the California Academy of Sciences, casts a new light on race concepts by relating skin-color variation to evolution and reproduction.

**Folate and the Sunshine Vitamin**

Melanin, the brown pigment in the skin, acts as a natural sunscreen. It protects against UV, and populations in the tropics are darker skinned since there is more sunlight where they live. UV ages the skin, causes skin cancer, and—most significant to Jablonski and Chaplin's work—breaks down folate, essential vitamin B needed for cell division and producing new DNA.

Pregnant women in particular require large amounts of folate to support rapid cell division in the embryo. Women of reproductive age are advised to take folate supplements to prevent serious birth defects such as spina bifida. So if a higher melanin level is so beneficial, why isn't everyone dark-skinned?
In their analysis of human evolutionary history, Jablonski and Chaplin concluded that modern humans most likely evolved in the tropics, where they were exposed to high UV levels. But as they moved into regions away from the equator, where UV levels are lower, humans became fairer so as to allow enough UV radiation to penetrate their skin and produce vitamin D, the "sunshine vitamin," also obtained from eating fish and marine mammals. Vitamin D is essential for maintaining healthy blood levels of calcium and phosphorous, and thus promoting bone growth.

Skin color, according to Jablonski and Chaplin, basically becomes a balancing act between the evolutionary demands of photo-protection and the need to create vitamin D in the skin.

But things aren't always what they ought to be. That is the case with Eskimos and other inhabitants of northern Alaska and northern Canada. "Looking at Alaska, one would think that the native people should be pale as ghosts," Jablonski says. One of the reasons they're not is that these populations have not lived in the region very long in terms of geological time. But more importantly, their traditional diet is rich in fish and other seafood. They've consumed huge doses of vitamin D, so they haven't had to undergo the same reduction in pigmentation that would otherwise be required at such high latitudes. "What's really interesting is that if these people don't eat their aboriginal diets of fish and marine mammals, they suffer tremendously high rates of vitamin D-deficiency diseases such as rickets in children and osteoporosis in adults," Jablonski says.

A similar problem occurs when dark-skinned people move to northern latitudes. "For years people couldn't understand why dark Indians and Pakistanis living in northern England suffered from vitamin D-deficiency diseases," Jablonski says. "Now it has become clear that the natural sunscreen in their skins wouldn't allow them to synthesize enough vitamin D from the sunlight." Cultural factors exacerbated the problem, such as the wearing of veils by some Muslim women. "It's a real detective story," she adds.

Race: A Manmade Grouping
One of the important implications of Jablonski and Chaplin's work is that it underlines the concept of race as purely a social construct, with no scientific grounds. DNA research has shown that genetically all humans, regardless of skin color and other surface distinctions, are basically the same. In an April 2001 article titled, "The Genetic Archaeology of Race," published in the Atlantic Monthly, Steve Olson writes "the genetic variants affecting skin color and facial features are essentially meaningless —they probably involve a few hundred of the billions of nucleotides in a person's DNA. Yet societies have built elaborate systems of privilege and control on these insignificant genetic differences."

Jablonski and Chaplin view their work as relevant to how we get along with each other. According to Jablonski, many people are "happy and relieved" when they hear about this research. "All of a sudden their own coloration isn't something that was just handed to them," she says. "It isn't a social stigma. It's something that evolved in their ancestors for a good set of biological reasons. And it takes the wind out of racism and bigotry. It's a fairly simple and beautiful explanation for one of the most obvious characteristics that distinguishes humans."
Meet Dr. Nina Jablonski, anthropologist at the California Academy of Sciences

Evolution of Human Skin Color

It appears that our earliest modern human ancestors (Homo sapien sapiens), who lived 100 - 150,000 years ago in eastern Africa, had dark skin to protect them against the deleterious effects of ultraviolet radiation. Many scientists used to believe that dark pigmentation evolved in Africa as a "sunscreen" to protect against skin cancer. However, this could not be the only selective pressure since most deaths from skin cancer occur only after reproductive age. According to the most recent theory, different skin colors evolved to ensure reproductive success by regulating the production of two critical vitamins.

Ultraviolet radiation (UV) catalyzes the synthesis of vitamin D, which is required for absorption of calcium and development of the skeleton. Vitamin D deficiency can lead to rickets, a crippling bone disease. But overexposure to UV radiation will break down vitamin B folate (folic acid), which is necessary for fetal neural development and fertility. Anthropologist Nina Jablonski theorizes that dark skin evolved near the equator. There, UV radiation penetration is high enough to stimulate vitamin D production while the dark skin protects against the breakdown of folate. Light skin evolved when early humans migrated to the high latitudes where UV radiation is much lower. The amount of melanin gradually decreased to facilitate vitamin D synthesis under low UV conditions. Today, as a result of recent migrations, many individuals do not live in the climate for which their skin is adapted. Dark-skinned people in high latitudes can get their vitamin D from sources like fish, while light-skinned people in the tropics can protect against folate breakdown by covering up with clothing.

Science Interchange reporter Stacey Fowler recently interviewed Nina Jablonski, co-author (with George Chaplin) of a paper entitled "The Evolution of Human Skin Coloration," which will be published in the July 2000 edition of the Journal of Human Evolution. Here are some highlights from the interview:

Dr. Jablonski, could you tell me about the recent research you conducted on the evolution of skin pigmentation?

Skin coloration is one of the most obvious ways in which humans vary from one to another. And so it is of obvious interest to everybody because you look at one another and you say, "Oh, that person's a different color than I am." What I've been interested in is what the evolutionary history of our skin coloration is.
And what is some of that history?

Well, skin is one of those things that isn't preserved in the fossil record. It's not like bones. And so, reconstructing the history of skin, whether we're talking about its sweating abilities or its color, is difficult and has to be done through indirect investigation. However, we've been able to shed some interesting light on this phenomenon by looking at some of the physiological characteristics of skin. For instance, skin--especially dark-colored skin--is particularly good at screening out ultraviolet radiation, and we consider it to be highly adaptive screening out ultraviolet radiation, and we consider it to be highly adaptive. It turns out that ultraviolet radiation not only causes skin damage, like wrinkling and things like that, but also it has much more sinister effects. It actually can cause the breakdown of some crucial metabolites, or nutrients, in our blood capillaries such as the nutrient folate, which turns out to be critical in normal development. So, if you get too much ultraviolet radiation through your skin, the folate in your blood can actually be broken down by the radiation. And this can have many deleterious effects. And so, having a natural sunscreen in your skin helps to prevent that breakdown of folate.

On the other hand, if you are living in areas where ultraviolet radiation is particularly low, such as areas near the Arctic or Antarctic circles, or actually as you move out of the tropics, you have another problem to deal with. The skin is the place where Vitamin D is synthesized using ultraviolet rays to catalyze the reaction. So you need some ultraviolet light to penetrate the skin in order to make Vitamin D. Vitamin D turns out to be critical to your body because it provides the means whereby you absorb calcium from your food in your digestive system. So if you don't have Vitamin D, you can't absorb calcium from your food and you can't build strong bones.

Making the proper skin color turns out to be a balancing act between having enough natural sunscreen to prevent a lot of damage to the contents of the blood system. On the other hand, you have to let in enough ultraviolet light to still permit the formation of Vitamin D in your skin. So people who live in conditions of lower ultraviolet light, away from the tropics and toward the poles, have to have lighter skin than those people who live closer to the tropics or closer to the equator. Those people really have to have darker skin to protect themselves from ultraviolet light.

Those of us who are sort of in the middle, like inhabitants of most of North America and most of Eurasia, have to have skin that is capable of some level of tanning so that we can protect ourselves from lots of ultraviolet radiation in the late spring and summer. But we can de-pigment ourselves as ultraviolet light becomes less intense in the winter so we can take advantage of the ambient ultraviolet radiation that does exist.

How did skin coloration evolve as our ancestors radiated out from Africa to inhabit other continents?
The history of our own species, Homo sapiens, in terms of skin is a fascinating history. If we look at our earliest Homo sapiens ancestors (about 100 to 150 thousand years ago in eastern Africa), we can reconstruct that those ancestors would have had dark skin to protect themselves from the deleterious effects of ultraviolet light. But those populations began to move out of the tropics and colonize areas that were much less intense in terms of ultraviolet light. As they first moved into the Circum Mediterranean, Western Asia, then onward into Eastern Asia, Europe, Southeast Asia, Australia and so forth, these populations would have to undergo some depigmentation in order for them to be able to synthesize enough Vitamin D in their skin.

Imagine, for instance, the populations that went from East Africa and slowly made their way into central Asia or northern Asia. These populations would have had to undergo quite extensive depigmentation in order to maintain enough Vitamin D synthesis potential in their skin. But imagine some of these populations that were eventually on their way into Southern India, or what is now Sri Lanka. Those populations that also originated, ultimately, in eastern Africa would have undergone some depigmentation as they moved out of the most intense UV of the tropics, and then they would have undergone repigmentation as they moved down, back into the intense ultraviolet regimes of southern India and Sri Lanka.

This same pattern of intense pigmentation to start out with, followed by a period of depigmentation perhaps 10, 20, or 30 thousand years long, followed again by another period of repigmentation, I think has been followed by many different populations as they have gone from one part of the world to another. It's not a deterministic process; it's simply an adaptive process as these populations have changed from one area with one particular ultraviolet light regime to another.

**Are we seeing any evidence that skin pigmentation is changing in response to current environmental factors?**

One of the most interesting changes that we are seeing today, of course, is that people are moving from one part of the world to another. You have lots of very light-skinned European people who are moving into areas where there's a lot of ultraviolet light -- either to the southern United States or people moving from England to northern Australia, for example. And so we're seeing people who are inherently well-adapted to low levels of ultraviolet light moving into areas where there's a lot of ultraviolet light, causing them to suffer tremendously from ultraviolet light damage to their skin.

On the other hand, we have an interesting phenomenon with people who are moving from where ultraviolet light is very intense, such as Africa and India, into regions where it's less intense, such as the United States or the UK. For instance, these days there are a lot of people from the subcontinent of India, including Pakistan, moving into the UK and the United States where there are much lower levels of ultraviolet light than they're used to. It turns out that these people are particularly susceptible to Vitamin D deficiencies of various kinds.

Although we don't see human skin changing in response to environmental changes because our time frame is too short to see any evolutionary change, what we are seeing are the dramatic
effects of human migrations as people move from areas of the world that they are well-adapted to areas of the world where they are not well-adapted in terms of ultraviolet radiation.

**If, for instance, an Indian family moved to the UK and lived there for several generations, at what point would their descendants begin to adapt to the climate?**

It's hard to say how long this adaptation would take because these days adaptation in any human characteristic is very much mediated by our cultural behavior. Humans do a lot of stuff: They wear clothes, they take shelter, they take vitamin supplements, they do all these things to change the nature of their interface with their physical environment. So it's now almost impossible to predict how long it might take for a human population to adapt to a different ultraviolet light regime because we do so much meddling.

**A final comment?**

I think one of the most important findings of our research is that skin color is a highly adaptive feature of the human body. It has changed over thousands of years to reflect environmental conditions. That is a wonderful thing in itself because it means that, basically, the skin is a highly flexible organ. We know this already from other types of physiological studies, but in terms of evolutionary biology it is also very flexible. It can change depending on the environmental conditions, which means that skin color itself is really of no value when we look at evolutionary relationships per se among different human populations. You can have individuals from different populations that share a similar bone structure, for instance, but have a completely different skin color. The two are unrelated. And so we can't use skin color for determining relationships between human groups.

The map above shows the potential for synthesis of vitamin D in human skin, as computed from annual average UV radiation at the Earth's surface (UVMED). The **highest annual values** for UVMED are shown in **light violet**, with incrementally **lower values shown in dark violet**, then in light to dark shades of **blue, orange, green and gray**. White denotes areas for which no UVMED data exist (Mercator projection). In the tropics, the zone of adequate UV radiation throughout the year is delimited by bold black lines. Light stippling indicates Zone 2, in which there is
not sufficient UV radiation during at least one month of the year to produce previtamin D3 in human skin. Zone 3, in which there is not sufficient UV radiation for previtamin D3 synthesis on average for the whole year, is indicated by heavy stippling. In short this means that within the tropics, people can meet their vitamin D needs through casual sun exposure. As you go farther north or south, this becomes an increasing problem. In the area we refer to as Zone 3, this is an acute problem for human populations. Successful habitation of that zone has required evolution of greatly depigmented skin and inclusion in the diet of lots of vitamin D-rich foods (like fish and marine mammals).