[crickets chirp]

[cymbal plays]

[chime plays]

[music plays]

**[JABLONSKI (narrated):]** Human brains are gray. Human blood is red. Our bones are off-white. Doesn't matter where you're born or to whom. But human skin is different.

[music plays]

Some of us have rich dark brown skin; some of us have pinkish white skin. Most of us are somewhere in between. For the longest time, why this variation exists was a real scientific mystery … that opened the door for some to invest this biological trait with moral value, and then use that to justify the suffering of others.

[elephant trumpets]

But biological traits aren't good or bad. They're features that have evolved because they enhance an organism's odds of surviving and passing on its genes.

**[JABLONSKI:]** Like other animal traits, the sepia rainbow of human skin color evolved through natural selection. Now, thanks to advances in anthropology and genetics, exactly how and why it did is no longer a mystery.

[music plays]

[background discussion]

**[JABLONSKI:]** Biological anthropologists like myself spend our lives studying how humans evolved, and why we differ from one another physically.

[music plays]

**[JABLONSKI (narrated):]** Our skin provides one of the most visible markers of human variability. It's something that sets us apart from our closest animal relatives. Under their dark fur, chimpanzees have pale skin, and millions of years ago that was probably also the case for the primates that were our common ancestors. So where did humanity's range of skin colors come from?

From physics we know that the color of any object comes from the wavelengths of light that it reflects back to an observer's eye. We see leaves as green because they reflect back the wavelengths our eyes see as green, absorbing the wavelengths we see as other colors like blue or red.

In humans, different wavelengths of light are reflected or absorbed by a pigment in the top layer of our skin. That pigment's called melanin. It sits inside what look like tiny grains—the melanosomes—that are produced by cells called melanocytes.

Our individual genetic inheritance determines the type of melanin inside our melanosomes. 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.

Melanin also colors human and animal hair, and the feathers of many birds.

**[JABLONSKI:]** Interestingly, the wavelengths of light that melanin reflects are far less important biologically than the ones it actually absorbs. And of the ones it absorbs, the ones that are the most important are those that we can't even see.

[music plays]

**[JABLONSKI (narrated):]** Much of the light given off by the sun is invisible to our eyes. Some of that is what's called ultraviolet radiation, which is highly energetic. So much so, it can actually penetrate living cells. When it does, it can wreak havoc within them. It can even cause mutations in skin cell DNA. What stands between us and that threat is the melanin in our skin.

[crowd noise]

**[ABDEL-MALEK:]** Melanin is kind of like a sensor; it's kind of like a guardian molecule. And its main job is protection.

**[JABLONSKI (narrated):]** For instance, by forming what are called supranuclear caps and absorbing UV.

**[ABDEL-MALEK:]** They're like little parasols around the nucleus. And UV cannot penetrate these to go and attack the DNA.

**[JABLONSKI (narrated):]** That's just one of the things molecular biologist Zalfa Abdel-Malek finds remarkable about melanin. Another is the broad range of benefits it provides a diverse collection of species.

**[ABDEL-MALEK:]** We know that melanin in lower vertebrates is important for regulating body temperature. It can also give animals camouflage. And allows them to recognize other members of the species to propagate the species.

**[JABLONSKI (narrated):]** In humans, one of melanin's functions is clearly to protect cells from UV damage. As we evolved, we lost hair and increased melanin production in our skin. So, is there a connection between the intensity of UV radiation and skin color?

**[JABLONSKI:]** Hi, Tess.

**[JABLONSKI (narrated):]** I first became fascinated with UV and skin color in the 1990s.

[pages turning]

But as I searched for information about the global distribution of solar UV, I discovered the available data was in fact quite spotty.

[paper rustling]

I began casting a wider net and almost by accident found exactly the raw data needed to fix that. It hadn't been collected by anyone interested in my questions, but rather by NASA.

[rocket engine roars]

**[MISSION CONTROL:]** Ignition.

And liftoff.

**[JABLONSKI (narrated):]** In the 1980s, concern about the health risk posed by the depletion of UV-blocking atmospheric ozone led NASA to take millions of UV measurements from space. I asked NASA to send me the data, and then asked my geographer husband, George Chaplin, to try to visualize it.

It turned out to be a bigger request than I'd realized, but he found a way to turn all those data points into a map, … a map that showed for the very first time exactly how UV exposure varies throughout the world.

**[CHAPLIN:]** This is the map.

**[JABLONSKI (narrated):]** Most striking was the clear gradient between the equator and the poles, which was interrupted only in places where altitude increased UV exposure …

**[CHAPLIN:]** This is actually in the Tibetan plateau …

**[JABLONSKI (narrated):]** … and persistent cloud cover decreased it.

**[CHAPLIN:]** … the Congo Basin. So it's full of humidity and moisture, which is blocking the UV.

**[JABLONSKI (narrated):]** Solar energy is a fundamental attribute of any environment. And it's a well-established fact that organisms living at different latitudes adapt in some way to their local solar conditions. To see how closely human skin color correlates with UV exposure, I collected skin pigment measurements made by anthropologists studying indigenous peoples.

**[JABLONSKI:]** For many years, anthropologists have faced the challenge of how to accurately measure skin color. We now use this little device called a reflectometer. Basically, it sends out light of specific colors, and then it measures the amount of light that is reflected back. This tells us what color Tess's skin is, and we can then compare this to people all over the world.

**[JABLONSKI (narrated):]** George then created a second map, using measured skin colors and environmental data. It showed UV intensity does indeed predict skin color. Wherever UV is strong, skin is dark, like it is near the equator or at high altitude. At the poles, the skin of indigenous people is almost always lighter. That suggests that variation in human skin melanin production arose as different populations adapted biologically to different solar conditions around the world.

**[JABLONSKI:]** As we've noted, our early ancestors probably had full body hair covering pale skin, just like other primates. So when did the darker shades of human skin begin to evolve?

[sea gulls calling]

**[JABLONSKI (narrated):]** DNA sequencing has made it possible to find evidence that can help answer that question. Rick Kittles is a geneticist who's skilled at deciphering such clues.

**[KITTLES:]** Whenever a species undergoes some form of selection, some form of natural selection, evidence of that selection is found in the genome. And so, as geneticists, we get really excited when we explore the genome for these signatures. One way in which that's done is by sampling worldwide populations and looking throughout the genome at variation and comparing across populations. And it's a very exciting process, I feel like a detective when I go through that process.

[music plays]

**[JABLONSKI (narrated):]** One of the many genes that genetic detectives have linked to human pigmentation is called MC1R. Sampling from around the world indicates there's a fair amount of variation in the DNA sequence of that gene. But not from every corner of the globe.

**[KITTLES:]** When we look at MC1R within African populations, we don't see a lot of diversity. And the particular allele that they have in those African populations is the one that codes for darker skin. MC1R codes for a protein which is involved in the switch from the production of pheomelanin to eumelanin. And we know pheomelanin is the reddish-yellow pigment, and then the eumelanin is the brown-black pigment.

[children talking]

**[JABLONSKI (narrated):]** The absence of MC1R diversity in African populations indicates that, in that part of the world, there is strong negative selection against any alleles that would alter dark skin. And how long has this allele been fixed in African populations? Other genetic studies have calculated that it has been as much as 1.2 million years. Since our species evolved in equatorial Africa, it's reasonable to conclude that, by that time, all humans were dark-skinned.

**[JABLONSKI:]** The fossil record supports what we've gleaned from genetic evidence. But here's where we confront what was, for me, the heart of the mystery.

**[JABLONSKI (narrated):]** The evolution of dark skin in humans suggests that, under strong UV light, that trait provided a survival advantage. So what exactly was that advantage? It's certainly true UV damage to skin cell DNA can lead to cancer, and skin cancer can be fatal. For a long time, that seemed the likeliest explanation. Except …

**[JABLONSKI:]** Skin cancer generally develops after a person's peak reproductive years. For that reason, though it might cut your life short, it's unlikely to affect your ability to pass on your genes.

**[JABLONSKI (narrated):]** As I was struggling to conceive of an alternative explanation, I happened to attend a lecture on severe birth defects.

[pages turn]

That talk was about a research project that had found evidence that certain birth defects are far more common among pregnant women with diets deficient in a B vitamin called folate. Only weeks before, I'd come across a paper that described how strong sunlight breaks down folate circulating in skin blood vessels. Here was a direct link between UV radiation, skin color, and reproductive success. It was a small "eureka" moment for me.

In the years since, we've learned that folate is not only essential for normal embryonic development, it's even needed for healthy sperm production in males.

**[JABLONSKI:]** Folate is biological gold. It is an essential nutrient, and it needs to be protected from UV radiation as it circulates in the blood vessels in the skin. That is what melanin does.

**[JABLONSKI (narrated):]** I felt I was halfway home on my quest to understand human skin color variation. But a big question remained:

**[JABLONSKI:]** Why aren't we all dark skinned?

**[JABLONSKI (narrated):]** It turns out there's another side to our relationship with UV light. UV light is not all bad. In fact, the small portion of it known as UVB is critical for the synthesis in our bodies of vitamin D—a process that starts in the skin. Without vitamin D, humans cannot absorb calcium from our diet, to build our bones and for a healthy immune system. Back when all of our ancestors lived close to the equator, there was no problem getting enough UVB through dark skin to make the vitamin D needed. But then some populations started moving north, where the UV striking the Earth's surface is much weaker.

**[JABLONSKI:]** In northern latitudes, dark skin makes it hard to produce the vitamin D that human bodies really need.

**[JABLONSKI (narrated):]** The consequences of vitamin D deficiency include rickets—a bone development disease that can cripple the young. In higher latitudes with less UV, the selective pressure on MC1R that produced dark skin in our ancient ancestors, began to abate.

**[KITTLES:]** When we look at the early movement out of Africa, when that constraint was relaxed, we then see a plethora of variation.

**[JABLONSKI (narrated):]** In European and Asian populations, geneticists have discovered greater variation in the MC1R gene, but less variation in several other genes—ones associated with lighter skin types.

**[KITTLES:]** Different environments led to other genes being selected for, and being important, for those populations, in terms of skin color.

**[JABLONSKI (narrated):]** Selection for light-skin gene variants occurred multiple times in different groups around the world, some of it in just the last 10,000 years. Support for the idea that the UV-vitamin D connection helped drive the evolution of paler skin comes from the fact that indigenous peoples with diets rich in this essential vitamin have dark pigmentation.

[music plays]

**[JABLONSKI:]** The tension between these two aspects of our biological inheritance—on the one hand, the need to protect ourselves from most ultraviolet radiation, and on the other, the need to use some ultraviolet radiation for our own benefit—these forces drove the evolution of the wonderful variation in human skin color that we see around us today.

**[JABLONSKI (narrated):]** It's the legacy of an evolutionary balancing act necessitated by the different environmental conditions people have faced around the globe. The thing is, where once human migrations took many generations, we now move about the planet at the speed of sound. That means increasing numbers of us have pigmentation that's not a good match with where we live.

**[ABDEL-MALEK:]** People with fair skin and red hair, your phenotype is telling you, you have a high risk of skin cancer if you're out in the sun. If you're a dark-skinned individual, living for example in Scandinavia or in Minnesota, you're not going to have optimal exposure to UV for optimal vitamin D synthesis and you need to take supplements.

**[JABLONSKI:]** We now know that we need to make cultural adaptations like these to stay healthy. But that's not all we've learned.

**[JABLONSKI (narrated):]** With the knowledge we now have about evolution, we also know that skin color is a flexible trait that has changed through time, as various groups of people moved to sunny or less sunny parts of the world. And we know that skin color is inherited independently of other traits, and is not associated with other aspects of a person's appearance or behavior. Skin color is a product of evolution and should never have been judged as something good or bad. We are a very clever and adaptable species, and we are one under the sun.

[music plays]