

## **PHENOTYPIC TRAIT**

*A phenotypic trait, simply trait, or character state is a distinct variant of a phenotypic characteristic of an organism; it may be either inherited or determined environmentally, but typically occurs as a combination of the two. For example, having eye color is a character of an organism, while blue, brown and hazel versions of eye color are traits. The term trait is generally used in genetics, often to describe phenotypic expression of different combinations of alleles in different individual organisms within a single population, such as the famous purple vs. white flower coloration in Gregor Mendel's pea plants. By contrast, in systematics, the term is character state is employed to describe features that represent fixed diagnostic differences among taxa, such as the absence of tails in great apes, relative to other primate groups.*

### **FIGURE 1**

**Eye color is an example of a (physical) phenotypic trait**

#### **Definition**

*A phenotypic trait is an obvious, observable, and measurable characteristic of an organism; it is the expression of genes in an observable way. An example of a phenotypic trait is a specific hair color or eye color. Underlying genes, that make up the genotype, determine the hair color, but the hair color observed is the phenotype. The phenotype is dependent on the genetic make-up of the organism, and also influenced by the environmental conditions to that of the organism is subjected across its ontogenetic development, including various epigenetic processes. Regardless of the degree of influence of genotype versus environment, the phenotype encompasses all of the characteristics of an organism, including traits at multiple levels of biological organization, ranging from behavior and evolutionary history of life traits (e.g., litter size), through morphology (e.g., body height and composition), physiology (e.g., blood pressure), cellular characteristics (e.g., membrane lipid composition, mitochondrial densities), components of biochemical pathways, and even messenger RNA.*

#### **Genetic origin of traits in diploid organisms**

*Different phenotypic traits are caused by different forms of genes, or alleles, which arise by mutation in a single individual and are passed on to successive generations.*

#### **Biochemistry of dominance and extensions to expression of traits**

*The biochemistry of the intermediate proteins determines how they interact in the cell. Therefore, biochemistry predicts how different combinations of alleles will produce varying traits.*

*Extended expression patterns seen in diploid organisms include facets of incomplete dominance, codominance, and multiple alleles. Incomplete dominance is the condition in which neither allele dominates the other in one heterozygote. Instead the phenotype is intermediate in heterozygotes. Thus you can tell that each allele is present in the heterozygote. Codominance refers to the allelic relationship that occurs when two alleles are both expressed in the heterozygote, and both phenotypes are seen simultaneously. Multiple alleles refers to the situation when there are more than 2 common alleles of a particular gene. Blood groups in humans is a classic example. The ABO blood group proteins are*

important in determining blood type in humans, and this is determined by different alleles of the one locus.

### **Continuum versus categorical traits**

Schizotypy is an example of a psychological phenotypic trait found in schizophrenia-spectrum disorders. Studies have shown that gender and age influences the expression of schizotypal traits. For instance, certain schizotypal traits may develop further during adolescence, whereas others stay the same during this period.

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## **EYE COLOR**

Eye color is a polygenic phenotypic trait determined by two factors: the pigmentation of the eye's iris and the frequency-dependence of the scattering of light by the turbid medium in the stroma of the iris.

### **FIGURE 2**

**The irises of human eyes exhibit a wide spectrum of colours**

In humans, the pigmentation of the iris varies from light brown to black, depending on the concentration of melanin in the iris pigment epithelium (located on the back of the iris), the melanin content within the iris stroma (located at the front of the iris), and the cellular density of the stroma. The appearance of blue, green, and hazel eyes results from the Tyndall scattering of light in the stroma, a phenomenon similar to Rayleigh scattering which accounts for the blue sky. Neither blue nor green pigments are present in the human iris or vitreous humour. This is an example of structural color, which depends on the lighting conditions, especially for lighter-colored eyes.

The brightly colored eyes of many bird species result from the presence of other pigments, such as pteridines, purines, and carotenoids. Humans and other animals have many phenotypic variations in eye color.

The genetics and inheritance of eye color in humans is complicated. As of 2010, as many as 16 genes have been associated with eye color inheritance. Some of the eye-color genes include OCA2 and HERC2. The earlier belief that blue eye color is a simple recessive trait has been shown to be incorrect. The genetics of eye color are so complex that almost any parent-child combination of eye colors can occur. However, OCA2 gene polymorphism, close to proximal 5' regulatory region, explains most human eye-color variation.

### **GENETIC DETERMINATION**

Eye color is an inherited trait determined by multiple genes. These genes are sought by studying small changes in the genes themselves and in neighboring genes, called single-nucleotide polymorphisms or SNPs. The total number of genes that contribute to eye color is unknown, but there are a few likely candidates. A study in Rotterdam (2009) found

that it was possible to predict eye color with more than 90% accuracy for brown and blue using just six SNPs.

In humans, eye color is a highly sexually dimorphic trait. Several studies have shown that men are more likely to have blue eyes than women, while women are more likely to have darker eye colors (green and brown eyes) than men. Gender is thus a major factor in the expression of eye color genotypes.

People of European descent show the greatest variety in eye color of any population worldwide. Recent advances in ancient DNA technology have revealed some of the history of eye color in Europe. Through the analysis of ancient DNA, a 2020 study published in *Experimental Dermatology* suggested that the common gene for blue eye color likely originated in the Near East and arrived in Europe around 42,000 years ago, after the exodus out of Africa.

There is evidence that as many as 16 different genes could be responsible for eye color in humans; however, the main two genes associated with eye color variation are OCA2 and HERC2, and both are localized in chromosome 15.

The gene OCA2 (OMIM: 203200), when in a variant form, causes the pink eye color and hypopigmentation common in human albinism. (The name of the gene is derived from the disorder it causes, oculocutaneous albinism type II.) Different SNPs within OCA2 are strongly associated with blue and green eyes as well as variations in freckling, mole counts, hair and skin tone. The polymorphisms may be in an OCA2 regulatory sequence, where they may influence the expression of the gene product, which in turn affects pigmentation. A specific mutation within the HERC2 gene, a gene that regulates OCA2 expression, is partly responsible for blue eyes. Other genes implicated in eye color variation are SLC24A4 and TYR. A 2010 study of eye color variation in hue and saturation values using high-resolution digital full-eye photographs found three new loci for a total of ten genes, allowing the explanation of about 50% of eye color variation.

| <b>Gene name</b> | <b>Effect on eye color</b>                                                      |
|------------------|---------------------------------------------------------------------------------|
| <b>OCA2</b>      | Associated with melanin producing cells. Central importance to eye color.       |
| <b>HERC2</b>     | Affects function of OCA2, with a specific mutation strongly linked to blue eyes |
| <b>SLC24A4</b>   | Associated with differences between blue and green eyes.                        |
| <b>TYR</b>       | Associated with differences between blue and green eyes.                        |

Blue eyes with a brown spot, green eyes, and gray eyes are caused by an entirely different part of the genome.

### **CHANGES IN EYE COLOR**

Most newborn babies who have European ancestry have light-colored eyes. As the child develops, melanocytes (cells found within the iris of human eyes, as well as skin and hair follicles) slowly begin to produce melanin. Because melanocyte cells continually produce

*pigment, in theory eye color can be changed. Adult eye color is usually established between 3 and 6 months of age, though this can be later. Observing the iris of an infant from the side using only transmitted light with no reflection from the back of the iris, it is possible to detect the presence or absence of low levels of melanin. An iris that appears blue under this method of observation is more likely to remain blue as the infant ages. An iris that appears golden contains some melanin even at this early age and is likely to turn from blue to green or brown as the infant ages.*

*Changes (lightening or darkening) of eye color during early childhood, puberty, pregnancy, and sometimes after serious trauma (like heterochromia) suggest that eyes sometimes change color under certain circumstances, due to chemical reactions or hormonal changes within the body.*

*Studies on Caucasian twins, both fraternal and identical, have shown that eye color over time can be subject to change, and major demelanization of the iris may also be genetically determined. Most eye color changes have been observed or reported in the Caucasian population with hazel and amber eyes. Under the same environmental conditions, there may be disagreement over the color of an object between two different people; the factor that causes this discrepancy is the presence of melanin in the iris, which is the main factor in determining eye color. The higher the amount of melanin in the iris and the denser the texture of the melanin, the darker the color of a person's eyes; the same melanin concentration also depends on many factors such as hereditary and environmental ones.*

### **EYE COLOR RANGE**

**★ BROWN**

#### **FIGURE 3**

***Dark brown iris is common in most parts of the world—Americas, Africa, West Asia, South Asia, East Asia and Southeast Asia.***

#### **FIGURE 4**

***Light brown iris can be found in Europe, West Asia, South Asia, Central Asia and among the Americas.***

#### **FIGURE 5**

***Light brown irises can be found in East Asia and Southeast Asia, though are relatively uncommon in the region. Subject exhibits a prominent limbal ring which is not present in all individuals.***

*Almost all mammals have brown or darkly-pigmented irises. In humans, brown is by far the most common eye color, with approximately 79% of people in the world having it. Brown eyes result from a relatively high concentration of melanin in the stroma of the iris, which causes light of both shorter and longer wavelengths to be absorbed.*

*Dark brown eyes are dominant in humans. In many parts of the world, it is nearly the only iris color present. Brown eyes are common in Europe, East Asia, Southeast Asia, Central Asia, South Asia, West Asia, Oceania, Africa and the Americas. Light or medium-pigmented brown eyes can also be commonly found in South Europe, among the Americas, and parts*

of Central Asia, West Asia and South Asia. Light brown eyes bordering amber and hazel coloration can also be observed in East Asia and Southeast Asia, though are uncommon in the region.

## ★ AMBER

### FIGURE 6 Amber eye

Amber eyes are a solid color with a strong yellowish/golden and russet/coppery tint, which may be due to the yellow pigment called lipochrome (also found in green eyes). Amber eyes should not be confused with hazel eyes. Although hazel eyes may contain specks of amber or gold, they usually tend to have many other colors, including green, brown and orange. Also, hazel eyes may appear to shift in color and consist of flecks and ripples, while amber eyes are of a solid gold hue. Even though amber is similar to gold, some people have russet or copper colored amber eyes that are mistaken for hazel, though hazel tends to be duller and contains green with red/gold flecks, as mentioned above. Amber eyes may also contain amounts of very light gold-ish gray.

The eyes of some pigeons contain yellow fluorescing pigments known as pteridines. The bright yellow eyes of the great horned owl are thought to be due to the presence of the pteridine pigment xanthopterin within certain chromatophores (called xanthophores) located in the iris stroma. In humans, yellowish specks or patches are thought to be due to the pigment lipofuscin, also known as lipochrome. Many animals such as canines, domestic cats, owls, eagles, pigeons and fish have amber eyes, whereas in humans this color occurs less frequently. Amber is the third-rarest natural eye color after green and gray, in 5% of the world's population. People with that eye color are found in the Balkan region, Southern France, the Iberian Peninsula, Italy, and Hungary, and in fewer numbers in the Middle East, North Africa and South America.

## ★ HAZEL

### FIGURE 7 Hazel eye

Hazel eyes are due to a combination of Rayleigh scattering and a moderate amount of melanin in the iris' anterior border layer. Hazel eyes often appear to shift in color from a brown to a green. Although hazel mostly consists of brown and green, the dominant color in the eye can either be brown/gold or green. This is why hazel eyes can be mistaken as amber and vice versa. The combination can sometimes produce a multicolored iris, i.e., an eye that is light brown/amber near the pupil and charcoal or dark green on the outer part of the iris (or vice versa) when observed in sunlight.

Definitions of the eye color hazel vary: it is sometimes considered to be synonymous with light brown or gold, as in the color of a hazelnut shell.

Around 18% of the US population and 5% of the world population have hazel eyes. Hazel eyes are more common in Spaniards, North Africa, the Middle East, and Brazil.

## ★ GREEN

**FIGURE 8**  
**Green eyes**

**FIGURE 9**  
**A Chinchilla Persian with sea-green eyes**

**FIGURE 10**  
**Green-hazel eyes**

## ★ BLUE

**FIGURE 11**  
**A light blue iris with limbal ring**

**FIGURE 12**  
**Blue iris**

*There is no blue pigmentation either in the iris or in the vitreous body. Dissection reveals that the iris pigment epithelium is brownish black due to the presence of melanin. Unlike brown eyes, blue eyes have low concentrations of melanin in the stroma of the iris, which lies in front of the dark epithelium. Longer wavelengths of light tend to be absorbed by the dark underlying epithelium, while shorter wavelengths are reflected and undergo Rayleigh scattering in the turbid medium of the stroma. This is the same scattering that accounts for the blue appearance of the sky. The result is a "Tyndall blue" structural color that varies with external lighting conditions.*

*The inheritance pattern followed by blue eyes was previously assumed to be a mendelian recessive trait, however, eye color inheritance is now recognized as a polygenic trait, meaning that it is controlled by the interactions of several genes.*

*In 2008, a team of researchers from the University of Copenhagen located a single mutation that causes the phenomenon of blue eyes. The research was published in the Journal of Human Genetics. The same DNA sequence of the OCA2 gene among blue-eyed people suggests they may have a single common ancestor. The researchers hypothesized that the OCA2 mutation responsible for blue eyes arose in an individual who lived in the northwestern part of the Black Sea region in Europe sometime between 6,000 and 10,000 years ago during the Neolithic period. However, more recent ancient DNA research has identified human remains much older than the Neolithic period with the OCA2 mutation for blue eyes. It is now believed that the OCA2 allele dates back to the recent migration of modern humans out of Africa roughly 50,000 years ago, and entered Europe from western Asia.*

*Eiberg and colleagues suggested in a study published in Human Genetics that a mutation in the 86th intron of the HERC2 gene, which is hypothesized to interact with the OCA2 gene promoter, reduced expression of OCA2 with subsequent reduction in melanin production. Blue eyes are predominant in northern and eastern Europe, particularly around the Baltic Sea. Blue eyes are also found in southern Europe, Central Asia, South Asia, North Africa and West Asia.*

**FIGURE 13*****A Birman kitten with distinctive sapphire blue eyes*****FIGURE 14*****Jungle crow*****FIGURE 15*****The first blue-eyed koala known to be born in captivity*****FIGURE 16*****Slater's lemur, also known as the blue-eyed black lemur***

Approximately 8% to 10% of the global population have blue eyes. A 2002 study found that the prevalence of blue eye color among the white population in the United States to be 33.8% for those born from 1936 through 1951, compared with 57.4% for those born from 1899 through 1905. As of 2006, one out of every six Americans, or 16.6% of the total US population, has blue eyes, including 22.3% of whites. The incidence of blue eyes continues to decline among American children. Of Slovenes, 56% have blue/green eyes. In Spain, the iris color distribution among the population is 16.3% blue-gray, 55.2% green-hazel, and 28.5% brown.

**★ GRAY****FIGURE 17*****Gray eye***

Like blue eyes, gray eyes have a dark epithelium at the back of the iris and a relatively clear stroma at the front. One possible explanation for the difference in the appearance of gray and blue eyes is that gray eyes have larger deposits of collagen in the stroma, so that the light that is reflected from the epithelium undergoes Mie scattering (which is not strongly frequency-dependent) rather than Rayleigh scattering (in which shorter wavelengths of light are scattered more). This would be analogous to the change in the color of the sky, from the blue given by the Rayleigh scattering of sunlight by small gas molecules when the sky is clear, to the gray caused by Mie scattering of large water droplets when the sky is cloudy. Alternatively, it has been suggested that gray and blue eyes might differ in the concentration of melanin at the front of the stroma.

Gray eyes can also be found among the Algerian Shawia peoples of the Aurès Mountains in Northwest Africa, in the Middle East/West Asia, Central Asia, and South Asia. The Greek goddess Athene appears with gray eyes (γλαυκῶπις). Under magnification, gray eyes exhibit small amounts of yellow and brown color in the iris.

Gray is the second-rarest natural eye color after green, with 3% of the world's population having it.

## SPECIAL CASES

### Two different colors

#### FIGURE 18

##### **Two different eye colors are known as heterochromia iridum**

As a result of heterochromia iridum, it is also possible to have two different eye colors. This occurs in humans and certain breeds of domesticated animals and affects less than 1 percent of the world's population.

#### ★ Red and violet

#### FIGURE 19

##### **Red-appearing albino eyes**

The eyes of people with severe forms of albinism may appear red under certain lighting conditions owing to the extremely low quantities of melanin, allowing the blood vessels to show through. In addition, flash photography can sometimes cause a "red-eye effect", in which the very bright light from a flash reflects off the retina, which is abundantly vascular, causing the pupil to appear red in the photograph.

Although the deep blue eyes of some people such as Elizabeth Taylor can appear purple or violet at certain times, "true" violet-colored eyes occur only due to albinism. Eyes that appear red or violet under certain conditions due to albinism are less than 1 percent of the world's population.

## MEDICAL IMPLICATIONS

The most important role of melanin in the iris is to protect the eyes from the sun's harmful rays. People with lighter eye colors, such as blue or green, have lessened protection from the sun, and so need greater protection from the sun's rays than those with darker eye colors.

Those with lighter iris color have been found to have a higher prevalence of age-related macular degeneration (ARMD) than those with darker iris color, lighter eye color is also associated with an increased risk of ARMD progression. A gray iris may indicate the presence of a uveitis, and an increased risk of uveal melanoma has been found in those with blue, green or gray eyes. However, a study in 2000 suggests that people with dark brown eyes are at increased risk of developing cataracts and therefore should protect their eyes from direct exposure to sunlight.

## WILSON'S DISEASE

#### FIGURE 20

##### **A Kayser–Fleischer ring in a patient with Wilson's disease**

Wilson's disease involves a mutation of the gene coding for the enzyme ATPase 7B, which prevents copper within the liver from entering the Golgi apparatus in cells. Instead, the copper accumulates in the liver and in other tissues, including the iris of the eye. This results in the formation of Kayser–Fleischer rings, which are dark rings that encircle the periphery of the iris.

### **COLORATION OF THE SCLERA**

Eye color outside of the iris may also be symptomatic of disease. Yellowing of the sclera (the "whites of the eyes") is associated with jaundice, and may be symptomatic of liver diseases such as cirrhosis or hepatitis. A blue coloration of the sclera may also be symptomatic of disease.

### **ANIRIDIA**

Aniridia is a congenital condition characterized by an extremely underdeveloped iris, which appears absent on superficial examination.

### **OCULAR ALBINISM AND EYE COLOR**

Normally, there is a thick layer of melanin on the back of the iris. Even people with the lightest blue eyes, with no melanin on the front of the iris at all, have dark brown coloration on the back of it, to prevent light from scattering around inside the eye. In those with milder forms of albinism, the color of the iris is typically blue but can vary from blue to brown. In severe forms of albinism, there is no pigment on the back of the iris, and light from inside the eye can pass through the iris to the front. In these cases, the only color seen is the red from the hemoglobin of the blood in the capillaries of the iris. Such albinos have pink eyes, as do albino rabbits, mice, or any other animal with a total lack of melanin. Transillumination defects can almost always be observed during an eye examination due to lack of iridial pigmentation. The ocular albino also lacks normal amounts of melanin in the retina as well, which allows more light than normal to reflect off the retina and out of the eye. Because of this, the pupillary reflex is much more pronounced in albino individuals, and this can emphasize the red eye effect in photographs.

### **HETEROCHROMIA**

#### **FIGURE 21**

**An example of complete heterochromia. The subject has one brown eye and one hazel eye.**

#### **FIGURE 22**

**An example of sectoral heterochromia. The subject has a blue iris with a brown section.**

Heterochromia (heterochromia iridum or heterochromia iridis) is an eye condition in which one iris is a different color from the other (complete heterochromia), or where a part of one iris is a different color from the remainder (partial heterochromia or sectoral heterochromia). It is a result of the relative excess or lack of pigment within an iris or part of an iris, which may be inherited or acquired by disease or injury. This uncommon condition usually results due to uneven melanin content. A number of causes are responsible, including genetic, such as chimerism, Horner's syndrome and Waardenburg syndrome.

A chimera can have two different colored eyes just like any two siblings can—because each cell has different eye color genes. A mosaic can have two different colored eyes if the DNA difference happens to be in an eye-color gene.

There are many other possible reasons for having two different-colored eyes. For example, the film actor Lee Van Cleef was born with one blue eye and one green eye, a trait that reportedly was common in his family, suggesting that it was a genetic trait. This anomaly, which film producers thought would be disturbing to film audiences, was "corrected" by having Van Cleef wear brown contact lenses. David Bowie, on the other hand, had the appearance of different eye colors due to an injury that caused one pupil to be permanently dilated.

Another hypothesis about heterochromia is that it can result from a viral infection in utero affecting the development of one eye, possibly through some sort of genetic mutation. Occasionally, heterochromia can be a sign of a serious medical condition.

A common cause in females with heterochromia is X-inactivation, which can result in a number of heterochromatic traits, such as calico cats. Trauma and certain medications, such as some prostaglandin analogues, can also cause increased pigmentation in one eye. On occasion, a difference in eye color is caused by blood staining the iris after injury.

## **LIMBAL RING**

### **FIGURE 23**

#### **Light brown iris with a dark limbal ring**

The limbal ring is also a feature of the iris contributing to eye color, appearing as a darkened, occasionally black region encircling the iris resulting from a manifestation of the optical properties of the corneal limbus. Limbal rings are not present in all individuals, and their thickness and prominence may correlate with health or youthfulness, and contributes to facial attractiveness.

## **IMPACT ON VISION**

Although people with lighter eye color are generally more sensitive to light because they have less pigment in the iris to protect them from sunlight, there is little to no evidence that eye color has a direct impact on vision qualities such as visual acuity. However, there is a study that found that dark-eyed people perform better at "reactive-type tasks", which suggests they may have better reaction times. People with light-colored eyes, however, performed better at so-called "self-paced tasks", which include activities like hitting a golf ball or throwing baseballs. In another study, people with darker eyes performed better at hitting racquetballs. There are also other studies that challenge these findings. According to scientists, more study is needed to verify these results.

## **CLASSIFICATION OF COLOR**

Iris color can provide a large amount of information about a person, and a classification of colors may be useful in documenting pathological changes or determining how a person may respond to ocular pharmaceuticals. Classification systems have ranged from a basic light or dark description to detailed gradings employing photographic standards for comparison. Others have attempted to set objective standards of color comparison.

The Martin–Schultz scale, developed from the Martin scale, is one standard color scale used in physical anthropology to establish the eye color of an individual. It was created by the

*anthropologists Rudolf Martin and Bruno K Schultz in the first half of the 20th century. The scale consists of 20 colors ranging from light blue to dark brown-black, corresponding to natural eye colors caused by the amount of melanin in the iris:*

*Normal eye colors range from the darkest shades of brown to the lightest tints of blue. To meet the need for standardized classification, at once simple yet detailed enough for research purposes, Seddon et al. developed a graded system based on the predominant iris color and the amount of brown or yellow pigment present. There are three pigment colors that determine, depending on their proportion, the outward appearance of the iris, along with structural color. Green irises, for example, have some yellow and the blue structural color. Brown irises contain more or less melanin. Some eyes have a dark ring around the iris, called a limbal ring.*

*Eye color in non-human animals is regulated differently. For example, instead of blue as in humans, autosomal recessive eye color in the skink species *Corucia zebrata* is black, and the autosomal dominant color is yellow-green.*

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## **HUMAN SKIN COLOR**

*Human skin color ranges from the darkest brown to the lightest hues. Differences in skin color among individuals is caused by variation in pigmentation, which is the result of genetics (inherited from one's biological parents), exposure to the sun, disorders, or some combination thereof. Differences across populations evolved through natural selection or sexual selection, because of social norms and differences in environment, as well as regulations of the biochemical effects of ultraviolet radiation penetrating the skin.*

*The actual skin color of different humans is affected by many substances, although the single most important substance is the pigment melanin. Melanin is produced within the skin in cells called melanocytes and it is the main determinant of the skin color of darker-skin humans. The skin color of people with light skin is determined mainly by the bluish-white connective tissue under the dermis and by the hemoglobin circulating in the veins of the dermis. The red color underlying the skin becomes more visible, especially in the face, when, as consequence of physical exercise or sexual arousal, or the stimulation of the nervous system (anger, embarrassment), arterioles dilate. Color is not entirely uniform across an individual's skin; for example, the skin of the palm and the sole is lighter than most other skin, and this is especially noticeable in darker-skinned people.*

*There is a direct correlation between the geographic distribution of ultraviolet radiation (UVR) and the distribution of indigenous skin pigmentation around the world. Areas that receive higher amounts of UVR, generally located closer to the equator, tend to have darker-skinned populations. Areas that are far from the tropics and closer to the poles have lower intensity of UVR, which is reflected in lighter-skinned populations. By the time modern Homo sapiens evolved, all humans were dark-skinned. Some researchers suggest that human populations over the past 50,000 years have changed from dark-skinned to light-skinned and vice versa as they migrated to different UV zones, and that such major changes in pigmentation may have happened in as little as 100 generations ( $\approx 2,500$  years) through selective sweeps. Natural skin color can also darken as a result of tanning due to exposure to sunlight. The leading theory is that skin color adapts to intense sunlight irradiation to provide partial protection against the ultraviolet fraction that produces damage and thus mutations in the DNA of the skin cells. In addition, it has been observed that females on average are significantly lighter in skin pigmentation than males. Females evolved to have lighter skin so their bodies absorb more calcium, which is needed during pregnancy and lactation. The body synthesizes vitamin D from sunlight, which helps it absorb calcium.*

*The social significance of differences in skin color has varied across cultures and over time, as demonstrated with regard to social status and discrimination.*

### **MELANIN AND GENES**

*Melanin is produced by cells called melanocytes in a process called melanogenesis. Melanin is made within small membrane-bound packages called melanosomes. As they become full of melanin, they move into the slender arms of melanocytes, from where they are transferred to the keratinocytes. Under normal conditions, melanosomes cover the upper part of the keratinocytes and protect them from genetic damage. One melanocyte supplies melanin to thirty-six keratinocytes according to signals from the keratinocytes. They also regulate*

*melanin production and replication of melanocytes. People have different skin colors mainly because their melanocytes produce different amount and kinds of melanin.*

*The genetic mechanism behind human skin color is mainly regulated by the enzyme tyrosinase, which creates the color of the skin, eyes, and hair shades. Differences in skin color are also attributed to differences in size and distribution of melanosomes in the skin. Melanocytes produce two types of melanin. The most common form of biological melanin is eumelanin, a brown-black polymer of dihydroxyindole carboxylic acids, and their reduced forms. Most are derived from the amino acid tyrosine. Eumelanin is found in hair, areola, and skin, and the hair colors gray, black, blond, and brown. In humans, it is more abundant in people with dark skin. Pheomelanin, a pink to red hue is found in particularly large quantities in red hair, the lips, nipples, glans of the penis, and vagina.*

*Both the amount and type of melanin produced is controlled by a number of genes that operate under incomplete dominance. One copy of each of the various genes is inherited from each parent. Each gene can come in several alleles, resulting in the great variety of human skin tones. Melanin controls the amount of ultraviolet (UV) radiation from the sun that penetrates the skin by absorption. While UV radiation can assist in the production of vitamin D, excessive exposure to UV can damage health.*

### **EVOLUTION OF SKIN COLOR**

#### **Time scale of skin color evolution**

*The earliest primate ancestors of humans most likely had pale non-pigmented skin, like our closest modern relative—the chimpanzee, and other great apes. Loss of body hair in Homo links to the thermoregulation through perspiration heat dissipation required for activity in hot open environments and endurance running. Humans as primates have a particular need for this thermoregulation since unlike other mammals they lack a carotid rete that allows precooling of blood to the brain, an organ extremely sensitive to changes in body temperature. Given endurance running and its needs for thermoregulation arose with H. erectus this links hairlessness with the origin of H. erectus about 2 million years ago. As hominids gradually lost their fur between 1.2 and 4 million years ago, to allow for better cooling through sweating, their naked skin was exposed to sunlight. In the tropics, natural selection favoured dark-skinned human populations as high levels of skin pigmentation protected against the harmful effects of sunlight. Indigenous populations' skin reflectance (the amount of sunlight the skin reflects) and the actual UV radiation in a particular geographic area is highly correlated, which supports this idea. Genetic evidence also supports this notion, demonstrating that around 1.2 million years ago there was a strong evolutionary pressure which acted on the development of dark skin pigmentation in early members of the genus Homo. Hairlessness exposes folate circulating subcutaneously and in the dermis to degradation from UV-radiation. The effect of sunlight on folic acid levels has been crucial in the development of dark skin and favored the emergence of skin pigmentation in order to protect from folate depletion due to the increased exposure to sunlight.*

*In 2017, a study showed that both dark and light pigmentation alleles arose before the origin of modern humans, with the older version of the variants in many cases being associated with lighter skin.*

*With the evolution of hairless skin, abundant sweat glands, and skin rich in melanin, early humans could walk, run, and forage for food for long periods of time under the hot sun without brain damage due to overheating, giving them an evolutionary advantage over other species. Research on the MC1R alleles using assumptions about past population size and*

an absence of population bottlenecks suggests the allele for dark skin present in modern Africans arose at least by 1.2 million years ago.

This was the genotype inherited by anatomically modern humans, but retained only by part of the extant populations, thus forming an aspect of human genetic variation. About 100,000–70,000 years ago, some anatomically modern humans (*Homo sapiens*) began to migrate away from the tropics to the north where they were exposed to less intense sunlight. This was possibly in part due to the need for greater use of clothing to protect against the colder climate. Under these conditions there was less photodestruction of folate and so the evolutionary pressure working against the survival of lighter-skinned gene variants was reduced. In addition, lighter skin is able to generate more vitamin D (cholecalciferol) than darker skin, so it would have represented a health benefit in reduced sunlight if there were limited sources of vitamin D. Hence the leading hypothesis for the evolution of human skin color proposes that:

- 1) From the origin of hairlessness and exposure to UV-radiation to less than 100,000 years ago, archaic humans, including archaic *Homo sapiens*, were dark-skinned.
- 2) As some *Homo sapiens* populations began to migrate, the evolutionary constraint keeping skin dark decreased proportionally to the distance north a population migrated, resulting in a range of skin tones within northern populations, although the bulk of humans remained dark-skinned.
- 3) At some point, some northern populations experienced positive selection for lighter skin due to the increased production of vitamin D from sunlight and the genes for darker skin disappeared from these populations.
- 4) Subsequent migrations into different UV environments and admixture between populations have resulted in the varied range of skin pigmentations we see today.

The genetic mutations leading to light skin, though partially different among East Asians and Western Europeans, suggest the two groups experienced a similar selective pressure after settlement in northern latitudes.

The theory is partially supported by a study into the *SLC24A5* gene which found that the allele associated with light skin in Europe "determined [...] that 18,000 years had passed since the light-skin allele was fixed in Europeans" but may have originated as recently as 12,000–6,000 years ago "given the imprecision of method", which is in line with the earliest evidence of farming.

Research by Nina Jablonski suggests that an estimated time of about 10,000 to 20,000 years is enough for human populations to achieve optimal skin pigmentation in a particular geographic area but that development of ideal skin coloration may happen faster if the evolutionary pressure is stronger, even in as little as 100 generations. The length of time is also affected by cultural practices such as food intake, clothing, body coverings, and shelter usage which can alter the ways in which the environment affects populations.

#### **FIGURE 24**

**Evolutionary model of human pigmentation in three continental populations. The rooted tree shows the genetic phylogeny of human populations from West Africa, North Europe and East Asia, with the colors of the branches roughly indicating the generalized skin pigmentation level of these populations.**

Population and admixture studies suggest a three-way model for the evolution of human skin color, with dark skin evolving in early *Homo sapiens* in Africa and light skin evolving only recently after modern humans had expanded out of Africa. For the most part, the evolution of light skin has followed different genetic paths in Western and Eastern Eurasian populations;

however, some mutations associated with lighter skin have estimated origin dates after humans spread out of Africa but before the divergence of the two lineages.

According to Crawford et al. (2017), most of the genetic variants associated with light and dark pigmentation in African populations appear to have originated more than 300,000 years ago. African, South Asian and Australo-Melanesian populations also carry derived alleles for dark skin pigmentation that are not found in Europeans or East Asians. Huang et al. 2021 found the existence of "selective pressure on light pigmentation in the ancestral population of Europeans and East Asians", prior to their divergence from each other. Skin pigmentation was also found to be affected by directional selection towards darker skin among Africans, as well as lighter skin among Eurasians. Crawford et al. (2017) similarly found evidence for selection towards light pigmentation prior to the divergence of West Eurasians and East Asians.

### **FUNCTIONAL CONSIDERATIONS**

Elias et. al. in 2010 showed a superior barrier function in darkly pigmented skin. Most protective functions of the skin, including the permeability barrier and the antimicrobial barrier, reside in the stratum corneum and the researchers surmise that the stratum corneum has undergone the most genetic change since the loss of human body hair. Natural selection would have favored mutations that protect this essential barrier; one such protective adaptation is the pigmentation of interfollicular epidermis, because it improves barrier function as compared to non-pigmented skin. The authors argue that lack of significant differences between modern light-skinned and dark-skinned populations in vitamin D deficiency, early death from UV-induced cancers and birth defects — as well as instances of light and dark populations living side-by-side in areas with similar UV — suggest the standard model is insufficient to explain the strong selection drive for pigmented skin. Jablonski rejects this theory on the grounds that the human tanning response is driven by UV-B exposure, not xeric stress, and that the positive selection for vitamin D production is "well-established".

### **GENETICS**

To some extent, skin color is determined independently of eye and hair color, as can be seen from variation in skin coloration in human populations. For the evolution of human skin color, see section above.

For skin color, heritability is very high, even though it can be modified by exposure to sunlight.

A recent systematic study found 169 genes involved in human skin coloration. Most of the genes were involved in melanosome biogenesis, endosomal transport, and gene regulation. Notably, the function of these genes was verified in tissue culture experiments using CRISPR-Cas9 knockouts, showing that these genes are indeed involved in melanin production.

### **DARK SKIN**

All modern humans share a common ancestor who lived around 200,000 years ago in Africa. Comparisons between known skin pigmentation genes in chimpanzees and modern Africans show that dark skin evolved along with the loss of body hair about 1.2 million years ago and that this common ancestor had dark skin. Investigations into dark-skinned populations in South Asia and Melanesia indicate that skin pigmentation in these populations is due to the preservation of this ancestral state and not due to new variations on a previously lightened population.

### **MC1R**

### **FIGURE 25**

**MC1R (rs885479)**

The melanocortin 1 receptor (MC1R) gene is primarily responsible for determining whether pheomelanin and eumelanin are produced in the human body. Research shows at least 10 differences in MC1R between African and chimpanzee samples and that the gene has probably undergone a strong positive selection (a selective sweep) in early Hominins around 1.2 million years ago. This is consistent with positive selection for the high-eumelanin phenotype seen in Africa and other environments with high UV exposure.

**Light skin**

For the most part, the evolution of light skin has followed different genetic paths in European and East Asian populations. Two genes, however, KITLG and ASIP, have mutations associated with lighter skin that have high frequencies in both European and East Asian populations. They are thought to have originated after humans spread out of Africa but before the divergence of the European and Asian lineages around 30,000 years ago. Two subsequent genome-wide association studies found no significant correlation between these genes and skin color, and suggest that the earlier findings may have been the result of incorrect correction methods and small panel sizes, or that the genes have an effect too small to be detected by the larger studies.

**KITLG****FIGURE 26****KITLG (rs1881227)**

The KIT ligand (KITLG) gene is involved in the permanent survival, proliferation and migration of melanocytes. A mutation in this gene, A326G (rs642742), has been positively associated with variations of skin color in African-Americans of mixed West African and European descent and is estimated to account for 15–20% of the melanin difference between African and European populations. This allele shows signs of strong positive selection outside Africa and occurs in over 80% of European and Asian samples, compared with less than 10% in African samples.

**ASIP**

Agouti signalling peptide (ASIP) acts as an inverse agonist, binding in place of alpha-MSH and thus inhibiting eumelanin production. Studies have found two alleles in the vicinity of ASIP are associated with skin color variation in humans. One, rs2424984, has been identified as an indicator of skin reflectance in a forensics analysis of human phenotypes across Caucasian, African-American, South Asian, East Asian, Hispanic and Native American populations and is about three times more common in non-African populations than in Africa. The other allele, 8188G (rs6058017) is significantly associated with skin color variation in African-Americans and the ancestral version occurs in only 12% of European and 28% of East Asian samples compared with 80% of West African samples.

**Europe****FIGURE 27****History of human pigmentation in Europe based on genetics**

A number of genes have been positively associated with the skin pigmentation difference between European and non-European populations. Mutations in SLC24A5 and SLC45A2 are believed to account for the bulk of this variation and show very strong signs of selection. A variation in TYR has also been identified as a contributor.

Research indicates the selection for the light-skin alleles of these genes in Europeans is comparatively recent, having occurred later than 20,000 years ago and perhaps as recently as 12,000 to 6,000 years ago. In the 1970s, Luca Cavalli-Sforza suggested that the selective sweep that rendered light skin ubiquitous in Europe might be correlated with the advent of

farming and thus have taken place only around 6,000 years ago; This scenario found support in a 2014 analysis of mesolithic (7,000 years old) hunter-gatherer DNA from La Braña, Spain, which showed a version of these genes not corresponding with light skin color. In 2015 researchers analysed for light skin genes in the DNA of 94 ancient skeletons ranging from 8,000 to 3,000 years old from Europe and Russia. They found c. 8,000-year-old hunter-gatherers in Spain, Luxembourg, and Hungary were dark skinned while similarly aged hunter-gatherers in Sweden were light skinned (having predominately derived alleles of SLC24A5, SLC45A2 and also HERC2/OCA2). Neolithic farmers entering Europe at around the same time were intermediate, being nearly fixed for the derived SLC24A5 variant but only having the derived SLC45A2 allele in low frequencies. The SLC24A5 variant spread very rapidly throughout central and southern Europe from about 8,000 years ago, whereas the light skin variant of SLC45A2 spread throughout Europe after 5,800 years ago. Some authors have expressed caution regarding the skin pigmentation predictions. According to Ju et al. (2021), in a study addressing 40,000 years of modern human history, stated :

*"Relatively dark skin pigmentation in Early Upper Paleolithic Europe would be consistent with those populations being relatively poorly adapted to high-latitude conditions as a result of having recently migrated from lower latitudes. On the other hand, although we have shown that these populations carried few of the light pigmentation alleles that are segregating in present-day Europe, they may have carried different alleles that we cannot now detect."*

#### **SLC24A5**

Solute carrier family 24 member 5 (SLC24A5) regulates calcium in melanocytes and is important in the process of melanogenesis. The SLC24A5 gene's derived Ala111Thr allele (rs1426654) has been shown to be a major factor in light skin pigmentation and is common in Western Eurasia.[61] Recent studies have found that the variant represents as much as 25–40% of the average skin tone difference between Europeans and West Africans. This derived allele is a reliable predictor of phenotype across a range of populations. It has been the subject of recent selection in Western Eurasia, and is fixed in European populations.

#### **SLC45A2**

Solute carrier family 45 member 2 (SLC45A2 or MATP) aids in the transport and processing of tyrosine, a precursor to melanin. It has also been shown to be one of the significant components of the skin color of modern Europeans through its Phe374Leu (rs16891982) allele that has been directly correlated with skin color variation across a range of populations. This variation is ubiquitous in European populations but extremely rare elsewhere and shows strong signs of selection.

#### **TYR**

The TYR gene encodes the enzyme tyrosinase, which is involved in the production of melanin from tyrosine. It has an allele, Ser192Tyr (rs1042602[81]), found solely in 40–50% of Europeans and linked to light-colored skin in studies of South Asian and African-American populations.

#### **EAST ASIA**

A number of genes known to affect skin color have alleles that show signs of positive selection in East Asian populations. Of these, only OCA2 has been directly related to skin color measurements, while DCT, MC1R and ATRN are marked as candidate genes for future study.

#### **OCA2**

#### **FIGURE 28**

#### **OCA2 (rs12913832)**

Oculocutaneous albinism II (OCA2) assists in the regulation of pH in melanocytes. The OCA2 gene's derived His615Arg (rs1800414) allele has been shown to account for about 8% of the skin tone difference between African and East Asian populations in studies of an East Asian population living in Toronto and a Chinese Han population. This variant is essentially restricted to East Asia, with highest frequencies in Eastern East Asia (49–63%), midrange frequencies in Southeast Asia, and the lowest frequencies in Western China and some Eastern European populations.

### **Candidate genes**

A number of studies have found genes linked to human skin pigmentation that have alleles with statistically significant frequencies in Chinese and East Asian populations. While not linked to measurements of skin tone variation directly, dopachrome tautomerase (DCT or TYRP2 rs2031526), melanocortin 1 receptor (MC1R) Arg163Gln (rs885479) and attractin (ATRN) have been indicated as potential contributors to the evolution of light skin in East Asian populations.

### **TANNING RESPONSE**

Tanning response in humans is controlled by a variety of genes. MC1R variants Arg151Ser (rs1805007), Arg160Trp (rs1805008[90]), Asp294Ser (rs1805009), Val60Leu (rs1805005) and Val92Met (rs2228479) have been associated with reduced tanning response in European and/or East Asian populations. These alleles show no signs of positive selection and only occur in relatively small numbers, reaching a peak in Europe with around 28% of the population having at least one allele of one of the variations. A study of self-reported tanning ability and skin type in American non-Hispanic Caucasians found that SLC24A5 Phe374Leu is significantly associated with reduced tanning ability and also associated TYR Arg402Gln (rs1126809), OCA2 Arg305Trp (rs1800401) and a 2-SNP haplotype in ASIP (rs4911414 and rs1015362) to skin type variation within a "fair/medium/olive" context.

### **Albinism**

Oculocutaneous albinism (OCA) is a lack of pigment in the eyes, skin and sometimes hair that occurs in a very small fraction of the population. The four known types of OCA are caused by mutations in the TYR, OCA2, TYRP1, and SLC45A2 genes.

### **AGE**

In hominids, the parts of the body not covered with hair, like the face and the back of the hands, start out pale in infants and turn darker as the skin is exposed to more sun. All human babies are born pale, regardless of what their adult color will be. In humans, melanin production does not peak until after puberty.

The skin of children becomes darker as they go through puberty and experience the effects of sex hormones. This darkening is especially noticeable in the skin of the nipples, the areola of the nipples, the labia majora in females, and the scrotum in males. In some people, the armpits become slightly darker during puberty. The interaction of genetic, hormonal, and environmental factors on skin coloration with age is still not adequately understood, but it is known that men are at their darkest baseline skin color around the age of 30, without considering the effects of tanning. Around the same age, women experience darkening of some areas of their skin.

Human skin color fades with age. Humans over the age of thirty experience a decrease in melanin-producing cells by about 10% to 20% per decade as melanocyte stem cells gradually die. The skin of face and hands has about twice the amount of pigment cells as unexposed areas of the body, as chronic exposure to the sun continues to stimulate melanocytes. The blotchy appearance of skin color in the face and hands of older people is

due to the uneven distribution of pigment cells and to changes in the interaction between melanocytes and keratinocytes.

### **SEXUAL DIMORPHISM**

It has been observed that females are found to have lighter skin pigmentation than males in some studied populations. This may be a form of sexual dimorphism due to the requirement in women for high amounts of calcium during pregnancy and lactation. Breastfeeding newborns, whose skeletons are growing, require high amounts of calcium intake from the mother's milk (about 4 times more than during prenatal development), part of which comes from reserves in the mother's skeleton. Adequate vitamin D resources are needed to absorb calcium from the diet, and it has been shown that deficiencies of vitamin D and calcium increase the likelihood of various birth defects such as spina bifida and rickets. Natural selection may have led to females with lighter skin than males in some indigenous populations because women must get enough vitamin D and calcium to support the development of fetus and nursing infants and to maintain their own health. However, in some populations such as in Italy, Poland, Ireland, Spain and Portugal men are found to have fairer complexions, and this has been ascribed as a cause to increased melanoma risk in men.

The sexes also differ in how they change their skin color with age. Men and women are not born with different skin color, they begin to diverge during puberty with the influence of sex hormones. Women can also change pigmentation in certain parts of their body, such as the areola, during the menstrual cycle and pregnancy and between 50 and 70% of pregnant women will develop the "mask of pregnancy" (melasma or chloasma) in the cheeks, upper lips, forehead, and chin. This is caused by increases in the female hormones estrogen and progesterone and it can develop in women who take birth control pills or participate in hormone replacement therapy.

### **DISORDERS OF PIGMENTATION**

Uneven pigmentation of some sort affects most people, regardless of bioethnic background or skin color. Skin may either appear lighter, or darker than normal, or lack pigmentation at all; there may be blotchy, uneven areas, patches of brown to gray discoloration or freckling. Apart from blood-related conditions such as jaundice, carotenosis, or argyria, skin pigmentation disorders generally occur because the body produces either too much or too little melanin.

### **DEPIGMENTATION**

#### **Albinism**

Some types of albinism affect only the skin and hair, while other types affect the skin, hair and eyes, and in rare cases only the eyes. All of them are caused by different genetic mutations. Albinism is a recessively inherited trait in humans where both pigmented parents may be carriers of the gene and pass it down to their children. Each child has a 25% chance of being albino and a 75% chance of having normally pigmented skin. One common type of albinism is oculocutaneous albinism or OCA, which has many subtypes caused by different genetic mutations. Albinism is a serious problem in areas of high sunlight intensity, leading to extreme sun sensitivity, skin cancer, and eye damage.

Albinism is more common in some parts of the world than in others, but it is estimated that 1 in 70 humans carry the gene for OCA. The most severe type of albinism is OCA1A, which is characterized by complete, lifelong loss of melanin production, other forms of OCA1B, OCA2, OCA3, OCA4, show some form of melanin accumulation and are less severe. The four known types of OCA are caused by mutations in the TYR, OCA2, TYRP1, and SLC45A2 genes.

Albinos often face social and cultural challenges (even threats), as the condition is often a source of ridicule, racism, fear, and violence. Many cultures around the world have developed beliefs regarding people with albinism. Albinos are persecuted in Tanzania by witchdoctors, who use the body parts of albinos as ingredients in rituals and potions, as they are thought to possess magical power.

### **VITILIGO**

#### **FIGURE 29**

**Former Chief Justice of India, P. Sathasivam, has vitiligo**

Vitiligo is a condition that causes depigmentation of sections of skin. It occurs when melanocytes die or are unable to function. The cause of vitiligo is unknown, but research suggests that it may arise from autoimmune, genetic, oxidative stress, neural, or viral causes. The incidence worldwide is less than 1%. Individuals affected by vitiligo sometimes suffer psychological discomfort because of their appearance.

### **HYPERPIGMENTATION**

Increased melanin production, also known as hyperpigmentation, can be a few different phenomena:

Melasma describes the darkening of the skin.

Chloasma describes skin discolorations caused by hormones. These hormonal changes are usually the result of pregnancy, birth control pills or estrogen replacement therapy.

Solar lentigo, also known as "liver spots" or "senile freckles", refers to darkened spots on the skin caused by aging and the sun. These spots are quite common in adults with a long history of unprotected sun exposure.

Aside from sun exposure and hormones, hyperpigmentation can be caused by skin damage, such as remnants of blemishes, wounds or rashes. This is especially true for those with darker skin tones.

The most typical cause of darkened areas of skin, brown spots or areas of discoloration is unprotected sun exposure. Once incorrectly referred to as liver spots, these pigment problems are not connected with the liver.

On lighter to medium skin tones, solar lentigenes emerge as small- to medium-sized brown patches of freckling that can grow and accumulate over time on areas of the body that receive the most unprotected sun exposure, such as the back of the hands, forearms, chest, and face. For those with darker skin colors, these discolorations can appear as patches or areas of ashen-gray skin.

### **Exposure to the sun**

#### **FIGURE 30**

**A suntanned arm showing darker skin** where it has been exposed. This pattern of tanning is often called a farmer's tan.

Melanin in the skin protects the body by absorbing solar radiation. In general, the more melanin there is in the skin the more solar radiation can be absorbed. Excessive solar radiation causes direct and indirect DNA damage to the skin and the body naturally combats and seeks to repair the damage and protect the skin by creating and releasing further melanin into the skin's cells. With the production of the melanin, the skin color darkens, but can also cause sunburn. The tanning process can also be created by artificial UV radiation. There are two different mechanisms involved. Firstly, the UVA-radiation creates oxidative stress, which in turn oxidizes existing melanin and leads to rapid darkening of the melanin, also known as IPD (immediate pigment darkening). Secondly, there is an increase in production of melanin known as melanogenesis. Melanogenesis leads to delayed tanning and first becomes visible about 72 hours after exposure. The tan that is created by an

increased melanogenesis lasts much longer than the one that is caused by oxidation of existing melanin. Tanning involves not just the increased melanin production in response to UV radiation but the thickening of the top layer of the epidermis, the stratum corneum. A person's natural skin color affects their reaction to exposure to the sun. Generally, those who start out with darker skin color and more melanin have better abilities to tan. Individuals with very light skin and albinos have no ability to tan. The biggest differences resulting from sun exposure are visible in individuals who start out with moderately pigmented brown skin: the change is dramatically visible as tan lines, where parts of the skin which tanned are delineated from unexposed skin.

Modern lifestyles and mobility have created mismatch between skin color and environment for many individuals. Vitamin D deficiencies and UVR overexposure are concerns for many. It is important for these people individually to adjust their diet and lifestyle according to their skin color, the environment they live in, and the time of year. For practical purposes, such as exposure time for sun tanning, six skin types are distinguished following Fitzpatrick (1975), listed in order of decreasing lightness:

### **Fitzpatrick Scale**

The following list shows the six categories of the Fitzpatrick scale in relation to the 36 categories of the older von Luschan scale:

| Type       | Also called                 | Sunburning  | Tanning behavior | Von Luschan's chromatic scale |
|------------|-----------------------------|-------------|------------------|-------------------------------|
| <b>I</b>   | Light, pale white           | Always      | Never            | 0–6                           |
| <b>II</b>  | White, fair                 | Usually     | Minimally        | 7–13                          |
| <b>III</b> | Medium white to light brown | Sometimes   | Uniformly        | 14–20                         |
| <b>IV</b>  | Olive, moderate brown       | Rarely      | Easily           | 21–27                         |
| <b>V</b>   | Brown, dark brown           | Very rarely | Very easily      | 28–34                         |
| <b>VI</b>  | Very dark brown to black    | Never       | Rarely           | 35–36                         |

Dark skin with large concentrations of melanin protects against ultraviolet light and skin cancers; light-skinned people have about a tenfold greater risk of dying from skin cancer, compared with dark-skinned persons, under equal sunlight exposure. Furthermore, UV-A rays from sunlight are believed to interact with folic acid in ways that may damage health. In a number of traditional societies the sun was avoided as much as possible, especially around noon when the ultraviolet radiation in sunlight is at its most intense. Midday was a time when people stayed in the shade and had the main meal followed by a nap, a practice similar to the modern siesta.

### **GEOGRAPHIC VARIATION**

Approximately 10% of the variance in skin color occurs within regions, and approximately 90% occurs between regions. Because skin color has been under strong selective pressure, similar skin colors can result from convergent adaptation rather than from genetic relatedness; populations with similar pigmentation may be genetically no more similar than other widely separated groups. Furthermore, in some parts of the world where people from different regions have mixed extensively, the connection between skin color and ancestry has substantially weakened. In Brazil, for example, skin color is not closely associated with the percentage of recent African ancestors a person has, as estimated from an analysis of genetic variants differing in frequency among continent groups.

In general, people living close to the equator are highly darkly pigmented, and those living near the poles are generally very lightly pigmented. The rest of humanity shows a high degree of skin color variation between these two extremes, generally correlating with UV exposure. The main exception to this rule is in the New World, where people have only lived for about 10,000 to 15,000 years and show a less pronounced degree of skin pigmentation. In recent times, humans have become increasingly mobile as a consequence of improved technology, domestication, environmental change, strong curiosity, and risk-taking. Migrations over the last 4000 years, and especially the last 400 years, have been the fastest in human history and have led to many people settling in places far away from their ancestral homelands. This means that skin colors today are not as confined to geographical location as they were previously.

### **SOCIAL STATUS, COLORISM AND RACISM**

#### **FIGURE 31**

#### **Skin colors according to von Luschan's chromatic scale**

According to classical scholar Frank Snowden, skin color did not determine social status in ancient Egypt, Greece or Rome. These ancient civilizations viewed relations between the major power and the subordinate state as more significant in a person's status than their skin colors.

Nevertheless, some social groups favor specific skin coloring. The preferred skin tone varies by culture and has varied over time. A number of indigenous African groups, such as the Maasai, associated pale skin with being cursed or caused by evil spirits associated with witchcraft. They would abandon their children born with conditions such as albinism and showed a sexual preference for darker skin.

Many cultures have historically favored lighter skin for women. Before the Industrial Revolution, inhabitants of the continent of Europe preferred pale skin, which they interpreted as a sign of high social status. The poorer classes worked outdoors and got darker skin from exposure to the sun, while the upper class stayed indoors and had light skin. Hence light skin became associated with wealth and high position. Women would put lead-based cosmetics on their skin to whiten their skin tone artificially. However, when not strictly monitored, these cosmetics caused lead poisoning. Other methods also aimed at achieving a light-skinned appearance, including the use of arsenic to whiten skin, and powders. Women would wear full-length clothes when outdoors, and would use gloves and parasols to provide shade from the sun.

Colonization and enslavement as carried out by European countries became involved with colorism and racism, associated with the belief that people with dark skin were uncivilized, inferior, and should be subordinate to lighter-skinned invaders. This belief exists to an extent in modern times as well. Institutionalized slavery in North America led people to perceive lighter-skinned African-Americans as more intelligent, cooperative, and beautiful. Such lighter-skinned individuals had a greater likelihood of working as house slaves and of

receiving preferential treatment from plantation owners and from overseers. For example, they had a chance to get an education. The preference for fair skin remained prominent until the end of the Gilded Age, but racial stereotypes about worth and beauty persisted in the last half of the 20th century and continue in the present day. African-American journalist Jill Nelson wrote that, "To be both prettiest and black was impossible," and elaborated:

*We learn as girls that in ways both subtle and obvious, personal and political, our value as females is largely determined by how we look. ... For black women, the domination of physical aspects of beauty in women's definition and value render us invisible, partially erased, or obsessed, sometimes for a lifetime, since most of us lack the major talismans of Western beauty. Black women find themselves involved in a lifelong effort to self-define in a culture that provides them no positive reflection.*

A preference for fair or lighter skin continues in some countries, including Latin American countries where whites form a minority. In Brazil, a dark-skinned person is more likely to experience discrimination. Many actors and actresses in Latin America have European features—blond hair, blue eyes, and pale skin. A light-skinned person is more privileged and has a higher social status; a person with light skin is considered more beautiful and lighter skin suggests that the person has more wealth. Skin color is such an obsession in some countries that specific words describe distinct skin tones - from (for example) "jincha", Puerto Rican slang for "glass of milk" to "morena", literally "brown".

In South Asia, society regards pale skin as more attractive and associates dark skin with lower class status; this results in a massive market for skin-whitening creams. Fairer skin-tones also correlate to higher caste-status in the Hindu social order—although the system is not based on skin tone. Actors and actresses in Indian cinema tend to have light skin tones, and Indian cinematographers have used graphics and intense lighting to achieve more "desirable" skin tones. Fair skin tones are advertised as an asset in Indian marketing. Skin-whitening products have remained popular over time, often due to historical beliefs and perceptions about fair skin. Sales of skin-whitening products across the world grew from \$40 billion to \$43 billion in 2008. In South and East Asian countries, people have traditionally seen light skin as more attractive, and a preference for lighter skin remains prevalent. In ancient China and Japan, for example, pale skin can be traced back to ancient drawings depicting women and goddesses with fair skin tones. In ancient China, Japan, and Southeast Asia, pale skin was seen as a sign of wealth. Thus skin-whitening cosmetic products are popular in East Asia. Four out of ten women surveyed in Hong Kong, Malaysia, the Philippines and South Korea used a skin-whitening cream, and more than 60 companies globally compete for Asia's estimated \$18 billion market. Changes in regulations in the cosmetic industry led to skin-care companies introducing harm-free skin lighteners. In Japan, the geisha have a reputation for their white-painted faces, and the appeal of the bihaku (美白), or "beautiful white", ideal leads many Japanese women to avoid any form of tanning. There are exceptions to this, with Japanese fashion trends such as ganguro emphasizing tanned skin. Skin whitening is also not uncommon in Africa, and several research projects have suggested a general preference for lighter skin in the African-American community. In contrast, one study on men of the Bikosso tribe in Cameroon found no preference for attractiveness of females based on lighter skin color, bringing into question the universality of earlier studies that had exclusively focused on skin-color preferences among non-African populations.

Significant exceptions to a preference for lighter skin started to appear in Western culture in the mid-20th century. However, a 2010 study found a preference for lighter-skinned women in New Zealand and California. Though sun-tanned skin was once associated with the

*sun-exposed manual labor of the lower class, the associations became dramatically reversed during this time—a change usually credited to the trendsetting Frenchwoman Coco Chanel (1883–1971) presenting tanned skin as fashionable, healthy, and luxurious. As of 2017, though an overall preference for lighter skin remains prevalent in the United States, many within the country regard tanned skin as both more attractive and healthier than pale or very dark skin. Western mass media and popular culture continued[when?] to reinforce negative stereotypes about dark skin, but in some circles pale skin has become associated with indoor office-work while tanned skin has become associated with increased leisure time, sportiness and good health that comes with wealth and higher social status. Studies have also emerged indicating that the degree of tanning is directly related to how attractive a young woman is.*

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