

Solar Radiation and Development of Human Skin Colours

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Abstract

The Sun has played a major role in the development of life on the Earth. Human skin is the most visible aspect of the human phenotype. It is distinguished mainly by its naked appearance, greatly enhanced abilities to dissipate body heat through sweating, and the great range of genetically determined skin colors present within a single species. In the Western culture, people are warned against sun exposure because of its adverse effects: erythema. There are signs that human ancestors lived in Africa 6–7 million years ago. Skin color has changed during human evolution. These changes may result from adaptations to solar ultraviolet radiation and/or sexual selection. Many aspects of the evolution of human skin and skin color can be reconstructed using comparative anatomy, physiology, and genomics. Enhancement of thermal sweating was a key innovation in human evolution that allowed maintenance of homeostasis during sustained physical activity in hot environments. Most likely, they had white skin colour which gradually turned dark. Humans have migrated out of Africa numerous times, mainly northwards, and each time their skin colour changed as an adaptation to lower rates of solar UV radiation. Human skin, exposed to UV gets immediately darker through reversible, photochemical processes and spatial rearrangements of melanin structures skin color has changed during human evolution. These changes may result from adaptations to solar ultraviolet radiation and/or sexual selection.

Keywords: Solar Radiation, Skin Colour, Africa, Western Culture, Sexual Selection.

Introduction

When humans visualize a body, they see mostly skin. The skin is the body's direct interface with the physical environment, conveying a state of health and personal identity. (Jablonski, 2004b). The skin comprises a sheet-like investiture that protects the body from attack by physical, chemical, and microbial agents. It is the organ that regulates body temperature through control of surface blood flow and sweating and detects critical information about the ambient environment and objects touched. The largest and most massive of the organs of the body, the skin of the average adult human exceeds 2m² yet is generally no thicker than 2mm (McGrath & Uitto, 2010). The skin also provides a forum for advertising. It provides information about a person's age, health, and some aspects of ancestry, and furnishes a placard upon which further information is placed through temporary and permanent decoration. There are signs that human ancestors lived in Africa 6–7 million years ago. (Jablonski & Chaplin, 2000) Most likely, they had white skin colour which gradually turned dark. Humans have migrated out of Africa numerous times, mainly northwards, and each time their skin colour changed as an adaptation to lower fluence rates

of solar UV radiation (Jablonski & Chaplin, 2010). Today, populations with recent ancestors from lower latitudes have darker skin than populations which have stayed for a long time at high latitudes. Diet, climate and/or sexual selection are secondary determinants of human skin pigmentation. Numerous hypotheses exist for skin darkening and whitening, some of which will be briefly discussed.

Different skin types and skin chromospheres

The development of humans is thought to have been significantly influenced by the skin. The transition to hairless skin boosted our capacity to regulate body temperature by sweating. This allowed the delicate brain to maintain a constant temperature even under challenging situations, like hot weather and strenuous physical labour (Jablonski, 2004b). Humans typically envision skin when they imagine a body. The skin serves as the body's primary physical interface with the outside world and communicates both a person's health and identity. The skin is an armor-like covering that shields the body from microbiological, chemical, and physical harm.(McGrath & Uitto, 2010). Figure 1.1 Extended Coloured family from South Africa showing some spectrum of human skin coloration (Jablonski, Nina, Chaplin, George, 2017). With the loss of hair, skin pigmentation became central to protect the body from harmful UV radiation. In particular, protection of light sensitive foliate molecules in the superficial blood capillaries is considered to have been important in the evolution of skin pigmentation. More

Pigmented skin absorbs and scatters light better and thus protect the underlying tissue from harmful UV radiation, while absorbing a larger fraction of the light illuminating the skin. Light penetration in tissue is actually modulated by two different mechanisms increase (Agus, 2012) in the skin pigmentation (meaning increased melanogenesis) or by non-pigmentary photo-protection. Non-pigmentary photoprotection is less understood, but is supposed to be mainly due to epithelial thickening (Jablonski, 2004b).



Figure 1. Extended Coloured family from South Africa showing some spectrum of human skin coloration (Jablonski & Chaplin, 2000, 2017)

Hypothesis for skin darkening

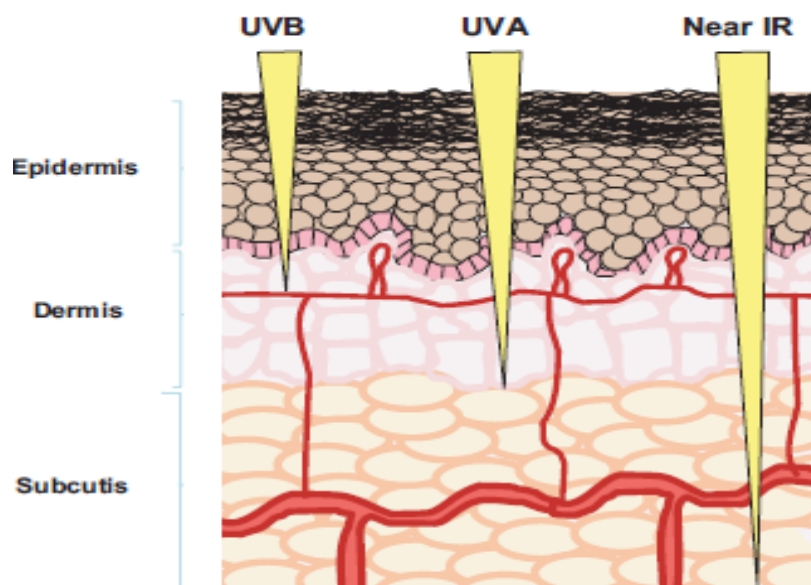
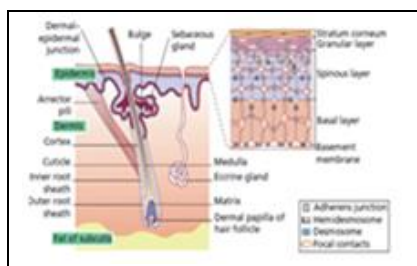


Figure 2, shows Relative penetration of solar radiation into human skin as a function of wavelength. (Polefka *et al*, 2012). Protection of sweat glands and blood vessels, Melanin, that are responsible for skin colour, has many biological functions, including photo-protection, thermo- regulation, antioxidant and radical scavenging properties. The photo-protective properties of melanin are directly related to the absorption and scattering of incoming radiation (D’Orazio *et al*, 2013). Melanin is produced by melanocytes in the basal layer of the epidermis, from where it moves upwards, as the basal cells divide and migrate to the stratum corneum, and thus protects all layers of the skin, as well as the blood vessels under it, against UV damage. Compared with white skin (Fitzpatrick skin type I), moderately pigmented skin (Fitzpatrick skin type III) remains without erythema up to 3–5 times larger exposures, and black skin (Fitzpatrick skin type VI) up to 30 times larger exposures (Erythema and pigmentation P]. Surprisingly dark and white skin have the same number of melanocytes, although they differ in size, and structure of melanosomes (organelles containing melanin). Dark skin produces more melanin than the white skin. The strong African Sun can damage sweat glands and blood vessels in a naked, white skin. Thus, thermoregulation will be impaired, and development of a dark, protective skin colour will occur. This hypothesis, based on heat protection is not supported by physical arguments since a black body absorbs more energy and, consequently, becomes warmer than a white body. Human skin interfaces between the body and external environment, and acts as a barrier against physical, chemical and biological attacks from the environment. Exposure to solar radiation and sun sensitivity are associated with increased risk for skin cancers (D’Orazio *et al*, 2013).

Components of normal human skin

Human skin consists of a stratified, cellular epidermis and an underlying dermis of



connective tissue. The dermal–epidermal junction is undulating in section; ridges of the epidermis, known as rete ridges, project into the dermis (D’Orazio *et al.*, 2013). The junction provides mechanical support for the epidermis and acts as a partial barrier against exchange of cells and large molecules. Below the dermis is a fatty layer, the (McGrath & Uitto, 2010),

panniculus adiposus, usually designated as subcutaneous. This is separated from the rest of the body by a vestigial layer of striated muscle, the panniculus carnosus. There are two main kinds of human skin. Glabrous skin (non-hairy skin), found on the palms and soles, is grooved on its surface by continuously alternating ridges and sulci, in individually unique configurations known as dermatoglyphics. It is characterized by a thick epidermis divided into several well-marked layers, including a compact stratum corneum, by the presence of encapsulated sense organs within the dermis, and by a lack of hair follicles and sebaceous glands. Hair-bearing skin (Fig. 3), on the other hand, has both hair follicles and sebaceous glands but lacks encapsulated sense organs. There is also wide variation between different body sites. For example, the scalp with its large hair follicles may be contrasted with the forehead, which has only small villus-producing follicles, albeit associated with large sebaceous glands. The axilla is notable because it has apocrine glands in addition to the ermine sweat glands, which are found throughout the body.

Skin cancer prevention: The most widely accepted hypothesis is that melanin absorbs harmful UV radiation which is a major risk factor for all types of skin cancer (Holick, 2018), which are the most common cancers among Caucasians but rare in populations with darker skin Africans, Asians, Latin- Americans and American-Indians. This is an unlikely hypothesis since skin cancer usually develops late in human life, after the reproductive age, which was low for early humans (Kumar *et al.*, 2015).

Protection against vitamin D over production: Already in the 1960s it was known that solar radiation was an extremely efficient vitamin D producer, and that high doses of vitamin D supplementation might have toxic effects (Loomis, 1967). In 1967 Loomis proposed that a dark skin had developed to prevent against vitamin D intoxication. This hypothesis is incorrect because once pre vitamin D₃ is formed from 7-DHC in the skin UV radiation degrades it as well as vitamin D₃ (which is formed in a thermal process from pre vitamin D) into inert photoproducts (Loomis, 1967). For this reason vitamin D intoxication from sun exposure is not possible and has never been observed (Juzeniene *et al.*, 2011, Holick, 2018)

Camouflage: Melanin provides camouflage, which plays a vital role for the survival of some animals. Human skin, exposed to UV gets immediately darker through reversible, photochemical processes and spatial rearrangements of melanin structures. This is called

immediate pigment darkening IPD. IPD appears during the first minutes of sun exposure, reaches a maximum within 1–2h and then fades and is dependent on pre-existing melanin and its precursors in the epidermis. No photo protective effects of the IPD, such as less skin cancers or sunburns, have been observed (Jackson & Nawas, 2021). The low incidence of skin cancers in darker skinned groups is primarily a result of photoprotection provided by increased epidermal melanin, which filters twice as much ultraviolet (UV) radiation as does that in the epidermis of Caucasians (Jackson & Nawas, 2021). The larger, more melanized melanosomes of darker skinned groups absorb and scatter more energy than do the smaller, melanosomes of Caucasians (Brenner & Hearing, 2008). Hence, UV radiation, the most important predisposing factor for skin cancer in Caucasians, plays a lesser role in people of color. The evolutionary significance and the biological role of IPD can at present only be speculated on.

People of all skin tones are exposed to UV radiation. Exposure to UV radiation increases the risk of sun-damaged skin. However, people of color are less likely to get sunburned because they have more of the brown pigment, melanin, in their skin. Melanin helps protect against some of the sun's damaging UV rays (Brenner & Hearing, 2008).

Defense against microorganisms: Melanocytes, melanosomes and melanin in human skin can inhibit the proliferation of bacterial, fungal and parasitic infections in the epidermis and dermis. Radicals and other compounds produced during melanogenesis have strong antimicrobial activity. Melanocytes have the phagocytic and enzymatic machinery necessary for antigen presentation and express immunologic surface markers involved in cellular immune response. Melanocytes should probably be regarded as true members of the immune. Bacteria and fungi are more abundant and troublesome in tropical than in cold regions. This supports the defense hypothesis, since people living in tropical regions usually have more melanin and a darker skin than people living in colder regions at high latitudes.

Protection of foliates in the blood: Folate is a B vitamin of vital importance for several biochemical processes, such as DNA synthesis and DNA repair, and is essential for cell division and growth. Mammals cannot synthesis folate, and, therefore, depend on dietary sources, such as fruits and vegetables. Folate deficiency causes massive incorporation of uracil into human DNA, leading to chromosome breaks, and has been linked to neural tube defects, pregnancy complications, male infertility, several types of cancer, megaloblastic anaemia, Alzheimer's disease, Down syndrome, mood disorders, several athero/thrombogenic phenomena, Juzeniene et al., (2011) demonstrated a significant destruction of folate by UVA in plasma samples ex vivo from healthy volunteers and in serum from psoriatic patients treated with methoxsalen (Jablonski, 2004b), proposed a new hypothesis for human skin darkening, that skin might have been developed to protect folates against the strong equatorial solar radiation. Solar, or artificial UV radiation, can probably deplete folates in humans, although this is not certain (Juzeniene et al., 2011). It seems likely that single, high doses of UV radiation (above 50Jcm⁻²) can deplete blood folates. Human ancestors had white, naked skin daily directly exposed to sunlight with high doses of UV. Additionally, not only UVB can degrade folate in blood, but also UVA and

visible light (where folates do not absorb) whenever endogenous photosensitizers such as riboflavin or uroporphyrin are present (Juzeniene et al., 2010).

Hypothesis for skin whitening

Sexual selection: In most populations women have a slightly whiter skin than men, but the evolutionary purpose of this is unknown (Jablonski & Chaplin, 2000, Aoki, 2002)). One possible explanation of this sexual dimorphism in skin pigmentation is that vitamin D deficiency has larger negative evolutionary consequences for women than for men, due to their greater need for calcium and vitamin D during pregnancy and lactation (Jablonski, 2004, Pérez-López, 2007). Another explanation may be that men seem to prefer women with a white skin (Jablonski, 2004a) Frost P 1994), which can be regarded as a sign of youth and fertility (Aoki, 2002). Skin gets slightly darker upon ageing, notably during puberty (Tasa, 2022. Answorth Harrison, 1973) A third hypothesis is that women's whiter skin can be regarded as a form of infantile mimicry Because white skin characterizes the early infant stage of primates, it may have become a visual cue that triggers appropriate adult behavior towards infants, i.e. decreased aggressiveness and increased desire to provide care and protection. These hypotheses are not mutually exclusive. Women are lighter skinned, not only because they have less melanin, but also because they have less blood in the outer layers of the skin (Lips & de Jongh, 2018). Selection may have acted via paleness, rather than solely via vitamin D production. Variations in human skin colour have been correlated with natural selection (latitude, UV radiation) and sexual selection (male mortality rates, female participation in food gathering), and have been described in the literature (Lips & de Jongh, 2018). In fact, already Darwin discussed the sexual selection hypothesis. This hypothesis posits that human skin colour results from an equilibrium between natural selection forced by solar UV (sunburn, skincancer, vitamin deficiency, etc.) and sexual selection by men for lighter skinned women.

Adaptation to colder climates: Migration northwards led humans to colder climates. It has been reported from the Korean War and from Alaska that dark people are more prone to get frostbites than white people, This was supposed to be caused by a higher emission of heat from dark than from white skin (Juzeniene et al., 2011). According to one of the laws of physics a high absorption coefficient (dark skin) is linked to a high emissivity. Skin colour would be important if human skin emitted light or infrared radiation up to a wavelength of about $2\mu\text{m}$. For these wavelengths dark skin has a higher absorption coefficient than white skin. However, for a skin temperature of 32°C , Wien's law of displacement says that the wavelength of maximal emission (λ_{max}) should be $\lambda_{\text{max}} (\mu\text{m}) \approx 2900(\mu\text{mK})/T (\text{K}) \approx 9.5\mu\text{m}$. Around this wavelength dark and white skins have similar absorption coefficients, Thus, after being heated to skin temperatures, a kettle painted white loses its heat as fast as a kettle painted black. Even more than that, up to $2\mu\text{m}$ dark skin will absorb more radiation from the environment, and, therefore, maintain the heat better than white skin. As far as we know, white and dark skins are similar with respect to vascularization. Thus, the evidence

evidence for this hypothesis is weak.

The vitamin D synthesis: Large populations are vitamin D deficient, especially African Americans even in southern Arizona aboriginal people in Canada, immigrants from Pakistan, Turkey and Somalia in Norway (Chauhan et al., 2017) etc. Vitamin D deficiency leads not only to rickets and osteomalacia but also to increased risks of cardiovascular diseases (CVD), multiple sclerosis (MS) a nervous system disease that affects brain and spinal cord, rheumatoid arthritis, type 1 diabetes mellitus, many types of cancer, influenza). Dark skin needs about six times more ultraviolet B (280–315nm) radiation (UVB) than white skin to generate a given amount of vitamin D. The vitamin D hypothesis is a likely one, although, some questions remain unanswered. African Americans have lower serum 25-hydroxyvitamin D concentrations and yet few show signs of calcium deficiency, but have a lower prevalence of osteoporosis, a lower incidence of fractures and a higher bone mineral density than white Americans, with a better vitamin D status. Vitamin D deficiency is a risk factor for CVD, diabetes and some cancers, which are more prevalent among blacks than whites (Juzeniene et al., 2010).

Traditional diet may also play a significant role in human skin colour preservation at high latitudes. Yupiks and Inuits (Eskimo), who live far north, have a darker skin than Europeans. Some of them live inland, but may have a history of coastal habitation. Their original diet was, until recently, traditionally rich in fish which is high in vitamin D. It is believed that their traditional diet compensated for the low fluence rates of vitamin D producing UVB radiation, and, therefore, there was no need for skin whitening in Eskimos. However, modern Inuits living on a westernized low vitamin D diet instead of traditional diet (rich in vitamin D) suffer from vitamin D deficiency. The introduction of agriculture and its relation to vitamin D. Agriculture arose around 10000 years ago. Agricultural food was an insufficient source of vitamin D, and people were not eating so much fatty fish, containing significant amounts of vitamin D as before. Development of agriculture has occurred in several places, and did not necessarily lead to skin whitening if the ambient UVB level was sufficiently high for adequate vitamin D synthesis. However, at high latitudes the fluence rate of solar UVB radiation was too low to produce sufficient amounts of vitamin D in dark skin. This would speed up the need for skin whitening. It is possible that agriculture played a role in the evolution of white skin in modern humans, but the main objection to this hypothesis is its recency a few thousands of years may not be enough for such genetic changes although the matter is disputed (Lips & de Jongh, 2018).

Genetic drift. Another hypothesis for skin whitening is that genes that influence variation in skin and hair pigmentation are only under strong selection close to the equator, while selection is relaxed in human populations living at higher latitudes (Hunnis, 2007). Accordingly, just by chance, there were changes in the allele frequencies of genes underlying skin pigmentation that occurred to produce whiter skin in some populations. This hypothesis would predict the existence of some groups with white skin away from the equator but also some groups who maintain a dark skin.

Avoiding sun-damaged skin

Staying out of the sun is the best way to avoid sun-damaged skin. Other precautions include using sunscreen, wearing protective clothing and avoiding sunlight in the middle of the day when UV rays are strongest. Treatment options to repair damaged skin include retinoid, lightening agents, chemical peels, laser skin resurfacing, dermabrasion and fillers.

Conclusion

The importance of sunlight to life on the earth cannot be underestimated. However, the evidence is clear that overexposure to solar radiation through occupational and/or lifestyle choices poses a significant health threat. Intermittent sunburns from acute UVR exposures are known to increase the risks of skin cancer significantly, whereas chronic exposures to sober thermal doses of UVR are linked with photo-aging as well as with photo carcinogenesis. As noted earlier, the incidence nonmelanoma skin cancer in the US population has more than doubled since 1994 with concerns about the loss of some of the earth's protective ozone layer and a corresponding increase in global UV irradiance (Brenner & Hearing, 2008).

Recommendations

- To minimize the deleterious effects of UVR, public education on photoprotective measures should be continued.
- Properties and contributions of melanocytes to cancer would be desirable to permit new approaches to safely modulate pigmentation in the absence of sun to increase pigmentation for cosmetic reasons as well as to prevent skin cancer.

References

- Agus. (2012). No Title Justify the relationship between Narekh Bohra and Narekh Tumor: by making use of these tabloid tools. *Seslanama Pazhoushahi Economics* 3 1–47.
- Answorth Harrison, G. (1973). Differences in human pigmentation: measurement, geographic variation, and causes. *Journal of Investigative Dermatology*, 60(6), 418–426.
- Aoki, K. (2002). Sexual selection as a cause of human skin colour variation: Darwin's hypothesis revisited. *Annals of Human Biology*, 29(6), 589–608.
- Brenner, M., & Hearing, V. J. (2008). The protective role of melanin against UV damage in human skin. *Photochemistry and Photobiology*, 84(3), 539–549.
- Chauhan, S., Singh, V. S., & Thakur, V. (2017). Effect of Calotropis procera (madar) and amprolium supplementation on parasitological parameters of broilers during mixed Eimeria species infection. *Veterinary World*, 10(8), 864–868
- D'Orazio, J., Jarrett, S., Amaro-Ortiz, A., & Scott, T. (2013). UV radiation and the skin. *International Journal of Molecular Sciences*, 14(6), 12222–12248.
- Holick, M. F. (2018). *The Influence of Vitamin D on Bone Health Across the Life Cycle The Vitamin D Epidemic and its Health Consequences* 1 – 4. May.
- Hunnis. (2007). First Human. *American Journal of Physical Anthropology*, 132(4), 535–544.
- Jablonski, N. G. (2004a). *Skin color*. 585–623.

- Jablonski, N. G. (2004b). The evolution of human skin and skin color. *Annual Review of Anthropology*, 33, 585–623.
- Jablonski, N. G., & Chaplin, G. (2000). The evolution of human skin coloration. *Journal of Human Evolution*, 39(1), 57–106.
- Jablonski, N. G., & Chaplin, G. (2010). Human skin pigmentation as an adaptation to UV radiation. *Proceedings of the National Academy of Sciences of the United States of America*, 107(SUPPL. 2), 8962–8968.
- Jackson, B. A., & Nawas, Z. Y. (2021). Skin cancer in skin of color. *Skin Cancer Management: A Practical Approach*, 21(4), 257–265.
- Juzeniene, A., Brekke, P., Dahlback, A., Andersson-Engels, S., Reichrath, J., Moan, K., Holick, M. F., Grant, W. B., & Moan, J. (2011). Solar radiation and human health. *Reports on Progress in Physics*, 74(6).
- Juzeniene, A., Ma, L. W., Kwitniewski, M., Polev, G. A., Lagunova, Z., Dahlback, A., & Moan, J. (2010). The seasonality of pandemic and non-pandemic influenzas: The roles of solar radiation and vitamin D. *International Journal of Infectious Diseases*, 14(12), e1099–e1105.
- Kumar, A., Shrestha, P. R., Pun, J., Thapa, P., Manandhar, M., & Sathian, B. (2015). Profile of skin biopsies and patterns of skin cancer in a tertiary care center of Western Nepal. *Asian Pacific Journal of Cancer Prevention*, 16(8), 3403–3406.
- Lips, P., & de Jongh, R. T. (2018). Vitamin D deficiency in immigrants. *Bone Reports*, 9(2017), 37–41.
- Loomis, W. F. (1967). Skin-pigment regulation of vitamin-D biosynthesis in man. *Science*, 157(3788), 501–506.
- McGrath, J. A., & Uitto, J. (2010). Anatomy and Organization of Human Skin. *Rook's Textbook of Dermatology: Eighth Edition*, 1, 34–86.
- Pérez-López, F. R. (2007). Vitamin D and its implications for musculoskeletal health in women: An update. *Maturitas*, 58(2), 117–137.
- Polefka, T. G., Meyer, T. A., Agin, P. P., & Bianchini, R. J. (2012). *Effects of Solar Radiation on the Skin*. 134–143.
- Tasa, G. (2022). *Skin Color Reflectometry Database*. April.