

## The Biological Significance of Melanin in Skin, Health and Evolution

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### DESCRIPTION

Melanin is a remarkable pigment responsible for the variety of skin, hair, and eye colours in humans and other animals. Its biological role goes beyond mere aesthetics; it plays a critical part in protecting the body from harmful Ultra Violet (UV) radiation, contributes to the immune system and even impacts certain neurological functions. Melanin is a natural pigment produced by specialized cells called melanocytes, found primarily in the skin, eyes and hair. There are three main types of melanin: Eumelanin, pheomelanin, and neuromelanin. Eumelanin is the most common and provides brown to black pigmentation, while pheomelanin gives red to yellow tones. Neuromelanin is found in the brain and is involved in neurological processes.

The production of melanin, known as melanogenesis, is regulated by the enzyme tyrosinase and influenced by genetic factors, hormonal changes, and environmental exposures like sunlight. When UV radiation from the sun strikes the skin, melanocytes respond by producing more melanin, which absorbs and dissipates the radiation, protecting cells from damage. Melanin's most prominent function is to protect the skin from UV radiation, a key factor in skin damage, premature aging, and the development of skin cancers like melanoma. When skin is exposed to sunlight, melanin absorbs and scatters UV rays, preventing them from penetrating deeper into the skin and damaging the DNA in cells. This protective role has evolutionary significance, as populations that evolved in regions with intense sunlight generally have higher melanin levels in their skin, providing greater UV protection.

In addition to UV protection, melanin serves other critical functions. Antioxidant properties as it helps neutralize free radicals, unstable molecules that can cause oxidative stress and lead to cellular damage. By reducing oxidative stress, melanin plays a role in minimizing inflammation and preventing various diseases. Melanin has been linked to immune function. It has the ability to trap certain pathogens and can influence immune cells, contributing to the body's defense against infections and disease. Neuromelanin, found in certain parts of the brain, is believed to play a role in protecting neurons and maintaining brain health. Its depletion has been associated with

neurodegenerative diseases like Parkinson's disease, indicating that melanin's importance extends beyond pigmentation.

The diversity of human skin tones, hair colours and eye colours is due to varying levels and types of melanin produced in the body. This variation is the result of genetic differences influenced by evolutionary pressures. In regions closer to the equator, where sunlight is intense, individuals tend to have higher concentrations of eumelanin, resulting in darker skin tones. This high melanin content provides greater protection against UV radiation and reduces the risk of sunburn and skin cancer. In contrast, populations in areas with less sunlight, such as northern Europe, have evolved to produce less melanin. Lighter skin allows for more efficient synthesis of vitamin D, which is critical in regions with limited sunlight exposure.

While melanin plays a protective role, its concentration also impacts certain risks. People with lighter skin, who produce less melanin, are more susceptible to UV damage, increasing their risk of developing skin cancer. On the other hand, darker-skinned individuals have a lower risk of skin cancer due to their higher melanin levels but may face challenges with vitamin D synthesis in low-sunlight environments.

Abnormalities in melanin production or distribution can lead to various skin conditions. Vitiligo occurs when melanocytes are destroyed, leading to patchy loss of skin pigmentation. Although the exact cause is unknown, it is believed to be an autoimmune disorder where the body attacks its own pigment-producing cells. Albinism is a genetic condition in which individuals produce little to no melanin. This results in very light skin, hair, and eye colour, and individuals with albinism are highly sensitive to sunlight and at greater risk for skin cancer. Melasma is a condition characterized by dark, discoloured patches on the skin, often triggered by hormonal changes such as pregnancy or sun exposure. It is more common in women and individuals with darker skin tones. Additionally, hyperpigmentation can occur when excess melanin is produced, leading to dark spots on the skin. This can be caused by sun damage, inflammation, or certain medications. Hypopigmentation, on the other hand, results in lighter patches of skin due to a lack of melanin production.

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Melanin's impact on human health is not limited to the skin. In the eyes, melanin helps protect the retina by absorbing excess light and preventing damage from UV rays. People with lighter eyes may be more prone to light sensitivity and eye damage over time. Additionally, some studies suggest that melanin plays a role in hearing, as it is present in the inner ear and helps protect against noise-induced damage. Neuromelanin's role in the brain has intrigued researchers. Neuromelanin is abundant in regions of the brain that control movement, such as the substantia nigra. A loss of neuromelanin in this region is associated with

Parkinson's disease, though the exact relationship between neuromelanin and neurodegeneration is still being studied.

Melanin is far more than just a pigment; it is a vital biological compound with far-reaching effects on human health. Its role in protecting the skin from UV radiation, contributing to immune and neurological functions and influencing the diversity of human appearance highlights its importance in both biology and evolution.