Human hair color

Hair color is the pigmentation of hair follicles due to two types of melanin: eumelanin and pheomelanin. Generally, if more eumelanin is present, the color of the hair is darker; if less eumelanin is present, the hair is lighter. Levels of melanin can vary over time causing a person's hair color to change, and it is possible to have hair follicles of more than one color.

A variety of the hair colors. From top left, clockwise: black,brown, blonde, white, red.

Particular hair colors are associated with ethnic groups. The shades of human hair color are assessed using the **Fischer–Saller scale.** The Fischer–Saller scale, named after Eugen Fischer and Karl Saller, is used in physical anthropology and medicine to determine the shades of hair color. The scale uses the following designations: A (light blond), B to E (blond), F to L (blond), M to O (dark blond), P to T (brown), U to Z (dark brown/black) andRoman numerals I to IV (red) and V to VI (red blond).[1] See also the Martin–Schultz scale for eye color.

Genetics and biochemistry of hair color

Two types of pigment give hair its color: eumelanin and pheomelanin. Pheomelanin colors hair orange and yellow. All humans have some pheomelanin in their hair. Eumelanin, which has two subtypes of black or brown, determines the darkness of the hair color. A low concentration of brown eumelanin results in blond hair, whereas a higher concentration of brown eumelanin will color the hair brown. High amounts of black eumelanin result in black hair, while low concentrations give gray hair.

Pheomelanin is more chemically stable than black eumelanin, but less chemically stable than brown eumelanin, so it breaks down more slowly when oxidized. This is why bleach gives darker hair a reddish tinge during the artificial coloring process. As the pheomelanin continues to break down, the hair will gradually become orange, then yellow, and finally white.

The genetics of hair colors are not yet firmly established. According to one theory, at least two gene pairs control human hair color.

One phenotype (brown/blond) has a dominant brown allele and a recessive blond allele. A person with a brown allele will have brown hair; a person with no brown alleles will be blond. This explains why two brown-haired parents can produce a blond-haired child.

The other gene pair is a non-red/red pair, where the non-red allele (which suppresses production of pheomelanin) is dominant and the allele for red hair is recessive. A person with two copies of the red-haired allele will have red hair.

The two-gene model does not account for all possible shades of brown, blond, or red (for example, platinum blond versus dark blond/light brown), nor does it explain why hair color sometimes darkens as a person ages. Several gene pairs control the light versus dark hair color in a cumulative effect. A person's genotype for a multifactorial trait can interact with environment to produce varying phenotypes (see quantitative trait locus).

Natural hair colors

Natural hair color can be black, brown, blond, red, gray or white.

Black hair

Natural black hair

Deepest brunette hair

Brown hair

Medium brown hair

Natural brown hair

Light brown hair

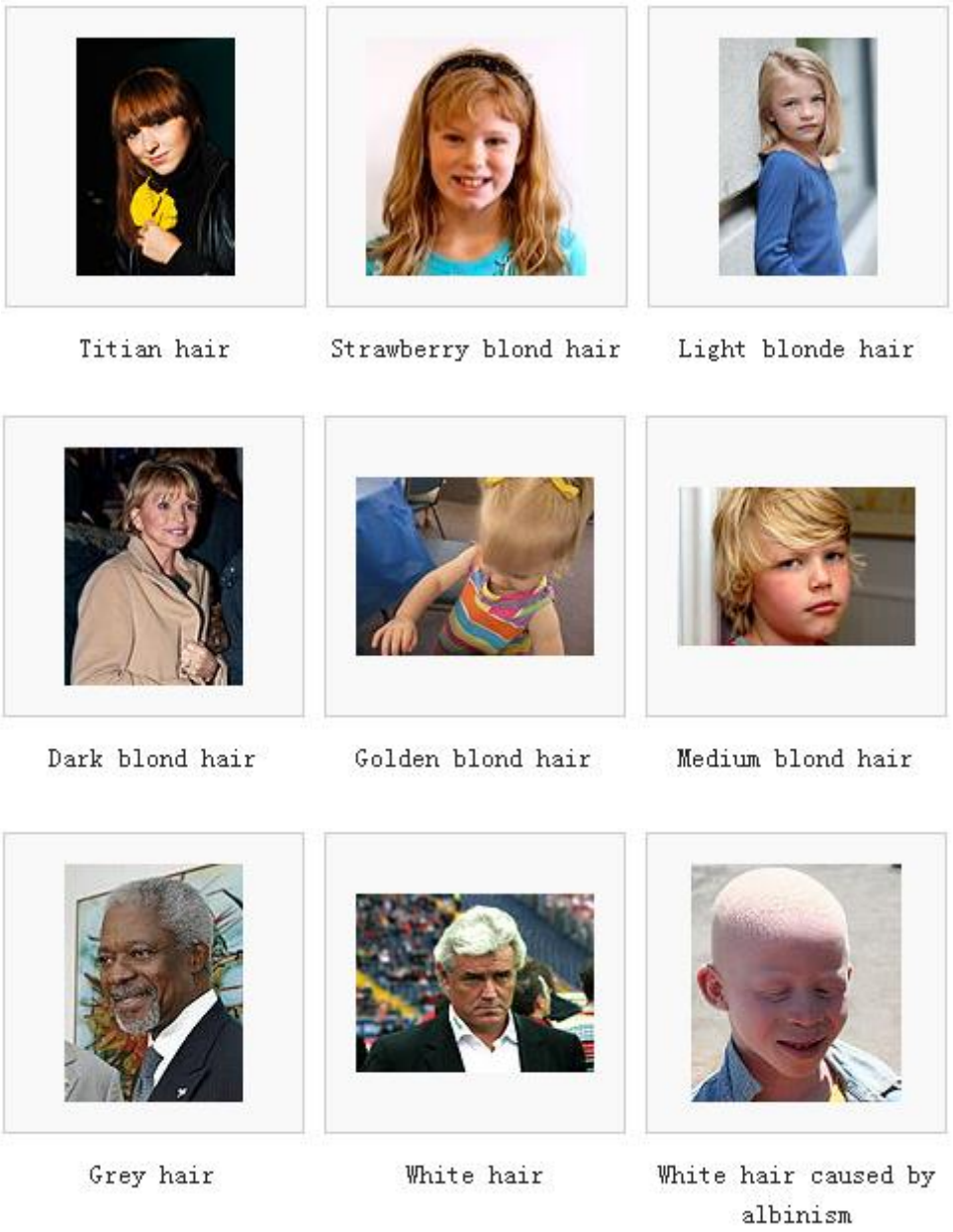
Chestnut brown hair

Light chestnut brown hair

Auburn hair

Copper hair

Red hair



Titian hair | Strawberry blond hair | Light blonde hair

Dark blond hair | Golden blond hair | Medium blond hair

Grey hair | White hair | White hair caused by albinism

Black hair

Black hair is the darkest color. It has large amounts of eumelanin and is less dense than other hair colors. It can range from soft black to brown-black, blue-black or jet-black.[2]

Brown hair

Brown hair is characterized by higher levels of eumelanin and lower levels of pheomelanin. Of the two types of eumelanin (black and brown), brown-haired people have brown eumelanin; they also usually have medium-thick strands of hair. Brown-haired girls or women are often known as brunette.

Blond hair

Blond (or *blonde*) hair ranges from nearly white (platinum blond, tow-haired) to a dark golden blond. Strawberry blond, a mixture of blond and red hair, is a much rarer type containing the most pheomelanin.

Blond hair can have almost any proportion of pheomelanin and eumelanin, but has only small amounts of both. More pheomelanin creates a more golden blond color, and more eumelanin creates an ash blond. Many children born with blond hair develop darker hair as they age, with the majority of natural blonds developing a hair color of a dark "gunmetal" hue by the time they reach middle age. Pregnancy hormones hasten this process. Natural blond hair is rare in adulthood, with some reports stating that only about 2% of the world's population is naturally blond.[3] Blond hair is most commonly found in Northern and Eastern Europeans and their descendants but can be found spread around most of Europe. Blond hair is rare outside of Europe but can also be found in populations in South America and Australia. Studies in 2012 showed that naturally blond hair of Melanesians is caused by a recessive mutation in tyrosinase-related protein 1 (TYRP1). In the Solomon Islands, 26% of the population carry the gene; however, it is absent outside of Oceania.[4]

Auburn hair

Auburn hair ranges along a spectrum of light to dark red-brown shades. The chemicals which cause auburn hair are eumelanin (brown) and pheomelanin(red), with a higher proportion of red-causing pheomelanin than is found in average brown hair. It is most commonly found in individuals of Northern and Western European descent.

Chestnut hair

Chestnut hair is a hair color which is a reddish shade of brown hair. In contrast to auburn hair, the reddish shade of chestnut is darker. Chestnut hair is common among the native peoples of Northern, Central, Western, and Eastern Europe.

Ginger/Red hair

Red hair ranges from light strawberry blond shades to titian, copper and less commonly "true" red. It is caused by a variation in the *Mc1r* gene and is recessive.[5] Red hair has the highest amounts of pheomelanin, around 67%, and usually low levels of eumelanin. At 1-2% of the population, it is the least common hair color in the world. It is most prominently found in Scotland, Ireland and England. Scotland has the highest proportion of redheads; 13 percent of the population has red hair and approximately 40 percent carries the recessive redhead gene. [6][7][8]

Gray and white hair

Gray or white hair—sometimes colloquially called "salt and pepper" when it is 'peppered' throughout dark hair—is not caused by a true gray or white pigment, but is due to a lack of pigmentation and melanin. The clear hairs appear as gray or white because of the way light is reflected from the hairs. Gray hair color typically occurs naturally as people age (see "Aging or achromotrichia", below). For some people this can happen at a very young age (for example, at the age of 10). The same is true for children with white hair, caused by Albinism. In some cases, gray hair may be caused by thyroid deficiencies, Waardenburg syndrome or a vitamin B_{12} deficiency.[9] At some point in the human life cycle, cells that are located in the base of the hair's follicles slow, and eventually stop producing pigment.[10]

The Journal of Investigative Dermatology published a study in 2005 which found that Caucasian people will begin to gray in their twenties and early thirties while Asian people begin graying in their late thirties, but most African people can retain their original hair color until their mid-forties. People with albinism may have white hair due to low amounts of melanin.

Conditions affecting hair color

Aging or achromotrichia

Children born with some hair colors may find it gradually darkens as they grow. Many blonde, strawberry blond, light brown, or red haired infants experience this. This is caused by genes being turned off and on during early childhood and puberty.[11]

Changes in hair color typically occur naturally as people age, eventually turning the hair gray and then white. This is called achromotrichia. Achromotrichia normally begins in the early to mid-twenties in men and late twenties in women. More than 60 percent of Americans have some gray hair by age 40. The age at which graying begins seems almost entirely due to genetics. Sometimes people are born with gray hair because they inherit the trait.

The order in which graying happens is usually: nose hair, hair on the head, beard, body hair, eyebrows.[12]

Two genes appear to be responsible for the process of graying, *Bcl2* and *Bcl-w*[13] The change in hair color occurs when melanin ceases to be produced in the hair root and new hairs grow in without pigment. The stem cells at the base of hair follicles produce melanocytes, the cells that produce and store pigment in hair and skin. The death of the melanocyte stem cells causes the onset of graying.[14] It remains unclear

why the stem cells of one hair follicle may die well over a decade before those in adjacent follicles less than a millimeter apart.

The Journal of the Federation of American Societies for Experimental Biology has reported that human gray hair is triggered by the accumulation of hydrogen peroxide. They found abnormally low levels of the enzyme catalase, which breaks down hydrogen peroxide and relieves oxidative stress in patients suffering from vitiligo. Since vitiligo can cause eyelashes to turn white, the same process is believed to be involved in hair on the head (and elsewhere) due to aging.[15]

The anti-cancer drug imatinib has recently been shown to reverse the graying process.[16] However, it is much too expensive with potentially severe and deadly side effects to be used to alter a person's hair color. Nevertheless, if the mechanism of action of imatinib on melanocyte stem cells can be discovered, it is possible that a safer and less expensive substitute drug might someday be developed. It is not yet known whether imatinib has an effect on catalase, or if its reversal of the graying process is due to something else.[17]

Stress

Anecdotes report that stress, both chronic and acute, may induce achromotrichia earlier in individuals than it otherwise would have.[18] Proponents point to survivors of disasters, such as *Titanic* survivor Harold Bride, or high-level politicians such as Bill Clinton or Barack Obama to support this view. There is some evidence for chronic stress causing premature achromotrichia,[19] but no definite link has been established.

Medical conditions

Albinism is a genetic abnormality in which little or no pigment is found in human hair, eyes, and skin. The hair is often white or pale blond. However, it can be red, darker blond, light brown, or rarely, even dark brown.

Vitiligo is a patchy loss of hair and skin color that may occur as the result of an auto-immune disease. In a preliminary 2013 study, researchers treated the buildup of hydrogen peroxide which causes this with a light-activated pseudo-catalase. This produced significant media coverage that further investigation may someday lead to a general non-dye treatment for grey hair.[20]

Malnutrition is also known to cause hair to become lighter, thinner, and more brittle. Dark hair may turn reddish or blondish due to the decreased production of melanin. The condition is reversible with proper nutrition.

Werner syndrome and pernicious anemia can also cause premature graying.

A 2005 uncontrolled study demonstrated that people 50–70 years of age with dark eyebrows but gray hair are significantly more likely to have type II diabetes than those with both gray eyebrows and hair.[21]

Artificial factors

A 1996 British Medical Journal study found that tobacco smoking may cause premature graying. Smokers were found to be four times more likely to begin graying prematurely, compared to nonsmokers.[22]

Gray hair may temporarily darken after inflammatory processes, after electron-beam-induced alopecia, and after some chemotherapy regimens. Much remains to be learned about the physiology of human graying.[23]

There are no special diets, nutritional supplements, vitamins, nor proteins that have been proven to slow, stop, or in any way affect the graying process, although many have been marketed over the years. However, French scientists treating leukemia patients with a new cancer drug noted an unexpected side effect: some of the patients' hair color was restored to their pre-gray color.[24]

Changes after death

The hair color of mummies or buried bodies can change. Hair contains a mixture of black-brown-yellow eumelanin and red pheomelanin. Eumelanin is less chemically stable than pheomelanin and breaks down faster when oxidized. It is for this reason that Egyptian mummies have reddish hair. The color of hair changes faster under extreme conditions. It changes more slowly under dry oxidizing conditions (such as in burials in sand or in ice) than under wet reducing conditions (such as burials in wood or plaster coffins).[25]

Hair coloring

Hair color can be changed by a chemical process. Hair coloring is classed as "permanent" or "semi-permanent".

A hairdresser colors a client's hair.

Permanent hair color means that the hair's structure has been chemically altered until it is eventually cut away. This does not mean that the synthetic color will remain permanently. During the process, the natural color is removed, one or more shades, and synthetic color has been put in its place. All pigments wash out of the cuticle. Natural color stays in much longer and artificial will fade the fastest (depending on the color molecules and the form of the dye pigments)

Permanent hair color gives the most flexibility because it can make hair lighter or darker as well as changing tone and color, but there are negatives. Constant (monthly or six-weekly) maintenance is essential to match new hair growing in to the rest of the hair, and remedy fading. A one-color permanent dye creates a flat, uniform color across the whole head, which can look unnatural and harsh, especially in a fair shade. To combat this, the modern trend is to use multiple colors - usually one color as a base with added highlights or lowlights in other shades.

Semi-permanent color washes out over a period of time – typically four to six weeks, so root regrowth is less noticeable. The final color of each strand is affected by its original color and porosity, so there will be subtle variations in color across the head - more natural and less harsh than a permanent dye. However, this means that gray and white hair will not dye to the same color as the rest of the head (in fact, some white hair will not absorb the color at all). A few gray and white hairs will blend in sufficiently not to be noticeable, but as they become more widespread, there will come a point where a semi-permanent alone will not be enough. The move to 100% permanent color can be delayed by using a semi-permanent as a base color, with permanent highlights.

Semi-permanent hair color cannot lighten hair. Hair can only be lightened using chemical lighteners, such as bleach. Bleaching is always permanent because it removes the natural pigment.

"Rinses" are a form of temporary hair color, usually applied to hair during a shampoo and washed out again the next time the hair is washed.

References

1. "Change in Hair Pigmentation in Children from Birth to 5 Years in a European Population (Longitudinal Study)". Forensic Science Communications. Retrieved 2014-03-19.
2. . Blackish hair is common in almost all world continents, and most second and third world countries have it as the dominant hair color."Hair Color:Two Hair Colors for an Infinite Pallette". Retrieved 2010-02-27.
3. "Race". Webspace.ship.edu. Retrieved 2012-04-03.
4. Melanesian blond hair is caused by an amino acid change in TYRP1.Kenny EE, Timpson NJ, Sikora M, Yee MC, Moreno-Estrada A, Eng C, Huntsman S, Burchard EG, Stoneking M, Bustamante CD, Myles S. (May 2012). *Science* **336** (6081): 554. doi:10.1126/science.1217849.PMC 3481182. PMID 22556244http://europepmc.org/articles/PMC3481182
5. In males, the supposedly recessive trait is often expressed in parts of the facial hair or beard. Valverde P, Healy E, Jackson I, Rees JL, Thody AJ (November 1995). "Variants of the melanocyte-stimulating hormone receptor gene are associated with red hair and fair skin in humans". *Nat. Genet.* **11** (3): 328–30.doi:10.1038/ng1195-328. PMID 7581459.
6. "Scientists question whether rare reds are headed for extinction". Azcentral.com. 2005-05-05. Retrieved 2012-04-03.
7. "The Genetics of Red Hair: What Causes Natural Red Hair?". Brighthub.com. 2009-09-04. Retrieved 2012-04-03.
8. "Michigan twins featured in book about rare red hair". MLive.com. Retrieved 2012-04-03.
9. Juangbhanit C, Nitidanhaprabhas P, Sirimachan S, Areekul S, Tanphaichitr VS (June 1991). "Vitamin B_{12} deficiency: report of a childhood case". *J Med Assoc Thai* **74** (6): 348–54. PMID 1744541.
10. Weir, Sarah B. (2012-10-02). "Why does hair turn grey? - Yahoo! Lifestyle UK". Uk.lifestyle.yahoo.com. Retrieved 2012-11-10.
11. "Understanding Genetics: Human Health and the Genome". Retrieved 2011-07-25.
12. **(Japanese)** "鼻毛にも白髪は生えるの？ ". Retrieved 3 July 2012.
13. "Research yields clues to why hair turns gray". Associated Press. Retrieved 5 August 2011.
14. Nishimura EK, Granter SR, Fisher DE. *Mechanisms of hair graying: Incomplete melanocyte stem cell maintenance in the niche*.
15. http://www.medicaldaily.com/articles/15163/20130503/cure-gray-hair-here-study-claims.htm
16. "Imatinib Mesylate and Gray Hair".

17. "Cancer drug restores hair colour". *BBC News*. 2002-08-08.
18. Saling, Joseph. "The Effects of Stress on Your Hair". Web MD. Retrieved 14 August 2013.
19. Ballantyne, Coco. "Fact or Fiction?: Stress Causes Grey Hair". Scientific American. Retrieved 14 August 2013.
20. http://www.fileymercury.co.uk/news/health-news/no-evidence-of-cure-to-prevent-hair-going-grey-1-5654448
21. Department of Dermatology, Academic Teaching Hospital Dresden-Friedrichstadt (2005 December;14). "Eyebrow color in diabetics".*Acta Dermatovenerol Alp Panonica Adriat.* **14** (4): 157–60.PMID 16435045.
22. Mosley JG, Gibbs AC (1996). "Premature grey hair and hair loss among smokers: a new opportunity for health education?". *BMJ* **313**(7072): 1616. doi:10.1136/bmj.313.7072.1616. PMC 2359122.PMID 8991008.
23. Cline DJ (April 1988). "Changes in hair color". *Dermatol Clin* **6**(2): 295–303. PMID 3288386.
24. "Cancer drug restores hair colour". *BBC News*. 2002-08-08.
25. "Interactive Dig Hierakonpolis - Archaeological Hair". Archaeology.org. Retrieved 2012-04-03.