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Research Progress in Composition, Classification and Influencing Factors of Hair

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Abstract

Human hair is a natural fiber with keratin and keratin-related proteins as a main component. Externally, hair is a thin, pliable tube of dead, fully keratinized epithelial cells, while inside the skin, it is part of a single living hair follicle. In addition to a large amount of protein, hair also contains low levels of lipids and pigments. The hair also has its own ecological balance system. Although the lipid content in hair is much lower than the protein content, it plays an important role in hair and influences hair texture to some extent. For example, prevent hair breakage and thinning; To act as a barrier to moisture loss; and improve the gloss, elasticity and tensile strength of the hair stem. Environment, hair dressing and daily care can all cause hair damage to varying degrees. Factors such as ultraviolet light and chemicals can make hair dry, rough, dull, stiff and brittle by destroying the proteins, pigment sand lipid sin the hair. In this paper, the composition, classification and influencing factors of hair were reviewed. The composition and function of lipids in hair were investigated emphatically. It aims to improve people's understanding of the physical and chemical properties and structure of hair. It provides reference value for the research and development of hair cosmetics for different hair states and washing purposes. The function of hair lipids on hair is not accurate. In addition, there is still some controversy on the existing role of hair lipids, which needs further research.

Keywords: Hair, Protein, Lipid, Microorganisms, Factors

Introduction

Hair is a derivative of the epidermis. Its main function is to protect the skin from mechanical damage and promote thermostatic temperature. The human scalp has both protective and cosmetic or decorative functions. The scalp acts as insulation, protecting the head from the elements. Hair protects the scalp from sunburn, other optical radiation and mechanical wear and tear. In addition, the general function of all hairs is as sensory receptors, since all hairs have sensory nerve endings. Sensory receptor function can enhance the protective effect of hair. Hair cuticles are closely related to the texture and shine of hair. Healthy hair has an even, intact and undamaged cuticle, reflecting smooth, silky hair, while damaged hair is rough, dry and dull. Hair is a protein fiber (85%) and contains low levels of lipids (1%–5%) and moisture (10%).

The Physiological Structure of Hair and its Differences

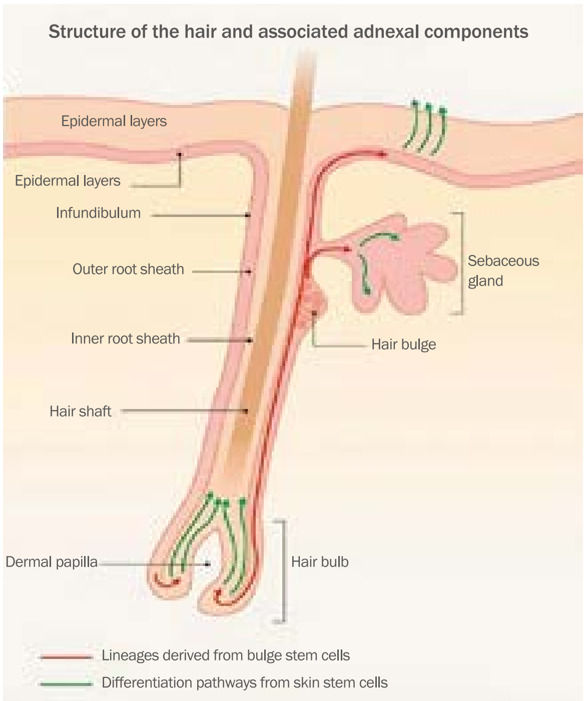

Figure 1. Structure of hair and associated accessories.
This figure also defines the major source of stem cells within the hair bulge. These cells can give rise to hair follicles, sebaceous glands and interfollicular epidermis. Epidermal stem cells are also found within the basal laver of the epidermis. Mesenchymal stem cells are present surrounding the hair follicle within the dermis. and in the subcutaneous fat. (Source: Lai-Cheong & McGrath, 2021.)

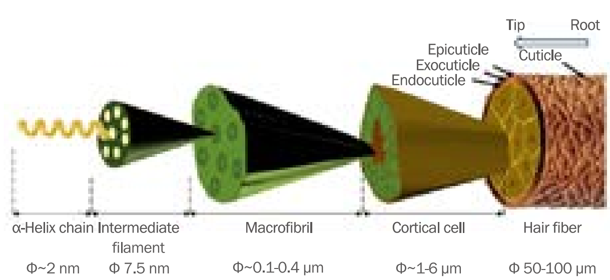

Figure 2. Schemati diagram of human hair hierarchy from α-helix chain to whole section.
(Source: Yu *et al*., 2017.)

1. Physiological structure

Hair has two structures: follicles inside the skin and hair stems outside the skin (Figure 1) (Robbins, 2011; Lai-Cheong & McGrath, 2021). Within the skin, the base of the hair follicle consists of the dermal papilla, located near the center of the bulb, which is important for hair follicle development and controls the three stages of hair growth1. Outside the skin, hair is a thin and flexible tube composed of dead and completely keratinized epithelial cells, which is composed of cortex and cuticle cells located outside and continuous or discontinuous medulla located inside (Figure 2) (Buffoli *et al*., 2014; Yu *et al*., 2017). The cortex, the largest part of the hair, is made up of about 50-60% of the large fibers, composed of microfiber rods embedded in the matrix, it is the main component of the hair fibers and plays an important role in the physical and mechanical properties of the hair (Buffoli *et al*., 2014).

2. Difference

There are two main differences, one is the difference between hair and other hair (Table 1)(Nguyen, 2014; Rajput, 2021; Zou *et al*., 2019; Marro *et al*., 2022; Shaiek *et al*., 2018; Hironori *et al*., 2018; Shenenberger & Utecht, 2002), and the other is the difference between different ethnic groups of hair (Table 2) (Leerunyakul & Suchonwanit, 2020; Franbourg *et al*., 2003; Oliver *et al*., 2006; Maymone *et al*., 2021).

Most of the human body is covered with hair, which varies in shape, thickness, density and color from part to part. Hair to the scalp hair is the thickest and long, cross-section is circular. Compared to scalp hair, the eyelash structure and composition are not much different from the hair structure and composition, but some keratin (K38, K82) distribution is different. Almost all eyelashes have a "tapered" appearance, with an oval cross section (Shaiek *et al*., 2018). Their growth cycle and growth rate is much slower than scalp hair, and as a result, lashes last a shorter length under normal healthy conditions (Shaiek *et al*., 2018). The eyebrows are composed of rows of arched hairs (5-7 rows) growing along the upper edge of the orbit. They are short and thin, but hard and not easy to bend (Rajput, 2021). The growth cycle of eyebrow hair follicle is shorter than that of scalp hair follicle, usually 2-4 weeks (Nguyen, 2014). The main types of human hair are villus and terminal hair. The fuzz is fine hair, usually without pigment, which exists in all parts of the body except the skin on the sole of the foot (palm and sole of the foot). On the contrary, the hair at the end is thick with pigment, with an average thickness of 0.05 cm and a length of more than 2 cm (Shenenberger & Utecht, 2002).

Racially, human hair is usually divided into three main categories based on ethnic origin, namely Asian, African and Caucasian.Each race has different hair characteristics, including aspects such as cross-sectional area, growth rate, pigment, lipid content and mechanical properties. Among the three human hair

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types, Asian hair has the largest cross-sectional area, with an average ovality of 90%. The average ovality of Africa is less than 60%, and the ovality of white people is about 75%. The two have relatively equal cross-sectional areas (Fujimoto *et al.*, 2009; Kim *et al.*, 2006). However, studies have shown that the cross-sectional area of hair is related to genotype diversity rather than individual race. EDAR gene is an important determinant of Asian hair thickness, because compared with cells from EDAR370V (1540T), cells from EDAR370A (1540C) are activating NF-κB showed higher ability to express and enhance signal effectiveness. In vivo, transgenic mice expressing EDAR370A produce a hair phenotype similar to Asian hair fibers, and the high production of EDAR370A may affect the hair morphology of Asian populations (Leerunyakul & Suchonwanit, 2020). CC genotype had the highest average area value, followed by TC and TT genotype. In addition, FGFR2 polymorphisms influence hair thickness in Asia by altering FGFR2 expression levels (Fujimoto *et al.*, 2009). The growth rate and diameter of hair are related to the distance between cuticles: the larger the cross-sectional area, the shorter the distance between cuticles, the faster the growth rate (Leerunyakul & Suchonwanit, 2020). Asian hair grows the fastest and African hair the least. Hair color is mainly

Table 1. Differences between hair and other hairs

	Hair	Eyelash	Eyebrow	Villus	Body end hair	Lanugo
Curvature and shape	Relative to the curl; Circle to ellipse	Naturally curving upper lashes are oval in cross section	Straightness	-	-	-
Growth cycle	3-5 years or more	1-3 month	2-4 weeks	<hair	<hair	<hair
Growth speed	0.3-0.45 mm/day	0.07-0.17 mm/day	Slow	0.03 mm/day; (upper lip: 0.05 mm/day)	slow (Female calf: 0.17 mm/day Male beard: 0.35 mm/day)	Slow
Cross-sectional area	4804±159 μm^2	Root larger than tip <hair	-	<hair	<hair	-
Pigment	Eumelanin; Pheomelanin	Dopachrome tautomerase	-	Achromatic (Smaller diameter); Pigmented (Larger diameter)	Pigmented	-
Density	187.3 hairs/cm^2	7fibers per mm	-	-	-	-
Diameter	55-120 μm	Root (80-100 μm) Tip (30-40 μm)	-	14-27 μm (Achromatic); 27 μm (Pigmented) (upper lip:16-53μm) <Hair and end hair	50-150 μm (Male beard: 40-150 μm Female calf: 40-100 μm)	-

Table 2. Differences in hair characteristics between different races

	Asian	African	Caucasian
Density	175±54 hairs/cm^2	161±50 hairs/cm^2	226±73 hairs/cm^2
Diameter and cross-sectional area	80-120 μm larger diameter; 4804±159 μm^2	55 μm Irregular hair diameter height along the hair shaft; 4274±215 μm^2	65μm Medium diameter ; 3857±132 μm^2
Curvature and shape	Relatively straight; Circular cross-section	Most curly/spiral; Ellipsoidal cross-section	Straight to curly; Round to oval cross-section
Pigment	Black/Brown; Mainly eumelanin	Black\Brown ; Mainly eumelanin	Brown/Blonde; Mainly eumelanin; Red: mainly pheomelanin
Growth rate	411±53 μm/day; The fastest	280±50 μm/day; The slowest	367±56 μm/day
Lipid content and hydration	2% polar lipids and free fatty acids	6% total lipid levels were the highest ; Nonpolar lipids; Lowest moisture content	3% Polar lipids and free fatty acids; Highest water content
Mechanical properties	Higher tension than Caucasians ; It is easier to change from α-helical structure to β-folded structure	More likely to break; Lower tensile strength than Caucasian hair	The same way Asian hair reacts to stress and strain
Permeability	Between the middle	The highest level	The lowest levels
Radial expansion	Taller than African hair	Lowest swelling rate	Similar to Asians
Chemical composition	The proteins and amino acids that make up keratin are similar in African, Asian, and Caucasian hair.		

affected by the type and amount of melanin contained in the hair fiber. African hair shows a larger melanosome size and a higher melanosome density compared to Caucasians and Asians (Leerunyakul & Suchonwanit, 2020). The permeability of hair fibers is closely related to the fluidity of stratum corneum lipids. African hair has the highest level of total lipids, and most of the lipids in the hair fibers come from the external sebaceous glands. Asian and Caucasian hair fibers have similar external lipid components (Oliver *et al*., 2006). The cuticle of Asian hair is thick, so it shows the strongest mechanical properties (Leerunyakul & Suchonwanit, 2020; Kim *et al*., 2006). In contrast, the mechanical properties of African hair are poor.

Composition and classification of hair

1. Material composition

1) Protein

The main structural components of hair fiber are hair keratin and keratin associated protein (KAP). Keratin molecular weight ranges from 40-70 kD. Human hair keratins are mainly divided into two categories: 40-48 kD and 59-63 kD. Hair keratin forms keratin intermediate filament (KIF) in hair cells (Shimomura & Ito, 2005). There are five recognized KIFs: type I (acidic keratin); Type II (basic keratin); Type III (desmin, vimentin, glial fibrillary acidic protein); Type IV (neurofilament protein); Type V (laminin)(Yu *et al*., 1993). KIF in scalp hair is mainly type I keratin (K31-K38) and type II keratin (K81-K86)(Barthélemy *et al*., 2012). The average content of cysteine residues in human hair keratin is 7.6%, while that in keratin is only 2.9%. Therefore, the utilization rate of disulfide bond in hair keratin increases, resulting in a harder and more durable structure, making hair rigid (Yu *et al*., 1993). Treatments with bleach and relaxants can damage the keratin structure of your hair. Bleaching is based on oxidants that oxidize melanin and other hair components. The relaxants alter the basic structure of the hair stem, causing cortical penetration, breaking of disulfide bonds in keratin, and causing the capping of the bonds, thus preventing the hair from becoming frizzed again (Barba *et al*., 2009).

2) Lipid

Hair lipids can be divided into exogenous lipids and endogenous lipids according to their sources, the former from sebaceous glands and the latter from hair stromal cells.Their presence is critical in maintaining the moisture content inside the fibers and the structural integrity of the hair, including hydrophobicity and stiffness (Shaw, 1979; Lee, 2011). Total hair lipids bind to the surface of cuticle cells or cortical cells, which is the only continuous structure in the total composition of hair, forming an environmentally tolerant lipid envelope. Unlike normal membranes, the lipids in most keratinized layers are mainly composed of ceramides, cholesterol, and free fatty acids. Normally, normal membranes do not act as a barrier, whereas the keratinized layer acts as an important barrier due to its linear lipid structure (Lee, 2011). Exogenous lipids are composed of free fatty acids (FFA), triglycerides, cholesterol (CH), wax esters and squalene (SQ), accounting for less than 1% of hair fibers. It is considered that it has no effect on hair morphology and has little or no functional role in hair (Coderch *et al*., 2017; Maneli *et al*., 2013; Csuka *et al*., 2022). However, some studies suggest that exogenous lipids in the cortex contribute to the bulge pattern of the cell membrane complex (CMC) (Masukawa *et al*., 2006; Wade *et al*., 2013). CMC can protect hair from external stimuli. Endogenous lipids include FFA, CH, ceramide (CER), glycosyl ceramide, cholesterol sulfate (CS) and 18 methyl eicosanoic acid (18-MEA), accounting for 2.5% of the total hair fibers. It is the structural lipid of hair and plays an important role in hair (Csuka *et al*., 2022). These lipids are the main components of cell membrane lipids, which can lead to the formation of stable and powerful CMC, which has the function of strengthening the barrier and preventing external materials from penetrating the hair fibers (Coderch *et al*., 2017; Coderch *et al*., 2008). The highest lipid concentration in human hair was 4.3 mg/g FFA, 3.3 mg/g CS, 0.6 mg/g CH and 0.2 mg/g fatty alcohol. Endogenous lipids such as CH and CER are negatively correlated with exogenous lipids, which is actually an obstacle to their penetration (Csuka *et al*., 2022). In addition, polar free lipids in hair are the main components of endogenous hair, including CER, glucosylceramide and CS; Non polar free lipids are the main components of exogenous lipids, including SQ, wax esters, cholesterol esters, FA, CH and trace triglycerides. Concentrations of all polar free lipids and covalently bound fatty acids were found to decrease from the root to the distal end of the hair, with levels of polar or structural lipids falling by up to 30% near the end. Binding lipids were reduced by 40 percent. The significantly reduced tensile properties of hair from the root to the distal end may be due in part to reduced

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lipid content in the cuticle, making the cortex more susceptible to protein degradation due to shampooing and environmental factors. Therefore, there may be an optimal lipid level required to maintain the integrity of the epidermis, thus protecting the hair from physical and environmental pressures. The gradual loss of endogenous free and covalently bound lipids in hair may be related to the normal weathering and combing practice of hair, mainly due to repeated washing, combing and ultraviolet radiation. In addition, chlorine, hair dye and bleach may also cause lipid loss (Duvel *et al*., 2005). The non-polar free lipid may be related to the luster of hair, and its content is evenly distributed along the length of hair.

Lipids have certain effects on the fiber properties of hair of different races. African hair has the highest lipid content, which is 6%. Caucasian hair is composed of 3% lipids, and Asian hair has 2% lipids (Csuka *et al*., 2022). The finding of higher concentrations of lipids in African hair has led to the hypothesis that increased lipid levels may be related to increased frizz in hair (Maneli *et al*., 2013). Studies have shown that hair shape is closely related to polymorphisms of proteins expressed in the internal root sheath (IRS) of hair follicles. The shape of human hair is defined in the hair follicle, not from the surface of the skin. Curvature, for example, requires asymmetry in cell proliferation and differentiation within hair follicle bulbs, and many proteins are expressed in asymmetric patterns in curly hair follicle bulbs (Westgate *et al*., 2013). Therefore, whether lipid has an impact on the degree of hair curl requires more accurate characterization. Internal unsaturated fats are responsible for more moisture in hair fibers, and their lack reduces moisture content. Moisture resistance is related to the fluidity of lipids in the cuticle. Caucasian hair with highly ordered lipids is more resistant to water absorption and has the highest moisture content of hair fibers. In contrast, African hair had the lowest lipid ordering and highest water diffusion, despite having a high lipid content in the cuticle. As a result, African hair, while having the highest lipid content, has the lowest moisture content. Studies have also shown that the permeability and moisture resistance of hair fibers are not affected by lipid loss (Coderch *et al*., 2017; Bildstein *et al*., 2020). Therefore, the effect of lipids on hair permeability and moisture resistance needs further study. The texture and shine of hair fibers are also affected by lipid content and removal. Due to the change in the refractive index of medulla, the content of unsaturated lipids in the medulla of hair fibers is reduced, which reduces the transmittance and scattering of light on the hair surface, thus reducing the hair glossiness (Csuka *et al*., 2022; Nagase, 2019).

Effects of chemical and environmental damage on lipid composition and properties of hair (Duvel *et al*., 2005). Alkaline treatments (dye, bleach, perm) or sunlight can reduce surface 18-MEA, FFA, and CMC lipid levels, causing hair to become dry, brittle, and lose elasticity and shine (Lee, 2011). Surfactants in hair products can cause hair lipid loss, mainly depending on the relative hydrophobicity and water solubility of the lipids. Lipid loss occurs mainly through two pathways: surface pathway and internal pathway. The internal pathway depends on the penetration of surfactant, which will remove highly hydrophobic lipids such as SQ and laurel palmitate (WE) when penetrating into the hair shaft. The surface pathway can be controlled by the diffusion and roll up mechanism of lipids in the hair. Surfactants coated on the hair surface will lose lower hydrophobic lipids (amphiphilic lipids), such as FFAs and CH (Song *et al*., 2019a; Song *et al*., 2019b). The loss of lipid will make the hair stiff, rough, susceptible to static electricity, dull, and easy to knot. Therefore, the loss of lipid must be prevented to maintain the health of the hair (Draelos, 2010). Exposure to ultraviolet rays (UVR) will also reduce lipid content, damage hair fibers, and cause dry, fragile, fragile and stiff hair. Sunshine damaged hair also shows reduced luster, color loss and rough surface texture (Habe *et al*., 2011).

Lipids have developed rapidly in the past ten years. Compared with other omics fields, one of the advantages of lipomics is that most of the existing lipid fragmentation pathways are known, allowing the definition of rules for identifying lipid types, rather than relying on spectral similarity between lipids. Therefore, lipid identification can be improved by correctly annotating lipids based on the obtained mass spectrum data and by using internal standards that allow accurate quantification. Lipomic analysis is particularly challenging because of the rich variety of isomers, mainly due to changes in acyl chain length and double bond position (Lipidomics Standards Initiative Consortium, 2019). The 18-MEA on the hair cuticle is covalently bound to hair keratin through ester bond. The base of each keratin cell is mainly covered by the linear structure of fatty acids (such as palmitic acid, stearic acid, oleic acid), which bind to the underlying protein through ester or thioester bonds. These covalent bonds make it difficult for the extraction solvent to recover lipids. Other structural lipids found in the cuticle and cortex are called free lipids (e.g. free fatty acids, cholesterol, ceramides); They are easily extracted from hair by solvents because they interact through weak intermolecular force interactions involving van der Waals bonds (hydrogen or salt bonds) (Maneli *et al*., 2013; Negri, 1993). At present, many hair lipid analysis methods have been developed, including spectral infrared or Raman imaging, microscopic imaging, chemical extraction and analysis, mechanical and sensory analysis and other analysis technologies. Due to the thin hair fiber and the resolution limitation of current imaging methods, the biochemical study of hair is limited by the difficulty of analyzing the structure of a single hair fiber. The change of lipid composition from root to tip will also affect the measurement of hair lipid composition (percentage), but it can be overcome by measuring along the hair length segment. In addition, the inability to separate hair layers for separate analysis of lipid content limits the ability to use chemical extraction methods to locate specific layers within the cross section hair axis (Csuka *et al*., 2022). At present, our research group has been skilled in lipid determination and analysis of hair root with hair follicle tissue through ultra-high performance liquid chromatography quadrupole time of flight mass spectrometry (UPLC-QTOF-MS) based on lipoomics (Ma & He, 2022; Wang *et al*., 2020).

3) Pigment

Melanin granules are located in the cortex (about 3% by weight). Hair pigment is a highly heterogeneous pigment polymer. Its type, size and quantity determine the color of hair (Santos & Joekes, 2004). These pigments are generally divided into two classes: black eumelanins and reddish-brown pheomelanins. These pigments are generally divided into two classes: black eumelanins and reddish-brown pheomelanins (Borges *et al*., 2001). Regardless of color, human hair contains varying amounts and proportions of eumelanin and pheomelanin. Therefore, the visual differentiation of hair color does not always reflect the type of melanogenesis in human hair follicles (Ortonne & Prota, 1993). Hair follicle melanocytes appear to be more sensitive to aging than skin or epidermis melanocytes, and hair often turns gray rapidly compared to the more gradual change in skin color (Westgate *et al*., 2013).

4) Microorganism

Skin is a complex biological ecosystem, containing a variety of microbial communities. Hair, as part of the skin, supports its own microbial habitat, which is also a variable within and between individuals. The hair shaft is part of the skin and part of the pilolipids unit, which is also a possible source of bacterial colonization. The result showed that microflora of scalp hair was mainly Staphylococcus, uncultured, Corynebacterium and unclassified, and the coryneform and spherical microflora were abundant in the stratum corneum, not only at the bottom but also at the top (Watanabe *et al*., 2019; Brinkac *et al*., 2018). The stratum corneum of scalp hair is suspected to be a favorable site for bacterial adhesion, and bacteria may adhere to the scalp hair shaft through unknown biological interactions (Watanabe *et al*., 2019). In addition, the electrostatically attractive and hydrophobic properties of hair appear to help enhance bacterial adhesion (Mase *et al*., 2000; Yun *et al*., 2010). Scalp hair shafts contain hair-specific Pseudomonas species, as well as skin-derived Cutibacterium and Staphylococcus species (Watanabe *et al*., 2021). The three main gates on the scalp hair shaft: Proteus (mean 53.0%), Actinomyces (mean 34.6%) and Firmicutes (mean 9.6%). Actinomycetes (71-78%) and Firmicutes (22-26%) are the two main phyla on the scalp (Watanabe *et al*., 2019). Staphylococcus is one of the common bacteria in the skin flora, and is also found in large quantities in hair. However, Propionibacterium, major bacteria that colonize skin and hair follicles, are not found in hair, probably because it prefers low oxygen levels and high sebum content (Leeming *et al*., 1984). The hypoxic microenvironment of the sebaceous glands, most commonly found on the face and scalp, supports the growth of lipophilic bacteria such as Propionibacterium, while Staphylococcus and Corynebacterium usually colonize areas of the skin associated with moist environments (Brinkac *et al*., 2018). Sebaceous glands secrete a variety of lipids, free fatty acids and antimicrobial peptides, all of which may regulate the growth of various types of bacteria and have different effects on them (Kobayashi *et al*., 2019). The widespread distribution of bacterial cells on the shaft and root of human scalp hair was demonstrated by low-voltage scanning electron microscopy and qPCR (Watanabe *et al*, 2019). It was found that the average number of bacteria-like cells in each part of hair shaft was 1.0 ($\pm$0.3)$\times 10^6$ cells/cm^2 in the base hair, 2.2 ($\pm$0.7)$\times 10^6$ cells/cm^2 in the middle hair and 1.6 ($\pm$0.7)$\times 10^5$ cells/cm^2 in the tip hair. These results showed that the bacteria were steadily attached to all parts of the head fur trunk (Watanabe *et al*., 2019). The bacterial cell density on scalp hair showed a higher level, about 10^7 cells/cm^2 in the root and 106 cells/cm^2 in the axis (Mase

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et al., 2000; Yun *et al*., 2010). The scalp hair microbiome is specific to each individual. Variable characteristics of hair, such as hair length, are one of many influencing factors that may influence the intra individual variability of the hair microbiome. Longer scalp hairs (>4cm) showed significantly greater alpha diversity than shorter hairs (<4cm) (Brinkac *et al*., 2018). Host sex influenced the number of bacteria in major genera, including Cutibacterium, Lawsonella, Moraxella and Staphylococcus. In addition to internal factors of the host, external factors such as hair style and color also affect the number of bacterial cells in the main genus. These factors and chemical treatments, such as bleaching and perming, also affect the ratio of *Pseudomonas* (Ps type) to Cutibacterium (Cu type). These results suggest that the bacterial community structure on the head fur stem is influenced by both intrinsic and extrinsic factors (Watanabe *et al*., 2021). The main bacteria on the human scalp hair stem are local, originating from the roots. In a comparative analysis of the bacterial community structure on the scalp hair shaft and the scalp skin, treatment with chemicals such as hair dye and bleach affected the bacterial community structure of the scalp hair stem, but shampooing or chemical treatment of the hair stem did not significantly affect the total cell count of the bacteria. Shampoos do not affect the adhesion of bacteria to scalp hair stems (Watanabe *et al*., 2019; Mase *et al*., 2000). Damage to the scalp hair surface and membrane may affect the adhesion of major bacteria (Watanabe *et al*., 2021).

2.Classification of geometry

The geometric classification of hair is basically a classification based on the physical characteristics of the hair, mainly a description of the external features of the hair, which, while impressive, are not necessarily a sign of other characteristics or even a response to disease, they may be a proxy for varying accuracy. Since the beginning of "anthropological thought", human hair has been classified according to three traditional human subgroups, namely African, Asian and European. As mentioned above for the classification of race, people mainly focus on the description of hair shape characteristics. However, with the passage of time, people have found that there are many problems with such a classification. For abandoning race to classify hair, Bigby *et al*. (2006) give several reasons: Ethnic classification lacks the reliability of genetics and anthropology; The origin and practice of racial categorization is itself racist; Racial categorization is often a barrier to diagnosis and treatment, not a help. Hrdy says there are few systematic studies to define these demographic differences, and that imprecise terms such as "frizzy" or "curly" have long been used to describe hair, with increasing ambiguity as use increases.The typology of the use of these terms has had an impact on current human logical thinking (Hrdy, 1973). Mkentane *et al*. (2017) believes that the use of ethnicity as a descriptor for hair shape has limitations because it is subjective and presents overlaps. De la Mettrie *et al*. (2007) argues that ethnic classification fails to take into account the complexity of human biodiversity, which is driven by history, population differentiation, and admixtures. As a result of the various debates over race, efforts have been made to find a more appropriate classification. A number of objective classification methods have emerged. First, anthropologist Hrdy (1973) assessed hair shape changes by measuring mean diameter, medulla, scale count, kinks, mean curvature, ratio of maximum to minimum curvature, crimpiness, and ratio of natural to straight hair length, and then using the F-test to compare differences within and between populations. Second, Bailey & Schliebe investigated the precision of the contribution of mean curvature to variation, and like Hrdy, they described mean curvature as the reciprocal of radius. They compared the curvature of the hair shapes of different members and found that the averages overlapped. Soon after, De la Mettrie (2007) extended the Bailey & Schliebe system without reference to the human race, introducing three additional variables (for curly hair), Curve diameter (CD), ratio of loose hair length to extended hair length (called curl index or i), number of twists (t), and number of waves (w) were measured. Hair can be divided globally into eight well-defined categories. The method involves an objective description of hair shape and is more reliable than traditional methods that rely on categories such as curls, waves and kinks. It applies to human diversity worldwide and avoids references to the supposed, ambiguous subject of ethnic origin. However, in a recent study, Mkentane *et al*. (2017) investigated the reliability of hair geometric classification (based on three measurements: curve diameter, curl index, and wave number), with three raters grading the hair of 48 volunteers on two separate occasions in eight and six classifications. A grader applied six classifications to an additional 80 volunteers to further confirm the reliability of the system. Kappa statistics are used to assess consistency within and within the rater. In his conclusion, Mkentane *et al*. (2017) argues that the 8-group geometric classification system proposed by De La Mettri *et al*.

(2007) and Loussouarn *et al*. (2001) makes a useful contribution to the scientific application of hair, but is not reliable. The six sets of geometric hair classification are faster and more reliable to perform, but still depend on the operator. The poor kappa statistics for hair type Ⅰ may reflect the small study sample or the need to further reduce the hair groups to five (and possibly even four), but this needs to be confirmed in a large study.

Influencing factors

1. Biophysical properties

The light scattering behavior and slanting structure of the cortex, medulla, and cuticle will affect the appearance of hair to some extent. The cuticle is scaly and slopes in one direction from the base to the tip (Nagase, 2019). When the hair is exposed to alkaline pH value, the cuticle scales expand, making the hair shaft more porous (Draelos, 2010). When the hair is seriously damaged due to excessive coloring and repeated washing, a large number of pores will be produced in the cortex (Nagase, 2019). The hair fiber will become turbid due to the light scattering from the porous and microporous structure of the hair fiber. On the contrary, nonporous structure is very important for hair with clear color, bright luster and high contrast. In addition, the cross section and curl degree of the hair will also affect the appearance of the hair, which to some extent determines the luster of the hair and the ability of the hair to be covered with sebum. Straight hair has more luster than twisted hair, because its smooth surface allows maximum light reflection and sebum to easily move down from the scalp to the hair shaft. Straight hair is also the easiest to comb, because the combing friction is very low, and twisted hair is easy to break when combing (Draelos, 2000).

2. UV

Ultraviolet and visible light radiation can damage hair. The photochemical degradation of hair causes the hair proteins and melanin to be attacked. Hair protein degradation is caused by wavelengths ranging from 254 to 400 nm. Melanin provides some photochemical protection for hair proteins, especially at lower wavelengths, where both pigment and protein absorb light, shock radiation by absorbing and filtering it, and then dissipate that energy as heat. However, in the process of protecting hair proteins from light, the pigments are also degraded or bleached. Hair that has been exposed to the sun for too long will turn yellow, especially white hair. Hair yellowness depends on hair type and radiation wavelength. The destructive effect of UVB is about 2–5 times that of UVA+ visible light radiation (Santos Nogueira & Joekes, 2001). It was found that the color change of white hair (without melanin) after irradiation was related to protein damage (Nogueira *et al*, 2007). In short, exposure to ultraviolet radiation can damage hair fibers. Exposure to sunlight can lead to dry hair, reduced strength, rough surface, fading, reduced luster, stiffness and brittleness.

3. Chemical

Chemicals in hair products may damage existing hair and affect hair growth. Chemical relaxants commonly used in hair beauty (dyeing, bleaching, straightening, etc.) will damage the integrity of the outermost layer of the hair shaft. Chemical relaxants include sodium, potassium or guanine hydroxide, sulfite or mercaptoacetate, all of which affect the hair appearance by affecting the cysteine disulfide bond of the hair. In this process, the rearrangement of disulfide bonds leads to structural damage of hair dryness and reduces its tensile strength. In addition, complications of hairdressers and powerful chemicals include traumatic hair breaks, scalp abrasions, sores and chemical burns, especially when using chemicals and dyes with very high pH values (Sanad *et al*., 2019). Washing only with sodium dodecyl sulfate aqueous solution will weaken hair cuticle cells, making them more fragile and easier to crack (Richena & Rezende, 2016).

4. Age

Hair graying is usually related to aging, mainly reflected in the regulation of melanin production (Maymone *et al*., 2021). The molar percentage of total melanin (TM) and 5,6-dihydroxyindole (DHI) units was positively correlated with age, while the molar percentage of phenylalanine was not correlated with age. TM is significantly related to the hair color parameters and melanosome volume. Therefore, the darkening of hair color caused by aging is due to the increase of TM caused by the increase of melanosome size. In addition, the increase of DHI mole percentage also contributes to the darkening of hair due to aging. DHI melanin has a certain effect on the morphological changes of melanosomes caused by aging (Itou *et al*., 2019). Hair whitening is also a gradual state. With the growth of age, the dilution of pigment level in hair will also lead to the loss of luster (Westgate *et al*., 2013).

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5. Hormone

Hair growth is also regulated by various hormones, such as thyroid hormones, glucocorticoids and androgens. Androgens are the most important regulators, and they can stimulate, maintain, or inhibit terminal hair growth, depending on the part of the body. Androgens can enlarge hair follicles in androgen-dependent areas, however, in the scalp hair follicles of susceptible men, androgens inhibit hair growth and promote the miniaturization and shortening of hair during growth, resulting in common baldness (Lolli *et al*., 2017).

Hair care

Personal daily hair care solution may be influenced by age, gender, cultural, economic environment and the influence of basic hairstyle. Hair damage is caused by mechanical or chemical damage, hair care products do not completely repair hair damage, can only improve the beauty value and function of the hair shaft, mainly by affecting the cuticle structure of the hair, usually hair oil cleansing and conditioner use. Shampoo products are the foundation of hair care, they can clean the hair and add a certain amount of nutrients to the hair. Formulated shampoos contain surfactants, foaming agents, conditioners, thickeners, opaque agents, softeners, release agents, fragrances, preservatives and special additives. Descalants are the main components for removing sebum and dirt; However, excessive removal of sebum can darken hair, be susceptible to static electricity, and be difficult to comb. Surfactants are the main active agents in shampoos and are chemically composed of lipophilic and hydrophilic parts. The lipophilic component adheres to the sebum, while the hydrophilic component allows the water to wash away impurities on the sebum (Draelos, 2000).The most commonly used detergents in shampoo include sodium lauryl ether sulfate, sodium dodecyl sulfate, dodecyl sulfate, ammonium lauryl ether sulfate, ammonium dodecyl sulfate, and sodium alkenesulfonate. Compared to shampoo, conditioner is essentially a cationic system that appears as a dispersant rather than a solution for optimal results. Hair conditioner is usually oil/wax in water lotion, with positive charge to promote net negative charge deposition of hair in weathering increased area (Gray, 2001). The hair conditioner can improve the beauty value of weathered dry hair by increasing luster, reducing static electricity, improving hair strength, and providing ultraviolet radiation protection and other mechanisms.Water is one of the important components in hair, and water molecules exist inside the hair through different interactions with keratin, which also has a significant impact on the physical properties of the hair. The hygroscopic effect of hydrophilic moisturizing ingredients or the film-forming and sealing effect of lipid components in hair care products can help suppress hair moisture loss (Barba *et al*., 2010).The frequency of hair washing is related to hair length, personal preferences, gender, and social pressure. Modern well formulated shampoos can effectively remove cosmetics such as debris, sebum, and hair gel deposits. If the product formula used is good, frequent and regular cleaning will not damage hair.

Conclusion

In this paper, the physiological structure, material composition, geometric classification and influencing factors of hair are reviewed in order to improve people's understanding of the rich information of physical and chemical properties and structures of hair. The classification of hair mainly focuses on the classification based on the physical characteristics of hair. Although the classification has largely reached the objective standard, it still cannot reflect the physiological state of hair. The physical composition of the hair maintains its health, and the various substances in the hair do their jobs. As far as the current findings are concerned, the role of lipids in human hair mainly has several aspects: 1) The lipids in hair are related to its mechanical properties. 2) Non-polar free lipids may be related to hair shine. 3) Lipids inside the hair enhance the hair's barrier function, preventing external substances from entering the hair fibers. 4) The change of aliphatic properties can regulate the hydrodynamics of the fibers, and its existence is crucial for maintaining the moisture content in the hair fibers. The moisture content in your hair plays a crucial role in the physical and cosmetic properties of your hair. 5) Lipid metabolism plays an important role in the lipid envelope of hair, but is also involved in the development and function of hair. Although hair is low in lipids compared to protein, it is important for hair fibers. Hair lipids are essential to protect hair from environmental and chemical damage; Prevent hair from breaking and thinning; Used as a barrier for water loss; It can also improve the luster, elasticity and tensile strength of hair dryness. At present, some functions of lipids are still speculated or controversial, and need to be further verified, such as whether lipids have an impact on hair curl, whether lipids have an impact on hair permeability and moisture resistance. In addition, the function of exogenous lipids needs further exploration. External factors can cause hair damage to varying degrees. For example, factors such as ultraviolet ray and chemical agents lead to the loss of hair lipid, making it dry, rough, lusterless, rigid and brittle. However, sebum is not the only source of hair lipids. Many internal lipids, including CER, CHO, FA and CS, do not come from sebum. Once the lipid in the hair shaft is lost, it must be partially recovered. Therefore, it is necessary to accurately characterize the lipid loss in hair and explore methods to prevent lipid loss. Lipomics method established by our research group has analyzed a lot of skin and hair follicle lipids, which can comprehensively and systematically analyze the influence of hair lipids on hair status, and guide the research and development of hair cosmetics with different hair status and washing purposes.

Author's contribution

QS consulted relevant literature, edited manuscripts and revised manuscripts. YJ gave advice for the article and revised the manuscript. CZ and CH have made great contributions to the concept of hair physiology and design of the article. QJ and ZW participated in the discussion and research of hair influencing factors, and made substantial contributions to the content of the article.

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국문초록

모발의 구성, 분류 및 영향 인자에 관한 연구

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모발은 케라틴과 케라틴 관련 단백질을 주성분으로 하는 천연 섬유이다. 외부에서 모발은 완전히 각질화된 죽은 상피 세포로 이루어진 얇고 유연한 관이지만, 피부 내부에서는 살아있는 모낭의 일부로 구성되어 있다. 모발에는 다량의 단백질 외에도 낮은 수준의 지질과 색소가 포함되어 있다. 그 외에도 모발에는 고유한 생태학적 균형 시스템이 있다. 모발의 지질 함량은 단백질 함량에 비해 훨씬 낮지만 모발에 중요한 역할을 하며 모발의 질감에도 어느 정도 영향을 미친다. 예를 들어, 모발의 파손과 숱이 줄어드는 것을 방지하고, 수분 손실을 막는 장벽 역할을 하며, 모발의 윤기와 탄력, 인장강도를 향상시킨다. 환경, 미용, 일상적인 관리 등은 모두 다양한 정도의 모발 손상을 유발할 수 있다. 자외선 및 화학 물질과 같은 요인은 모발의 단백질, 색소, 지질을 파괴하여 모발을 건조하고, 거칠고, 둔하고, 뻣뻣하고 부서지기 쉽게 만들 수 있다. 본 총설에서는 모발의 구성, 분류, 영향요인에 대해 종합적으로 고찰하였고, 특히 모발 내 지질의 구성과 기능을 집중적으로 고찰하였다. 본 총설은 모발의 물리적, 화학적 특성과 구조에 대한 사람들의 이해를 높이는 것을 목표로 하여, 다양한 모발 상태와 세척 목적에 따른 모발 화장품 연구 개발에 기초적인 가치를 제공하고자 한다. 모발에 대한 모발 지질의 기능은 명확하지 않으며, 모발 지질의 기존 역할에 대해서 여전히 논란이 있어 추가 연구가 필요하다고 사료된다.

핵심어: 모발, 단백질, 지질, 미생물, 인자

中文摘要

头发的组成、分类及影响因素的研究进展

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头发是一种天然纤维，以角蛋白和角蛋白相关蛋白为主要成分。从外部看，头发是由死亡的、完全角化的上皮细胞组成的薄而柔韧的管状物，而在皮肤内部，它是单个活毛囊的一部分。头发内除了含有大量的蛋白质外，还含有低水平的脂质和色素。除此之外，头发上有着自己的生态平衡体系。尽管头发中脂质的含量远低于蛋白质含量，但其在头发中扮演着重要的角色，对头发质地有一定程度的影响。例如，防止头发断裂和变薄；用作水分损失的屏障；并改善发干的光泽度、弹性和拉伸强度等。环境、美发及日常护理等均会不同程度地造成头发的损伤。例如紫外线、化学剂等因素，通过破坏头发的蛋白质、色素和脂质等，使头发变得干燥、粗糙、无光泽、僵硬和易脆。本文对头发的物质组成、分类概况及影响因素进行综述。着重调查了头发中脂质的成分及其作用。旨在提高人们对头发理化性质和结构的了解。为不同头发状态和洗涤目的的头发化妆品的研发提供参考价值。 头发脂质对头发的功能作用并不精确，此外，对头发脂质已有的作用仍存在一定的争议，需要进一步研究。

关键词: 头发，蛋白质，脂质，微生物，因素

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