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# Differences Between Adult and Children's Hair

HERMAN BOGATY, B.S.*

**Synopsis**—A review—much of it from the anthropological literature—is given on the structural, morphological, and color changes of hair on the head with aging of the subject. Children's hair is on the average finer, rounder, less frequently medullated, and lighter in color than adults' hair. Scaliness and cuticle-cortex ratio are less certainly related to age, nor is there a consistent effect reported on changes in chemical and physical properties. The physics of hair color is discussed and some limited experimental data are reported suggesting that children's hair is more transparent and is less red in hue, with a trend to higher purity.

## Introduction

In connection with hair color studies, the technical literature on the differences between adult and children's hair was searched. While hair appearance and color were the primary concern, information on the geometry, shape, and chemistry was also uncovered. Much of the published data found appeared in literature normally not available to cosmetic scientists—in physical anthropology and anatomy—and in the period between 1925 and 1945. Because the findings may be of general interest, it was thought useful to bring together in one place the information obtained and to provide a fairly complete set of references against future needs.

Some brief comment on background and terminology may be helpful. Criteria for classification of hair have included gross size, time of appearance during the life span, and structural variations. Lanugo, or primary hair, is characteristic of the fetal stage of life. It tends to be fine and silky, is nonmedullated and may be considerably pigmented. Secondary, or vellus,

* The Toni Company, Chicago, Ill. Present address: Warner Lambert Research Institute, Morris Plains, N. J. 07950.

hair is short, fine, and usually unpigmented; the downy underfur of some mammals and the fine body hair of children and women are probably characteristic. Some authors restrict the term vellus to such fibers rather than to any type of scalp hair. The tertiary, or terminal, hair is normally considered to be long, coarse, and pigmented, and associated with the mature individual. There is considerable overlap in the various types, and on any given animal or in any specific region of the skin all types may be evident, as well as intermediate varieties. Most anthropologists view the changes that take place as developmental, whenever the transition from the primary through the terminal types occurs with increasing age (1–3). A corollary of this view is that the changes do not occur all at once, and that at any given time some fraction of the more primitive hairs may be present. Thus, Danforth (1) observes that between 6 and 21% vellus hairs may still be present in late childhood during the transition to terminal piliation.

## Dimensions and Morphology

### *Cross-Sectional Size and Shape of the Hair*

Both of these characteristics have usually been measured together on the same samples. In an early paper, Wynkoop (4) concludes that "hair shaft diameter bears little or no relationship to the age of the individual, though there seems to be a rough correlation . . . with age group of individuals . . . ." Examination of her data indicates that the 0- to 9-year age group of hair samples does have substantially finer hair than the samples of older groups measured.

Trotter and her coworkers (5–7) investigated these hair characteristics more thoroughly by using a somewhat better technique. Some data from these sources, regrouped and rearranged, are given in Tables I and II. These results show the average increase in linear density and of cross-sectional area with age at least through the teen years. There is also a suggestion of a modest decline with older age groups. The ellipticity, as measured by hair index, does not in these data correlate with age. It is emphasized that these results are averages and that each head contains individual fibers of a wide range with much overlap among the age groups.

In view of the subject-to-subject variability, the results from two additional papers by this group of workers are more conclusive (8, 9). The hair index and size of a small group of children were followed by sampling their heads on a regular time schedule from birth through early teen age; the data are given in Table III.

Table I

Fineness and Ellipticity of Hair of American Whites[a]

| Age of Group | Number of Subjects | Average Cross-Sectional Area, Square "Units"[b] | Average Hair Index,[c] % |
|---|---|---|---|
| 0–4 | 24 | 31 | 75 |
| 5–9 | 42 | 42 | |
| 10–14 | 40 | 47 | 73 |
| 15–19 | 35 | 56 | |
| 20–29 | 55 | 50 | 77 |
| 30–49 | 100 | 51 | 74 |
| 50+ | 44 | 46 | 76 |

[a]From Trotter (5).
[b]The precise units employed are not clear in the original paper. The computed area is based on the microscope scaling device employed.
[c]Ratio of minor to major axis.

Table II

Fineness and Ellipticity of Hair of French Canadians and Americans[a]

| | French Canadians | | | | Americans | |
|---|---|---|---|---|---|---|
| Age of Group | No. of Subjects | Hair Index, % | Cross-Sect. Area, $mm^2 \times 10^5$ | Wt./100 cm, mg | No. of Subjects | Wt./100 cm, mg |
| 0–4 | 46 | 73 | 268 | 3.4 | 17 | 2.9 |
| 5–9 | 36 | 74 | 341 | 4.2 | 37 | 3.9 |
| 10–14 | 45 | 74 | 378 | 4.7 | 36 | 4.5 |
| 15–19 | 46 | 73 | 425 | 5.4 | 38 | 5.3 |
| 20–29 | 52 | 72 | 422 | 5.3 | 55 | 4.6 |
| 30+ | 75 | 72 | 380 | 4.7 | 137 | 4.5 |

[a]After Trotter and Dawson (6).

Table III

Cross Section and Hair Index of Children from Birth to Youth[a]

| No. of Individuals | Age Group, years | Hair Index, % | Cross-Sect. Area, $mm^2 \times 10^5$ |
|---|---|---|---|
| 15 | 1 | 76 | 75 |
| 16 | 2–4 | 70 | 237 |
| 16 | 5–9 | 72 | 312 |
| 11 | 10+ | 73 | 336 |

[a]After Trotter *et al.* (8, 9).

The relationship of age and cross section is very evident and is shown consistently by all of the subjects. The average hair index is not clearly related to maturation, although there is a suggestion that the hair from the one-year-olds is somewhat rounder. This suggestion is reinforced by the detailed results of Trotter and Duggins (8) giving hair index measurements at one month, seven months, and two years for each of 15 children. In 14 out of 15 cases the two-year indices are lower than either of the younger values, and in 13 of the 15 the seven-month indices are lower than the

Table IV
Medullation and Scale Index as a Function of Age[a]

| Age Group, Years | Approximate No. of Individuals in Group | Incidence of Medullas, % | Proportion of Medullas of the Broken or Continuous Type[b] % | Scale Index[c] |
|---|---|---|---|---|
| 0–9 | 70 | 40 | 48 | 0.24 |
| 10–19 | 30 | 82 | 89 | 0.085 |
| 20–29 | 40 | 55 | 67 | 0.10 |
| 30–49 | 37 | 80 | 68 | 0.11 |
| 50–99 | 60 | 76 | 65 | 0.135 |

[a]After Wynkoop (4).
[b]Four types are described: absent, fragmentary, broken (large segments), and continuous. The latter two represent more definite and massive medullation.
[c]Ratio of scale length (proximo-distal) to fiber diameter.

one-month values. Interestingly, the average hair indices measured on three different racial groups of Australian aborigines (7) show a trend to greater flattening of the hair with increasing age.

### *Medullation and Scaliness of the Hair*

Some data on these aspects of morphology are given in Table IV from data obtained by Wynkoop (4). Medullas are less frequently observed in hair sampled from young people. Even when present in youth, the medullas are more often fragmentary in appearance rather than massive or continuous as in older ages. The scale index measurements also indicate that larger scales relative to fiber diameter are observed in youngsters' hair. A rough calculation suggests that the individual scales are absolutely, as well as relatively, larger in the 0- to 9-year group. Curiously, the author rejects the conclusion that the incidence of medullation increases and that the scale index decreases with age. She believes the correlation is most likely with

Table V
Medullation in Children's Hair[a]

| Age Group | No. of Hairs Showing Medullas, % | No. of Subjects Showing Any Medullas, % | Types of Medullas Seen[b] |
|---|---|---|---|
| At birth | 1.0 | 17 | Scanty and extremely |
| 1–2 mos. | 0.4 | 32 | fragmented |
| 3–5 mos. | 7.7 | 31 | Scanty-broken |
| 6–7 mos. | 34 | 73 | Broken-continuous |
| 1 yr. | 48 | Most | .... |
| 2–4 yrs. | 25 | Most | .... |
| 5–9 yrs. | 36 | Most | .... |
| 10+ yrs. | 31 | Most | .... |

[a]After Duggins and Trotter (9).
[b]See footnote, Table IV.

fiber diameter, but her evidence and argument in the published paper are not persuasive.

Hausman (10) also concludes that medullation and scaliness are functions of diameter from a consideration of a large number of animal species, but he did not study age *per se;* Wynkoop was probably a student of Hausman and, thus, was led to the same conclusion. In a later paper, Hausman (11) briefly notes "a study of 483 specimens of human head hair taken from individuals ranging from 3 hours to 91 years of age" with correlation being found with diameter of the hair shaft.

A good review of the earlier literature and views on hair morphology is given by Noback (12).

Duggins and Trotter (9), in following the same group of children referred to earlier, also examined medullation in samples from the same heads. Data compiled from this paper (Table V) show the rapid increase in the incidence of medullation in the first months of life; the change in character of the medulla from scanty-fragmentary to broken and continuous is noteworthy. These authors conclude that the presence of medullas is a developmental characteristic related to age.

The same authors (13) also examined these children's hair for scaliness by counting the number of scales per unit length in a direction parallel to fiber axis. They found no relationship with age and very high individual and sample variability. A good summary of all of the work with this single group of children is given by these authors (14).

With the groups of Australian natives mentioned earlier (7), the frequency of observed hairs containing medullas rises with age and extends into the older age groups as well. No correlation of scale count with age could be asserted for this group.

Fourt (15) interested himself in hair structure in relation to physical properties of human hair. Some of his findings are assembled in Table VI. In the upper portion of this table, the tendency for finer hairs to have a large fraction of their cross section in the cuticle is to be noted; in this case the finest hairs come from children. The relationship between coarseness and medulla frequency is also shown, with the fine children's hair being less often medullated. Fourt observes that fibers with high cuticle-to-cortex ratio tend to be finer and rounder. In a second series of measurements (lower half of Table VI), he sorted two lots of adult hair into fine and coarse subgroups. His results indicate that fine hair from a given adult contains proportionately more cuticle, is less frequently medullated, and is rounder than the coarse hair from the same head. These sorting experiments lend support to the view of Wynkoop and Hausman referred to earlier that fineness is the primary correlate rather than age *per se;* nonetheless, vestigial fine hair on an adult head may involve a lack of maturation from the developmental point of view.

The actual thickness of the cuticle is slightly larger for the coarse than for the fine hair, but not very much so. Fourt's limited data on fiber mechanical properties show no consistent effect relating to age, size, or morphology.

Table VI

Fineness, Cuticle Thickness, Medullation, and Ellipticity of Human Hair[a]

| | | Cuticle Area | | | | |
|---|---|---|---|---|---|---|
| Sample | Average Cross-Sect. Area, $mm^2 \times 10^5$ | % of Cross Sect. | % of Cortex Area | Fraction of Sample Medullated, % | Minor/Major Axis, % | Cuticle Thickness, microns |
| A | 610 | 16.6 | .... | 66 | .... | .... |
| B | 448 | 18.9 | .... | 32 | .... | .... |
| C | 435 | 19.0 | .... | 34 | .... | .... |
| 2½ yr. girl | 325 | 21.4 | .... | 16 | .... | .... |
| 6 mo. boy | 136 | 26.3 | .... | 4 | .... | .... |
| RMH—Coarse | 331 | .... | 18.7 | 20 | 70.1 | 2.60 |
| Fine | 143 | .... | 27.2 | 0 | 91.9 | 2.42 |
| 146 —Coarse | 568 | .... | 16.3 | 91 | 64.7 | 2.96 |
| Fine | 210 | .... | 21.8 | 16 | 79.6 | 2.35 |

Note: All samples adult hair except where noted.

[a]After Fourt (15).

## Chemical Differences Relating to Age

### *Cystine and Sulfur Content*

An early paper (16) describes the results of elemental analyses on a variety of hair types. This work reports Caucasian adult hair to be richer in sulfur and nitrogen and poorer in oxygen content than children's hair. This paper is so poorly done and the methods are so uncertain that its credibility is very dubious.

Wilson and Lewis (17) conclude that no relation can be demonstrated between cystine content of the hair and age of the subject, although "we cannot fail to be impressed by the apparent tendency . . . for cystine in adult hair to be slightly lower . . . ."

More recent work (18) reports measurements of cystine, cysteine, nitrogen, and sulfur with no consistent relation with age. In contrast, Japanese workers (19) published data which revealed wide variation but some trend to declining cystine contents with age of the group.

To add to the confusion on this point, it might be noted that hair of young, nonhuman mammals (cows and chimpanzees) reportedly (20) has lower cystine levels than that of adults. Also, some of the published work (18, 21–23) suggests an association of cystine with hair color; the more heavily pigmented fibers usually exhibit higher cystine levels. As will be shown later, children's hair is lighter in color on the average, and if this secondary correlation exists, then one would expect children's hair to be lower in cystine and sulfur.

This welter of inconsistency merely indicates large and expected biological variability. Most of the work done has simply been inadequate in methodology and in sampling scope to ascertain the existence of a relationship, if present. Furthermore, it seems probable that factors other than age—e.g., diet and hormonal patterns—would have a strong influence on some of these chemical characteristics.

### *Fatty Materials Associated with Scalp Hair*

It is well known that changes in oily secretions associated with skin and hair are related to age, e.g., the increase in secretion associated with puberty. A number of workers (24, 25) have published data indicating that children exhibit hair of lower fat content than adults. The chemical character of the fat is also different: cholesterol and cholesterol esters are at higher levels, and squalene, free fatty acids, and wax esters are at lower levels in children than in adults. These differences are undoubtedly related to hormonal effects.

## Hair Color

### *Changes with Age*

It is a commonly accepted opinion that hair darkens with age of the subject, and this view is amply confirmed in the anthropometric literature. Some typical data obtained by matching against color standards (made of dyed swatches) for American whites (5) and French Canadians (6) are collected in Table VII. The trend to darkening with age is clear and seems to occur most rapidly in the early years. Similar findings have been reported with all population groups: in Virginians, Danes, Swedes, French, Czechs (26), and even in very dark-haired Australians (7). A review by Trotter (27) notes many comments by others on this subject and discusses means for describing hair color.

A useful longitudinal study on color and aging was done by Steggerda (28). In this work, a series of children was followed over a 10-year period in Holland, Michigan. Color comparisons were made annually by matching against the Fischer-Saller scale and converting the letter designations to numbers for averaging purposes. A light blonde corresponds to a low number like one, and a pure black corresponds to a high number like 24. The relevant information in this paper is given in Table VIII. In substance, the head hair of this group of children becomes darker by almost one unit

Table VII

Hair Color as a Function of Age[a]

| | Percentage of Samples of American Hair of the Specified Hair Color in Age Group | | | | |
|---|---|---|---|---|---|
| Hair Color | 0–9 | 10–19 | 20–29 | 30–49 | 50–79 |
| White-Lt. Blonde | 19 | 3 | 0 | 0 | 0 |
| Blonde-Dark Blonde | 61 | 44 | 35 | 25 | 16 |
| Brown-Brown Black | 20 | 53 | 65 | 75 | 84 |

| | Percentage of Samples of French-Canadian Hair of the Specified Hair Color in Age Group | | | | | |
|---|---|---|---|---|---|---|
| Hair Color | 0–4 | 5–9 | 10–14 | 15–19 | 20–29 | 30–89 |
| White-Lt. Blonde | 15 | 3 | 0 | 0 | 0 | 0 |
| Blonde-Dark Blonde | 50 | 22 | 4 | 2 | 2 | 3 |
| Brown-Brown Black | 35 | 75 | 96 | 98 | 98 | 97 |

Note: A small number of red colors have been omitted in computing the percentages in this table. Only pigmented fibers read by the authors; i.e., senile gray not considered.

[a]After Trotter (5) and Trotter and Dawson (6).

with each year of age for the ages of 6 to 18. No significant sex differences were found.

Curiously, the basis for the change in color is hardly discussed in the literature except as the comment, "adults appear to generate more pigment" —not a very satisfactory explanation. In view of the apparent continued change with time over the full life span of the individual, a specific hormonal basis is unlikely.

*Physical and Morphological Effects on Color*

The appearance of hair depends, of course, on the optical physics of the situation—the nature of the incident light and the way it is reflected, absorbed, and scattered by structural elements of the fiber and by the geometrical arrangements of the hairs as a group. On the latter point, it is a fact of common experience that a neatly parallel array of fibers is conducive to high luster and brightness if the angles of the incident light and of the eye are properly disposed; a tousled head of hair is generally dull in appearance.

Some facts on the physics of hair color, following the views of Garn (29), may be instructive for general background.

Light that falls on hair is absorbed to a large extent (70–95%), a small amount is transmitted through the fiber, and from 2–20% is reflected—the last being most important in the hair's appearance. The reflected light has two components: (a) that reflected from the surface of the fiber, and (b) that re-reflected after absorption. The surface-reflected light is plane-

Table VIII
Hair Color as a Function of Age[a]

| Age | Mean Hair Color | No. of Cases |
|---|---|---|
| 6 | 5.5 | 80 |
| 7 | 6.4 | 178 |
| 8 | 7.6 | 224 |
| 9 | 8.7 | 218 |
| 10 | 9.2 | 246 |
| 11 | 10.2 | 267 |
| 12 | 11.1 | 285 |
| 13 | 11.9 | 304 |
| 14 | 12.5 | 307 |
| 15 | 13.5 | 302 |
| 16 | 14.3 | 219 |
| 17 | 15.2 | 128 |
| 18 | 15.7 | 43 |

[a]After Steggerda (28).

polarized and contributes to the sense of sheen or gloss; smooth coatings like oils increase the mirror-like reflectance, and particulate deposits such as dirt, detergent residue, or hair spray particles decrease it. A smooth cuticle and a regular cross section lead to maximum reflectance. Greater scaliness and the presence of lateral ridges along the shaft (said to be present in some Negro hair) or a crenulated, irregular cross-sectional shape result in a more diffuse reflection pattern. The reflected light has the same spectral characteristics as the incident light—"the hair shines with the same color as the illuminant"—and thus the tonal characteristic of the innate hair color is diluted.

The absorbed light that is re-reflected is selective with respect to wavelength. The maximum absorption is in the near UV, about 400 m$\mu$, and the minimum absorption is at 700 m$\mu$ and beyond. In the visible region, the curve of reflectance with wavelength is quite linear over the range of 400–700 m$\mu$, with a slight upward curvature for reddish tone hair (30). Other things being equal, two pigment characteristics influence the reflectivity after absorption: the size of the pigment particles and their density of distribution. These factors plus the depth of the pigment bed—i.e., the length of the absorption path—affect the color. Darkening with aging may be related to the larger diameter discussed earlier, but there is also evidence for increase in size and number of pigment granules as well.

A small fraction of light transmitted through the hair exhibits a different spectrum from that for absorption and reflectance; it is redder due to scattering by the pigment granules. Since the incidence of medullation increases with aging, scattering from this cause would be expected to increase and to result in reddening of the hue with age.

It may be desirable here to sketch an over-all basis for the existence of various kinds of natural hair color.

Color in hair is produced by pigment particles (brownish-black melanin granules) dispersed in a clear transparent matrix of hair keratin substance. The principal difference in the appearance with respect to blondness or brownness is a consequence of the number of pigment granules present. A high density of pigment leads to the appearance of brown or dark hair and a low density of pigment to blonde. An analogous situation is seen in screen printing, where the density of black dots on a printed page affects the visual appearance of darkness or lightness. It seems reasonable to suppose that production of melanin pigment increases with age, and thus more granules per fiber are present in older people.

In addition to the melanotic brown pigment, there may also be present a much more diffusely dispersed or "soluble" red-gold stain throughout the cortex (11, 27). The presence of the diffuse red material gives rise to reddish tones varying from true reds in the absence of much melanin through strawberry blonds, chestnut browns, to reddish blacks. With the diffuse red component absent, ash and drab hair color is seen, tending to the blue-black as the melanin granule content increases. Flesch *et al.* (31, 32) have discussed an iron-containing nonmelanin pigment found in red hair.

With regard to the subject of aging and hair appearance, the morphological changes are likely to influence the mode by which light is reflected on the hair and hence its appearance. If "young" hair exhibits a lower density of melanin, is less frequently medullated, and is composed of a larger fraction of nonpigmented cuticle, one would expect children's hair to be more transparent than adults'. This might be construed as giving children's hair a quality of depth, softness, and transparency. Some measurements with the Den Beste reflectometer (33), which can partition the light reflected from the surface and internally, are consistent with this speculation. In Table IX, data are given for hair taken from four people at different ages. The column headed "Transparency" gives the ratio of light reflected after penetrating the hair to that believed to come from the hair surface. The transparency does decrease with age for all four subjects.

The pigment density may be expected to affect the hue, since melanin is brown. Thus age should increase the reflectance in the lower wavelengths. The data in Table IX show that the dominant wavelength, computed from tristimulus values, increases slightly but consistently with age. Thus, younger hair might be thought of as cooler and calmer in appearance, i.e., less red.

Table IX

Reflectometer Measurements of Hair of Individuals at Several Ages

| Subject | Hair Color | Age | Transparency[a] | Hue, Dominant Wavelength | Purity, % |
|---|---|---|---|---|---|
| Lavonne | Blonde | 5 | 1.26 | 578 | 17 |
| | | 10 | 1.12 | 581 | 20 |
| Lynette | Reddish-Blonde | 10 | 1.05 | 580 | 51 |
| | | 14 | 0.69 | 584 | 28 |
| Becky | Brown | 3½ | 0.76 | 579 | 24 |
| | | 7 | 0.66 | 585 | 20 |
| Vivian | Black | 8 | 0.85 | 589 | 20 |
| | | 21 | 0.55 | 604 | 11 |

[a]Ratio of reflection after passage through hair to that reflected from the surface.

The significance of the purity values given is not clear. The data suggest a trend to less purity with age, purity being the degree of closeness with which a color resembles a true spectrum color. Low purity colors are closer to white, gray, or black, and thus younger hair may be more truly colored, less drab, perhaps from the smaller amount of pigment present.

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