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# The Spatial Distribution of Copper in Individual Human Hairs

Studies of the trace element content of human hair are of interest from several points of view. Since trace elements enter hair from the environment, either directly or via the diet, their concentration in hair may represent an indicator of environmental quality [*1–3*]. Further, since hair samples are fairly durable, those secured in an historical or archeological context may provide environmental information from times past [*4*].

Hair analyses may also reveal evidence of accumulation in the hair of toxic substances ingested by (or administered to) the subject concerned in quantities exceeding those normally derived from the environment. Such studies may have significant historical aspects [*5,6*] or may be important in a current forensic context [*7*].

Another forensic problem, namely that of identifying hairs as coming from a common source, continues to be an important and incompletely resolved problem; this is especially true for the common circumstance where samples consist of single human hairs.

The determination of the trace element content of human head hairs, via the technique of neutron activation analysis, has been applied widely in this connection [*8*].

Large-scale surveys of the trace element concentration distributions in the hair from various populations have been conducted by Perkons and Jervis [*9,10*], Coleman [*11*], Bate and Dyer [*12*], and more recently by Gordus [*2*]. In such studies, the concentration of particular trace elements, averaged over the sample in question (in many cases consisting of bundles of hair many centimetres in length), were determined. Initially the indications [*13,14*] were that the variation of the average concentrations of a particular element among hair bundles all taken from the same head was small compared with that among bundles taken from different heads.

Recent studies [*15*] of samples consisting of 10-cm segments of single hairs, however, have shown that the variation of the concentration of such elements as chromium, selenium, iron, antimony, and silver can be substantial among hairs taken from immediately adjacent sites on the scalp, and all identified as being in the anagen or growing phase of the hair growth cycle. In the same study, an increase in the concentration of most trace elements was found between the hair root and the distal end of the hair, by as much as a factor of 20. Thus, if two single hair samples are to be compared under the circumstance where the positions on the scalp and the phase of the hair growth cycle in each case are not known, and where the distance from the hair root is not determinable, matching for forensic purposes by measurement of trace element concentrations averaged even over 10-cm segments appears to be of dubious validity. So too does deduction of an ingestion history from hair samples of similarly deficient documentation.

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The recent development of flameless atomic absorption (AA) spectrometry, with the concomitant improvement in sensitivity in the determination of many elements, has made possible the analysis of hair segments of much shorter length and without prior chemical dissolution (and hence with lesser risk of contamination). The technique was first applied to copper (Cu) and lead (Pb) measurements on 1-cm segments of individual hairs by Renshaw et al [*16*].

Studies in this laboratory have applied this technique to hair segments of a length approaching the minimum handleable by conventional manipulative techniques. They revealed the existence of patterns in the spatial distribution of trace elements in hair of potential value in clinical and forensic studies. Some results on spatial patterns for several trace elements were reported in a previous paper [*17*].

Following these preliminary studies, it was decided to study the concentration patterns of a series of elements in detail. The present paper describes the results obtained for Cu, an essential element in human biochemistry, distributed in substantial quantities in the environment, and a convenient element for analysis via flameless atomic absorption. These data have been presented in preliminary forms before the 4th International Conference on Atomic Spectroscopy (Toronto, 29 Oct.–2 Nov. 1973), the 1974 Northwest Regional Meeting of the American Chemical Society (Spokane, Washington, 13–14 June 1974) and the 21st Canadian Spectroscopy Symposium (Ottawa, 7–9 Oct. 1974).

## Experimental Techniques

### *Hair Acquisition*

Hairs were plucked individually from the heads of the several subjects investigated, the experimenter wearing disposable plastic gloves and employing Teflon®-coated forceps to reduce contamination. Only hairs in the anagen phase of the hair growth cycle were to be studied, in view of the potential interest of the correlation in time of features observed in various single hairs; thus plucked hairs with the root attached were subjected to microsopic examination to verify the growth cycle phase. Hairs in the anagen phase were taken to be those with a plump and pigmented root, with the white root sheath attached. Hairs without a clear indication of being in the anagen phase were rejected.

### *Washing Technique*

The desirability of washing hair samples prior to analysis for forensic purposes has been discussed elsewhere [*15*]. For the present study a washing procedure was used [*18*] similar to that employed earlier [*17*]. Successive washings were effected in diethyl ether (Fisher anhydrous), acetone (Fisher spectroscopy grade), distilled-deionized water, acetone, ether, acetone, water, acetone, and finally ether, for time periods of five minutes per step, as discussed later. Hairs were then air-dried. If hairs were to be stored for longer than one or two days prior to measurement, it was found necessary to take stringent precautions to avoid contamination. Encapsulation in Pyrex® glass tubing (previously rinsed with ultrapure $HNO_3$ and distilled-deionized water) under reduced pressure ($\cong 6 \times 10^{-3}$ cm mercury) was found to be satisfactory.

### *Cutting and Weighing Hair Segments*

For the purposes of the present study, segments had to be cut accurately to a known length, and some information on segment weight was also required. Furthermore, contamination of the segments by handling prior to analysis had to be kept to a minimum.

For cutting, a hair was loaded into a glass capillary tube previously cleaned by means of $HNO_3$ and deionized-distilled water as described previously. The capillary tube was

mounted on a vernier-equipped carriage, in turn mounted on a microscope stage, with the portion of the hair to be cut protruding from the end of the capillary. The cutting operation was watched through a microscope with ×50 magnification, and the length to be cut off was measured both by the vernier and by means of a graticule in the field of view (to an estimated accuracy of ± <5%). Cutting was done with a stainless steel surgical scalpel bearing on a quartz plate, both cleaned by the technique outlined earlier; the rest of the cutting apparatus was constructed from Teflon®.

The 2-mm segments were not weighed individually because of contamination problems and the analytical data are generally reported in terms of weight of Cu found per 2-mm length of hair. In addition, a 1-mm segment was cut for weighing periodically along the length of the hair. Some data are then reported in terms of parts per million of Cu by weight in the individual hair segments, under the assumption that changes in weight from segment to segment were proportional to distance down the hair for small distances. More detailed studies reported below show, however, that such concentration data are only approximate.

*Atomic Absorption Measurements*

The copper content of individual segments was measured by means of a Model 305 Perkin-Elmer atomic absorption spectrometer, equipped with an HGA-70 carbon tube furnace. Two-millimetre segments cut for analysis were transferred to the center of the graphite furnace. The centering was found (as expected from the variation of furnace temperature with distance along the axis) to be most important for obtaining consistent measurements.

The hair segments were dried in the furnace at a temperature of 100°C for 10 s, ashed at 1100°C for 15 s, and finally atomized at a temperature of 2400°C. Calibration of the analysis was by means of aliquots of a standard solution of cupric ion (prepared in turn from a known weight of pure copper metal) pipeted into the furnace, as discussed later.

It was found that during the drying and ashing stages of the analysis, the very light hair segments tended to be blown away from the center of the furnace by the stream of argon gas with which the furnace is flushed. This problem was alleviated by means of a graphite tube configuration featuring a central region of increased diameter (Perkin Elmer Corp.) and by interrupting the argon gas flow for the drying and ashing stages of the analysis.

The precision with which the analysis of the Cu content of hair segments was made was difficult to assess, since replicate segments, identical in Cu content, evidently do not exist. Analysis via the present flameless AA technique of aliquots of a copper solution indicated a reproducibility of better than ±5%. The data in Table 1 on analysis of weighed aliquots of a (presumably homogeneous) copper-containing solid protein indicated a reproducibility of ±9%. Thus a conservative estimate of ±10% is considered reasonable for the precision of the copper-in-hair analysis results reported below, and given the data in Table 1 on analysis of a solid material of known content plus the careful calibration presently employed, the accuracy is expected to be similar.

TABLE 1—*Analysis of Cu content of tyrosinase via atomic absorption spectrometry and X-ray fluorescence spectrometry (precision ±10%).*

| | XRF, ppm | AA, ppm |
|---|---|---|
| Dissolved samples | 302 | 273 |
| Solid Samples | 382 | 288, 338, 285 |

## Results for Indigenous Copper in Hair

### *General Form of Results*

Figure 1 shows the mass of Cu found (and the corresponding calculated Cu concentration) in 2-mm segments of individual human hairs as a function of the distance of the segment from the hair root. Data in each part of the figure are for several hairs plucked from randomly located sites on a single human head, all hairs verified as being in the anagen phase of the growth cycle at the moment of plucking. The subjects concerned in the several parts of the figure are described in Table 2; a comparison of the Cu patterns found in hairs plucked from three different female subjects is to be found in Fig. 2.

It is seen that hairs from a single head exhibit generally similar Cu patterns; hairs from different heads differ in average Cu content (as expected from previous data on the dis-

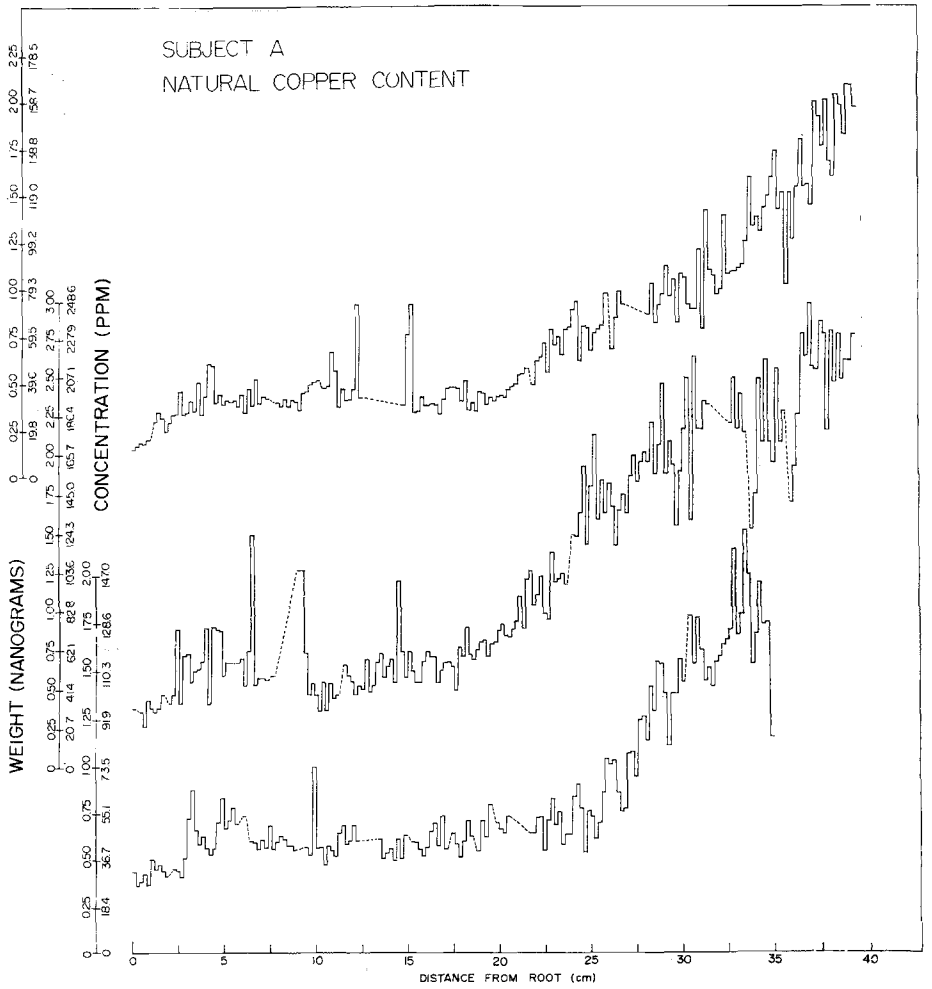


FIG. 1—*Variation of the copper content as a function of distance from the root for individual human hairs (in the anagen phase) in groups all drawn each from one head. Subjects are described in Table 1.* (a) *Subject A.*

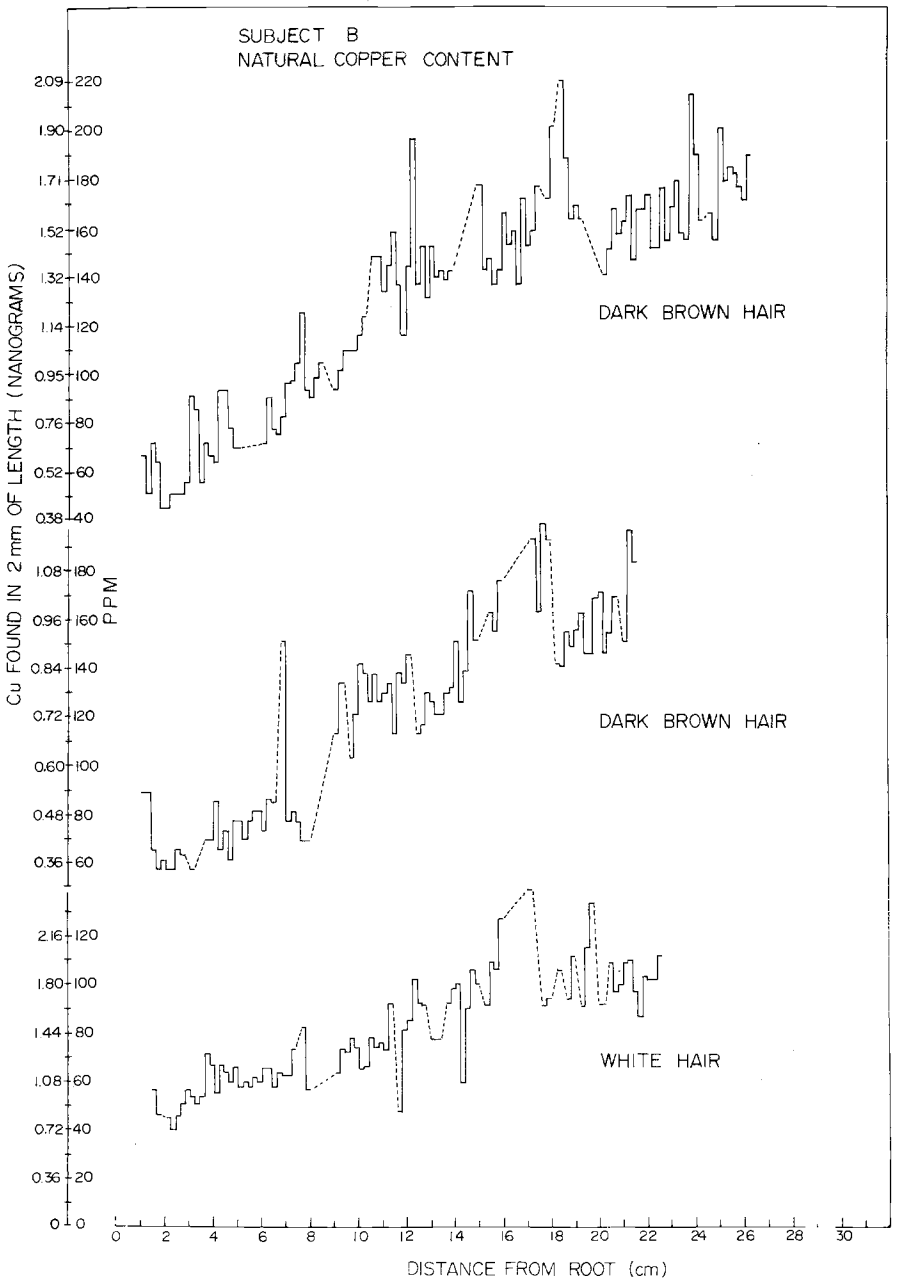


FIG. 1b—*Variation of the copper content as a function of distance from the root for Subject B.*

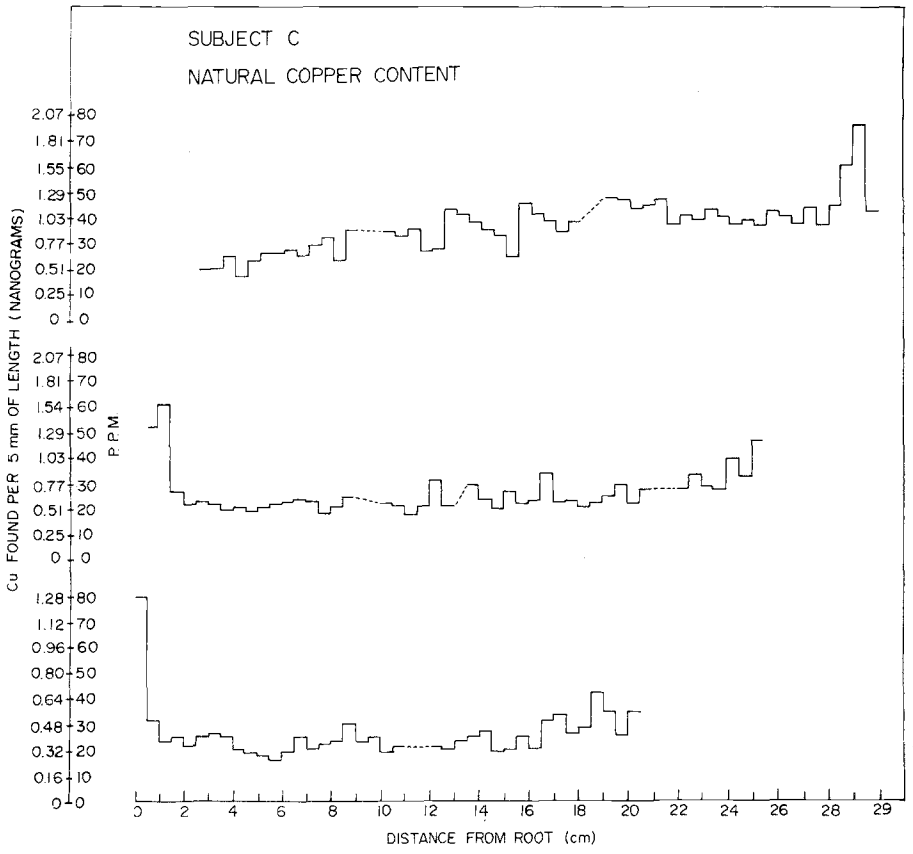


FIG. 1c—*Variation of the copper content as a function of distance from the root for Subject C.*

tribution of average Cu content of hair from a general population [*9*]) and also in the magnitude of features such as slopes and local concentration fluctuations.

All the patterns measured, for these subjects and others, show, however, three general characteristics: (1) a fluctuation of the Cu content between adjacent segments by as much as a factor of two; (2) a minimum Cu concentration at about 1–2 cm from the root and a generally increasing concentration of copper with increasing distance from the root; and (3) superimposed on this general trend, regions of the hair—several centimetres long—of increased and decreased Cu concentration, which may be particularly prominent for some subjects such as A.

These characteristics may be rationalized in the following terms, given among other things the interpretation of hair trace element data found in earlier papers.

1. The observed segment-to-segment fluctuations might be due to faulty analytical technique, to external contamination of the hair surface, or to contamination introduced during analysis.

2. The increasing concentration from the root to the distal end might be due to absorption of Cu from the environment, which had proceeded to a greater extent with increasing distance from the root due to the increasing total exposure time.

3. The regions of locally increased and decreased Cu content might reflect changes in the dietary Cu content, which might induce corresponding changes in the blood Cu con-

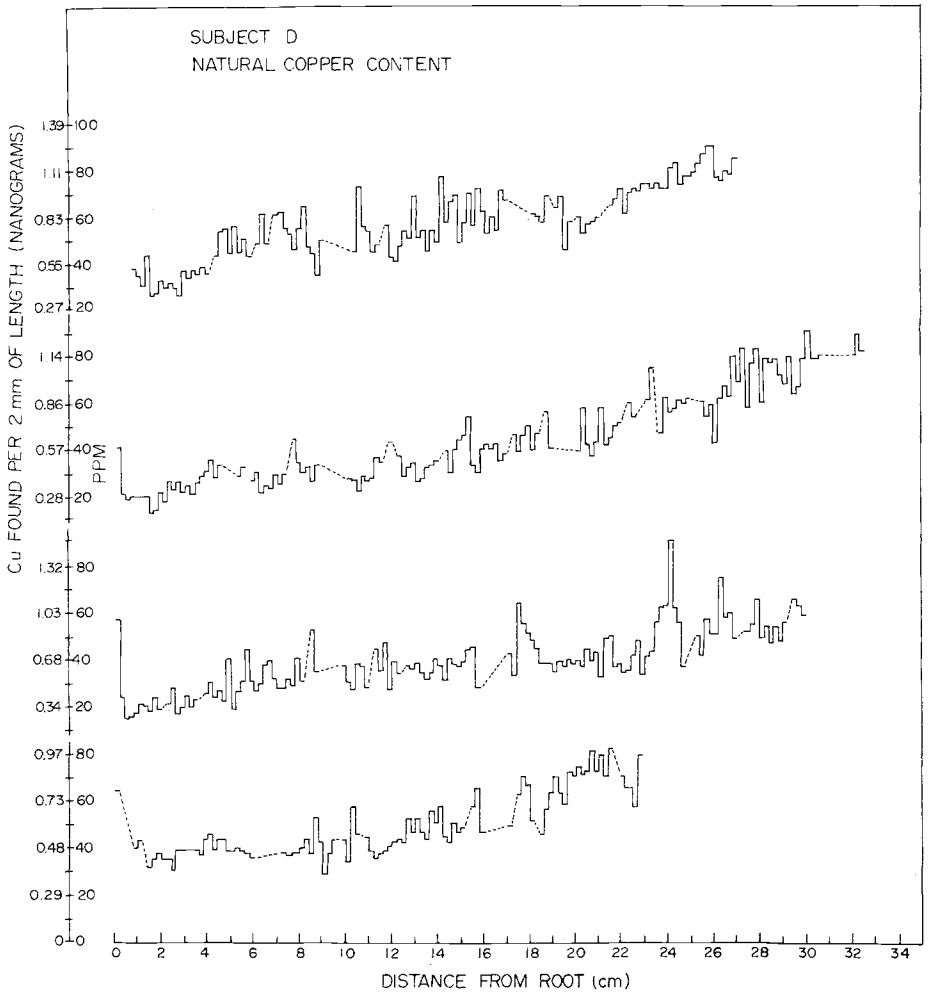


FIG. 1d—*Variation of the copper content as a function of distance from the root for Subject D.*

tent and hence in the extent of incorporation of Cu into the hair growing from a given follicle.

In what follows, these rationalizations are subjected to experimental test.

### *Validity of Analysis*

A question arises as to whether atomization of Cu in the sample is complete in the environment of the furnace tube; also the validity may be questioned of calibrating the absorption signal measured during the atomization of a solid hair sample by comparison with the signal obtained from an aliquot of a standard solution. This was examined in several ways.

First, a comparison was attempted between hair segments analyzed in the solid phase as described above, and (larger) segments of another hair from the same subject which were subjected to a prior dissolution in concentrated nitric acid, aliquots of the resulting

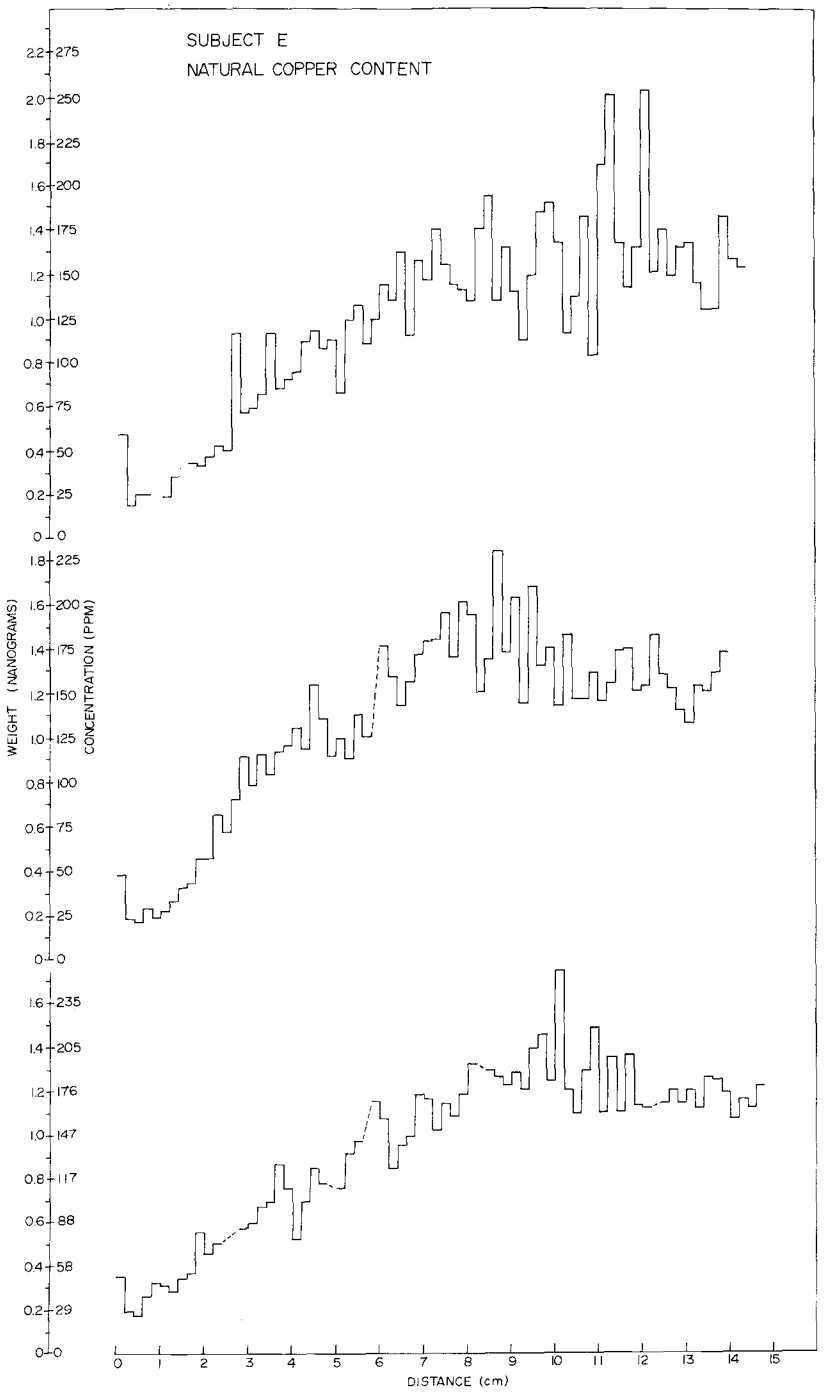


FIG. 1e—*Variation of the copper content as a function of distance from the root for Subject E.*

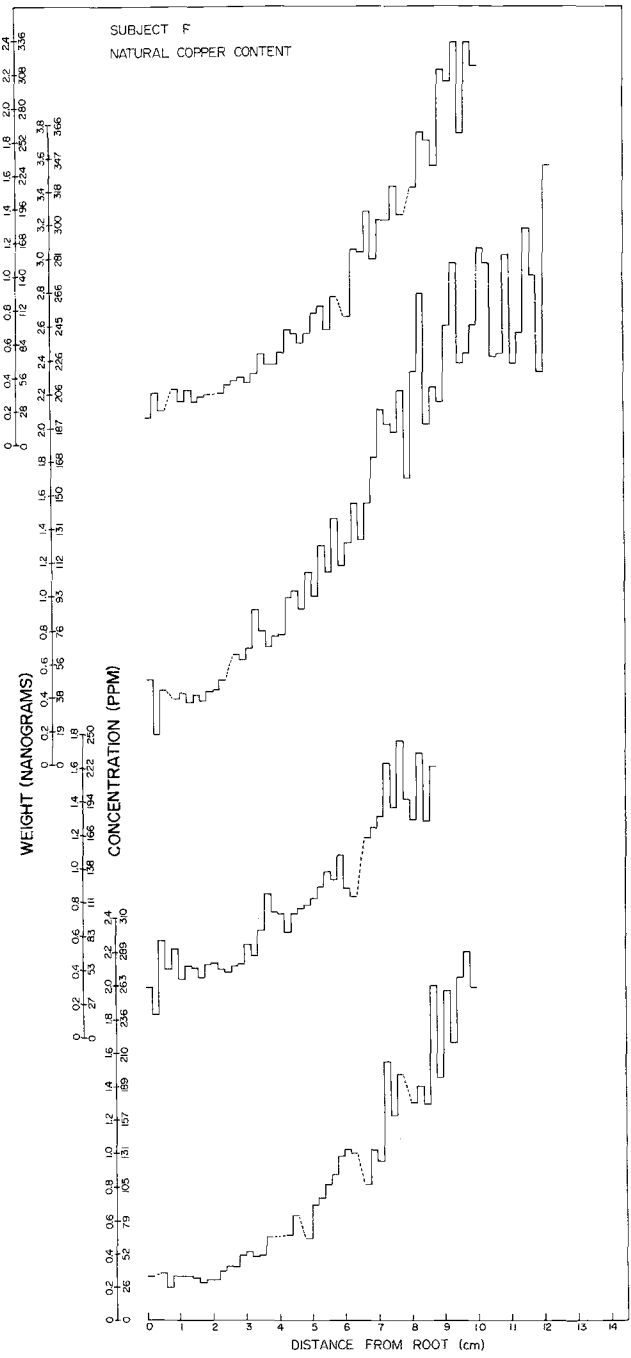


FIG. 1f—*Variation of the copper content as a function of distance from the root for Subject F.*

TABLE 2—*Subjects from whom hair samples were analyzed.*

| | Subject | | | | | | |
|---|---|---|---|---|---|---|---|
| Subject | A | B | C | D | E | F | G |
| Age | 21 | 43 | 18 | 25 | 31 | 30 | 22 |
| Sex | female | female | female | female | male | male | female |
| Domicile | Vancouver, B.C. | Vancouver, B.C. | Paris, France | Vancouver, B.C. | Vancouver, B.C. | Vancouver, B.C. | Vancouver, B.C. |
| Hair color | light brown | dark brown or black changing to white or gray | blond | medium brown brown | light brown brown | dark blond | brown, partially bleached |

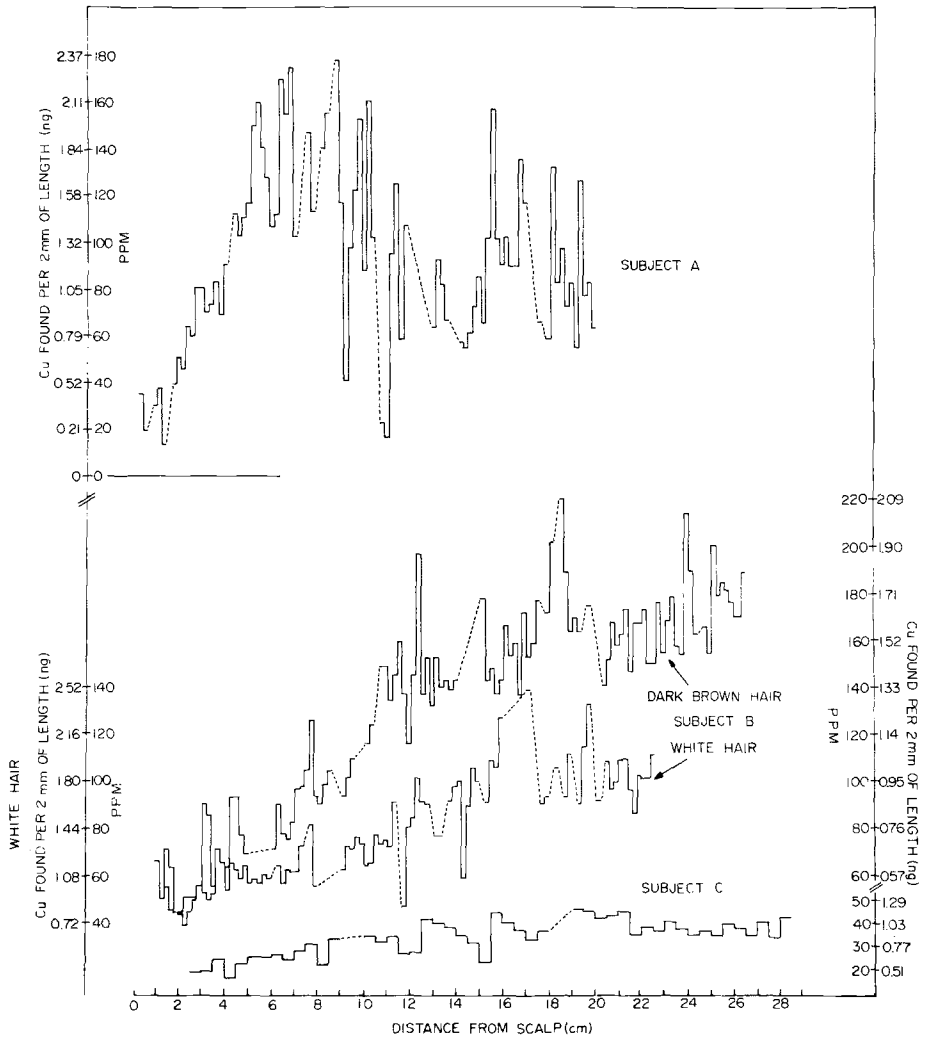


FIG. 2—*Comparison of the copper patterns for anagen hairs from Subjects A, B, and C.*

solution being pipeted into the furnace. Several problems affect such a comparison. First one would, ideally, prefer to compare hair segments of identical composition. Unfortunately these do not exist. The best that can be done is to compare the measured average Cu values and patterns for the two hairs from the same subject. A second problem is in the contamination introduced specifically by the dissolution procedure.

Figure 3 shows the results that were obtained with hairs from Subject A. These, plus the data contained in Table 1 on tyrosinase analysis by AA, suggest that analysis of samples in the solid phase and after dissolution give the same Cu concentration value to within 10 or 20%. Values from the analysis of hair segments after dissolution are perhaps higher than those from direct analysis of the solid samples; this could be accounted for in part by contamination during the dissolution and by the Cu content of the acid used.

Second, the influence of proteinaceous material present in the furnace during analysis on the analytical results was checked by comparison with the results of an analytical

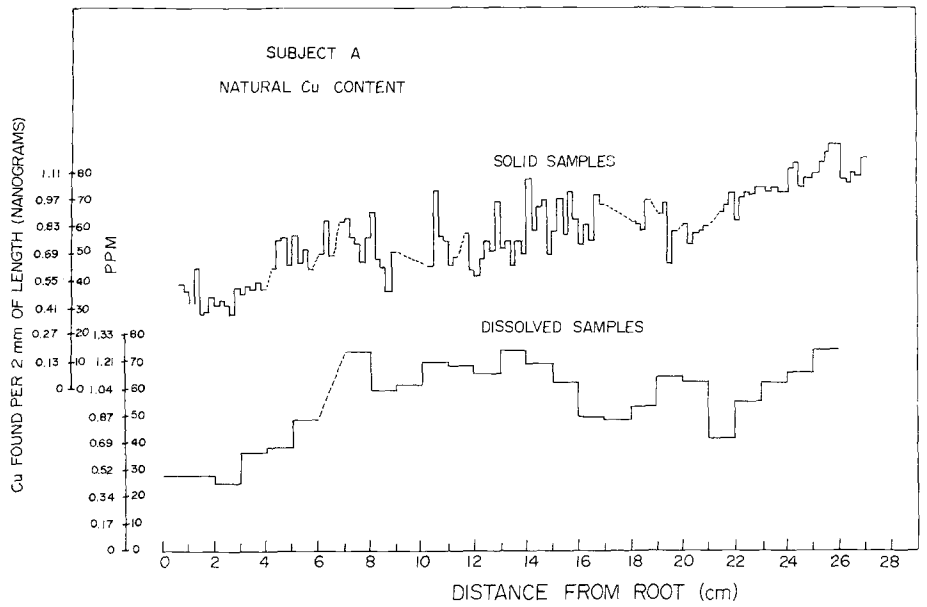


FIG. 3—*Comparison of the copper pattern in hairs from subject A, as measured by atomization of solid samples and atomization after dissolution in concentrated nitric acid.*

technique which is presumably free of this problem, namely X-ray fluorescence analysis. A sample of tyrosinase (Sigma Laboratories) with a Cu content of about 300 ppm was employed. The Cu content was measured directly by AA in a solid sample of this material; the material was then dissolved in $HNO_3$, and the Cu content determined on aliquots of the solution first by AA and secondarily by X-ray fluorescence analysis of the evaporated residue. Calibration in both cases was achieved by comparison with similarly treated aliquots of a standard Cu solution, or a standard National Bureau of Standards orchard leaves material of known Cu content. The results are shown in Table 1 and indicate an agreement consistent with the estimated $\pm 10\%$ error of the AA technique, given possible inhomogeneity of the protein material.

Finally, the segment-to-segment variation observed in the measurements on hair suggested variable contamination during analysis as a possible problem. This was checked by analysis of 2-mm segments of a nylon monofilament fishing line of a diameter similar to that of the hair samples examined and handled in an identical way. The results are shown in Fig. 4. Not only are the segment-to-segment copper content variations smaller ($\sigma \cong 18\%$) than those generally observed with hair, but the measured Cu level is a small fraction of that observed generally in hair samples. The observed segment-to-segment variation in weight was smaller ($\sigma \cong 2\%$); thus, what was observed may have been variable contamination or variable Cu content of the nylon line. If the Cu measured in the nylon *was* entirely due to contamination, such contamination appeared to be rather constant and at a level negligible when compared with the Cu content generally observed in hair.

### *Effects of Hair Washing*

Superficial contamination of hair as collected was suggested by highly erratic results obtained from analysis of hair samples that had not been subjected to a prior washing procedure. At the same time washing procedures are known [*19*] to lead to loss of metallic ions from the hair structure, the loss being greater for extended washing periods. Choice

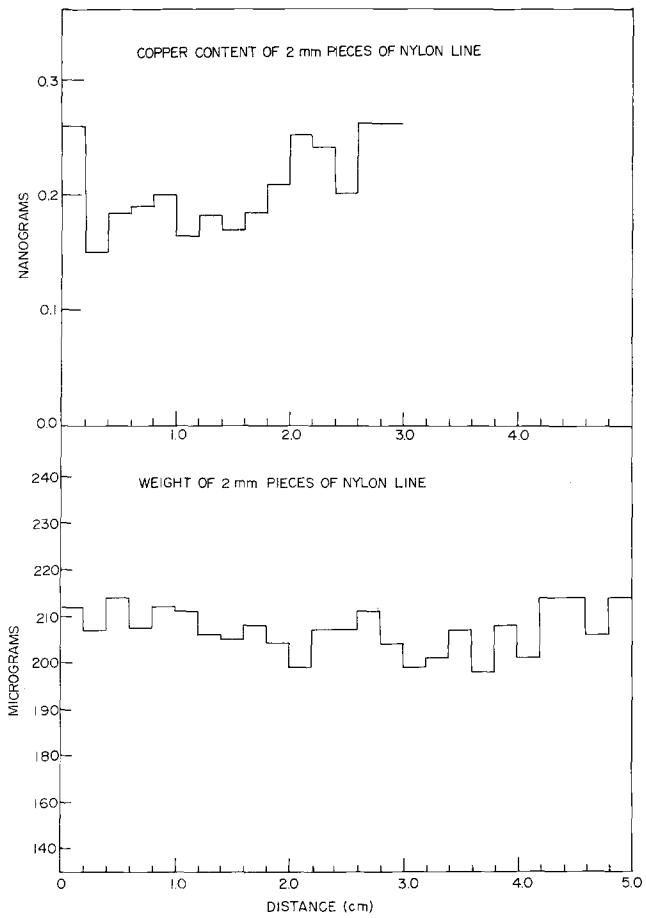


FIG. 4—*Copper pattern, observed by flameless AA analysis, and weight variation observed in successive 2-mm segments of nylon monofilament fishing line. The data are for two different regions of the same stock.*

of an optimum washing time was therefore attempted by an experiment involving three hairs drawn from the head of a single subject (Subject A). The hairs were separately subjected to the washing sequence described earlier but with times of 5 min, 10 min, and 15 min per step of the procedure. The results are shown in Fig. 5.

It is seen that for this subject the structure of the Cu distribution pattern is pronounced after a 5-min washing per step, somewhat attenuated after 10 min per step, and considerably attenuated after 15 min per step. Comparison of data (such as those in Fig. 1) for hairs from a given subject all subjected to 5 min per step, however, indicated that the kind of highly erratic variations previously ascribed to superficial contamination appeared now to be absent; thus, a washing time of 5 min per step seemed to be a reasonable compromise between removing contamination and avoiding washing out a potentially significant concentration pattern. The smaller segment-to-segment fluctuations referred to earlier are seen to persist even for washing times extended to 15 min per step of the nine-step procedure. This information plus the checks on the analytical procedure described above suggest that the fluctuations are real (and not an analytical artifact) and may be associated, for example, with variations in the protein content of successive segments rather than with surface contamination.

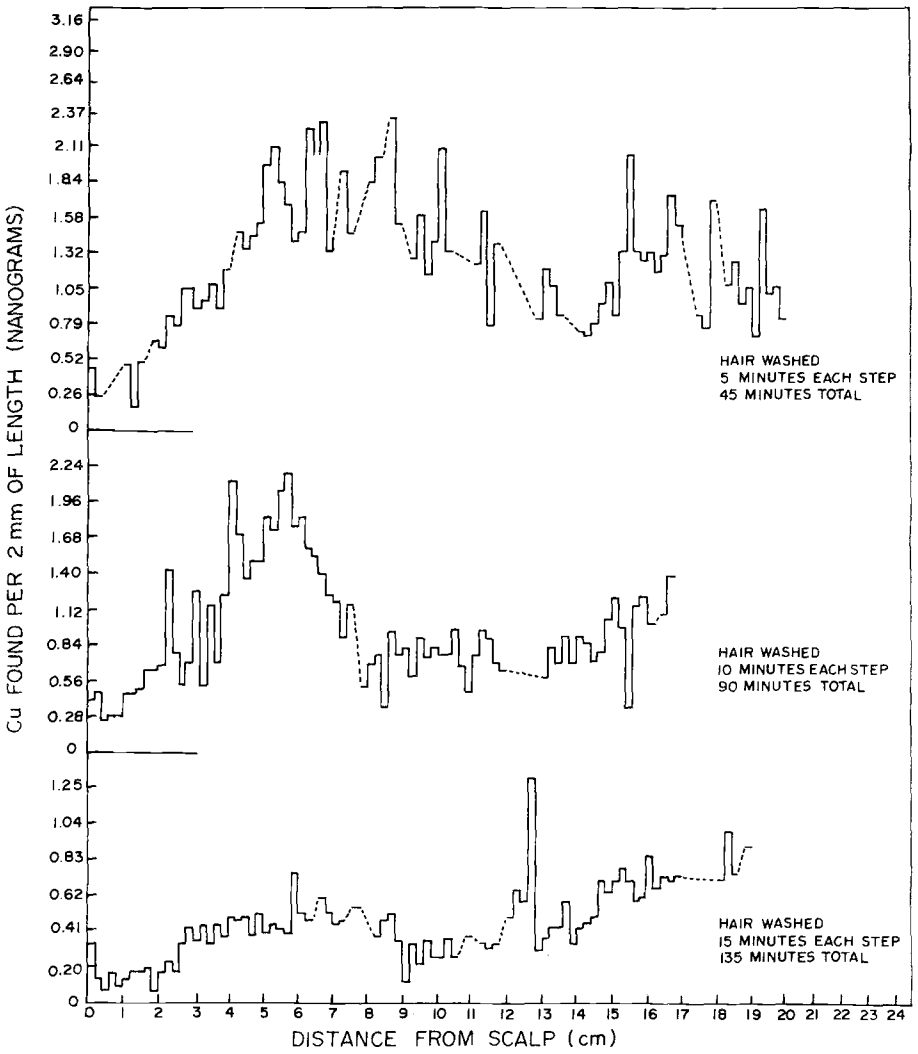


FIG. 5—*Effect of increased washing times (within a nine-step ether-acetone-water cycle) on the copper pattern in hairs from Subject A.*

Another quantity of perhaps the same kind might be hair density or diameter. Figure 6 shows the result of weighing successive 2-mm segments of a hair typical of those from Subject A, together with the estimated precision of such measurements. Such weight fluctuations as exist are of smaller magnitude than those in Cu content, although the weight (like the Cu content) appears to increase with distance from the root.

The diameter of a hair from Subject A was measured microscopically at intervals along the hair much shorter than the 2 mm imposed otherwise by the necessity of manipulating individual cut segments. The results are shown in Fig. 7 (plus the estimated precision) together with weight data repeated from Fig. 6. Beyond cyclic variations arising from the hair's helical structure, there are local points of significantly reduced and increased diameter, and while again these are not of such a magnitude as would directly correspond to the measured Cu content variations, it is clear that the hair structure is not homogeneous over millimetre distances along the hair, and this may be related to the Cu content fluctuations observed.

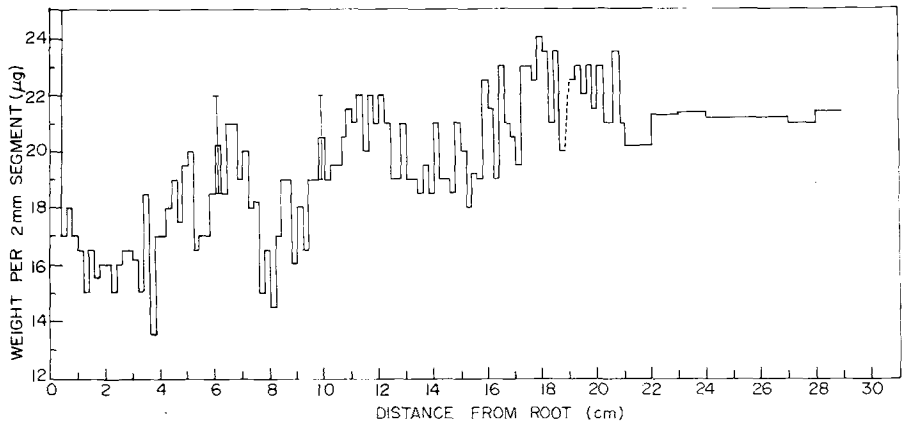


FIG. 6—*Variation in the weight of 2-mm segments of a head hair from Subject A, as a function of distance from the root.*

## Experimental Tracer Techniques

Certain features of the Cu patterns observed in hairs may perhaps, as noted earlier, be rationalized in terms of external contamination (either from sweat or fallout) soaking into the hairs. Experiments were therefore conducted to measure the response of hairs to soaking in Cu solutions.

### *Inactive Tracers*

Solutions of cupric ion were prepared from weighed quantities of pure Cu metal dissolved in nitric acid. The solutions were diluted to a concentration either of 0.1 or 1.0 mg/ml; the pH was adjusted to 4.9 by adding sodium hydroxide solution. This pH value has been shown [*19*] to be close to that at which maximum Cu absorption by human hair takes place. Human hairs were plucked and washed by the procedures outlined above. They were then soaked in the cupric ion solutions for a specified length of time, and then washed again for five minutes in distilled deionized water, five minutes in acetone, and five minutes in ether (to remove Cu solution wetting the external hair surface), and then air-dried. The hairs were next stored for a specified period, after which they were subjected to the cutting and atomic absorption analysis procedure described earlier.

### *Radioactive Tracers*

Pure Cu metal was irradiated with thermal neutrons in the nuclear reactor of the University of Washington, Seattle, Washington, until a $^{64}$Cu specific activity of 0.09 mCi/mg was obtained. The irradiated Cu metal was then dissolved in nitric acid and diluted with distilled deionized water to produce a solution in which the total Cu concentration was 0.6 mg/ml. The pH was then adjusted to 4.9 as before, and the solution used for soaking hairs which had been plucked and washed by the previously described procedure.

After soaking, the hairs were again rinsed as described in the previous section (but for 1 min per step instead of 5 min), cut into 2-mm segments by previously described techniques, and each individual segment was mounted on an aluminium planchette for radioactivity assay. The total beta radioactivity was measured by means of a Si(Li) detector coupled to conventional electronic apparatus, the efficiency and background counting rate of the assembly being monitored with and without standard radioactive sources during the duration of the experiment. From the known initial specific activity of the

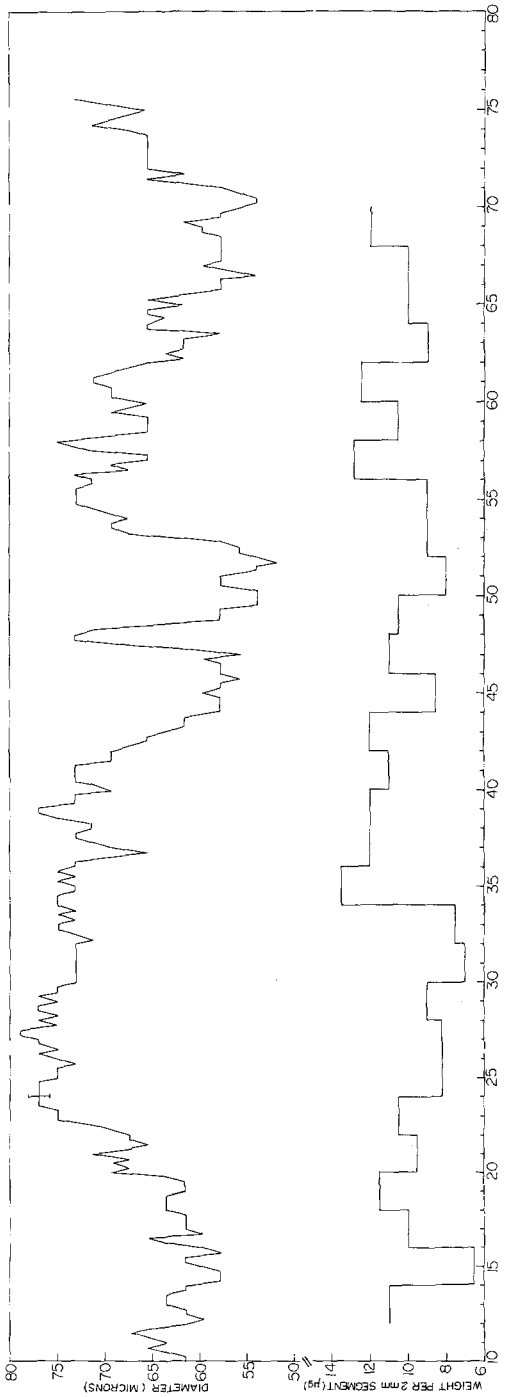


FIG. 7—*Variation in the projected diameter of a head hair from Subject A, in comparison with the weight of 2-mm segments, as a function of distance from the root.*

copper solution, and the known radioactive decay half-life of $^{64}Cu$, the radioactivity measurements were converted to mass of Cu taken up per segment during the soaking operation.

**Results from Tracer Experiments**

If the observed increasing concentration of indigenous Cu in a single hair with increasing distance from the root were indeed, as suggested earlier, due to progressively longer exposure times to contamination, then after soaking a hair in a Cu solution (under such conditions that the added Cu is very much greater in quantity than the indigenous Cu), the new Cu concentration should be relatively constant from one end of the hair to the other. This follows from the exposure time now being the same for all locations on the hair. Likewise, if the regions of locally increased and decreased Cu concentration are indeed, as suggested, due to dietary influences, then after such an intensive soaking operation such features should be submerged. Such expectations were subjected to direct test.

*Inactive Tracers*

Hairs plucked from the head of Subject A were subjected to the experimental procedure described in Experimental Tracer Techniques. The results are shown in Fig. 8, the concentration and time of soaking plus the delay time prior to measurements being indicated for each hair. Black and white hairs taken from the head of Subject B were also subjected to the same procedure. The results are shown in Fig. 9.

Several features are to be noted in these data. First, the Cu taken up by the hair during the soaking is not taken up uniformly along the length of the hair, whether the amount added is four, ten, or more times the content prior to soaking. Generally the first 2 mm, including the root, take up many times more Cu than the region 1 to 2 cm from the root. At greater distances from the root the amount of Cu increases in a manner similar to the increase in the natural Cu content. Thus, the increase with distance from the root in the natural Cu content may in large part or entirely be due to an increasing capacity with distance from the root for absorption of Cu from the environment, rather than to the increased exposure time as previously speculated. The large absorption capacity of the root region, the decreased absorption capacity found 1 to 2 cm from the root, and the increasing capacity found at greater distances presumably are linked to changes in hair structure on maturation or exposure to the atmosphere.

In addition, in the case of those subjects where the indigenous Cu concentration was found to have elevated values at particular sites along the hair, increased concentrations of Cu added during soaking were also found at about the same locations. This indicates that dietary Cu fluctuations are possibly not the origin, but evidently not the only origin, of this phenomenon. Further segment-to-segment variations are observed also in the added Cu levels, indicating that they too arise from detailed variations in the absorption capacity of the hair for Cu.

*Radioactive Tracers*

The employment of radioactive Cu solutions for soaking experiments as described in Experimental Tracer Techniques allowed study of the foregoing unexpected phenomena by an alternative measurement technique. In Fig. 10, data are assembled on four hairs drawn from Subject A, two at one time and two others plucked at a date four months later. The figure shows the pattern for indigenous Cu, for inactive Cu tracer added by the above techniques, and for two hairs treated with radioactive Cu tracer (the radioactivity indicating, of course, *added* Cu only). In each case a region of increased Cu concentration

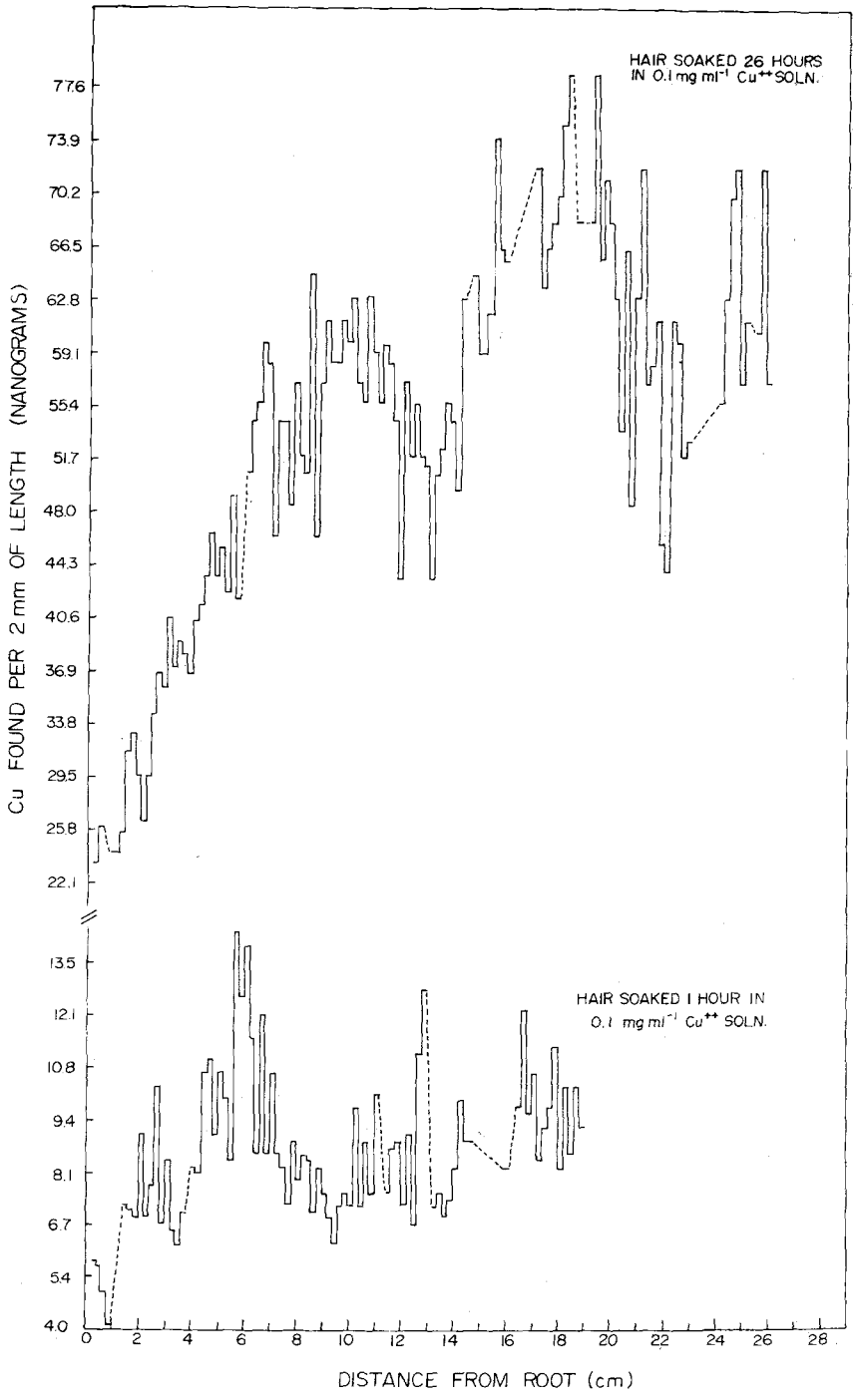


FIG. 8—*Copper patterns in head hairs from Subject A, after soaking in cupric ion solutions.*

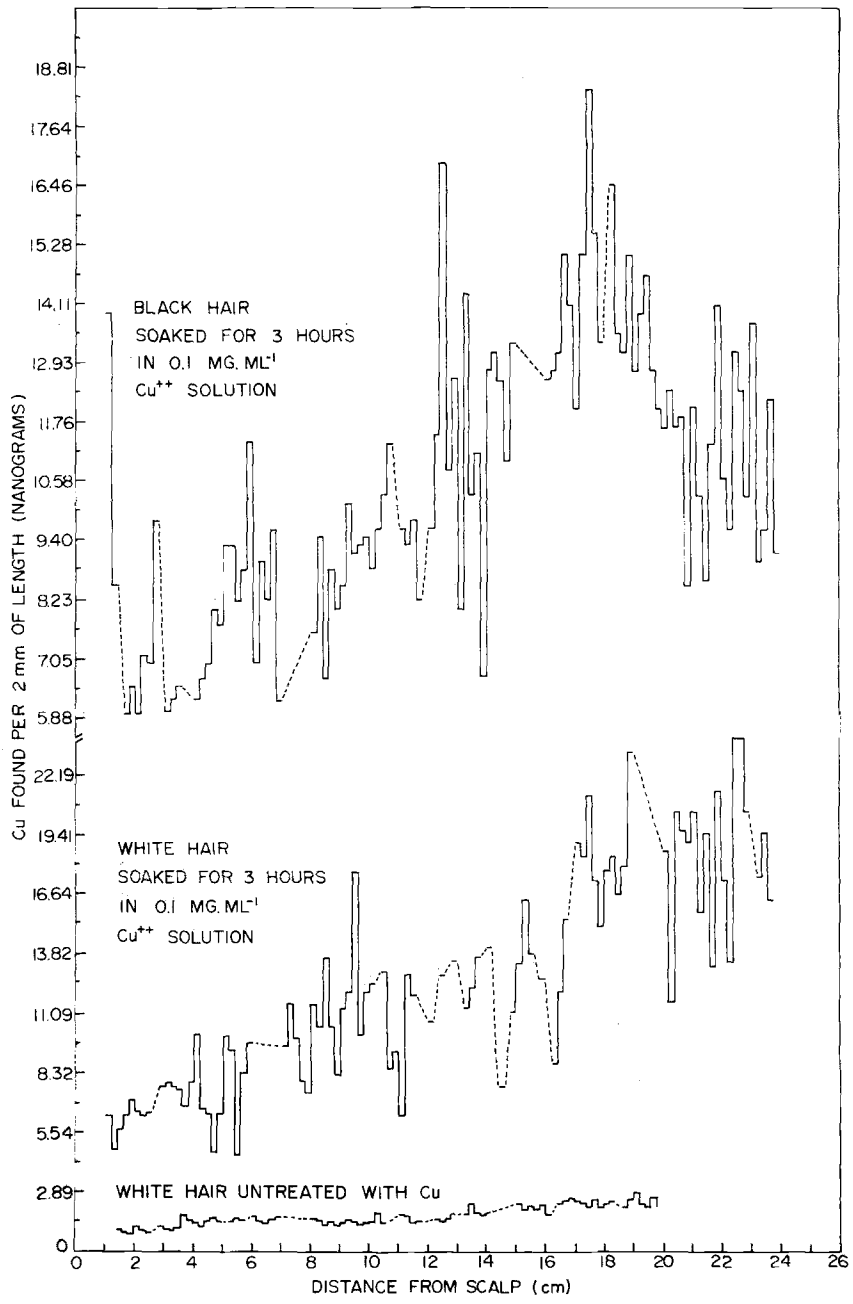


FIG. 9—*Copper patterns in head hairs from Subject B, before and after soaking in cupric ion solution.*

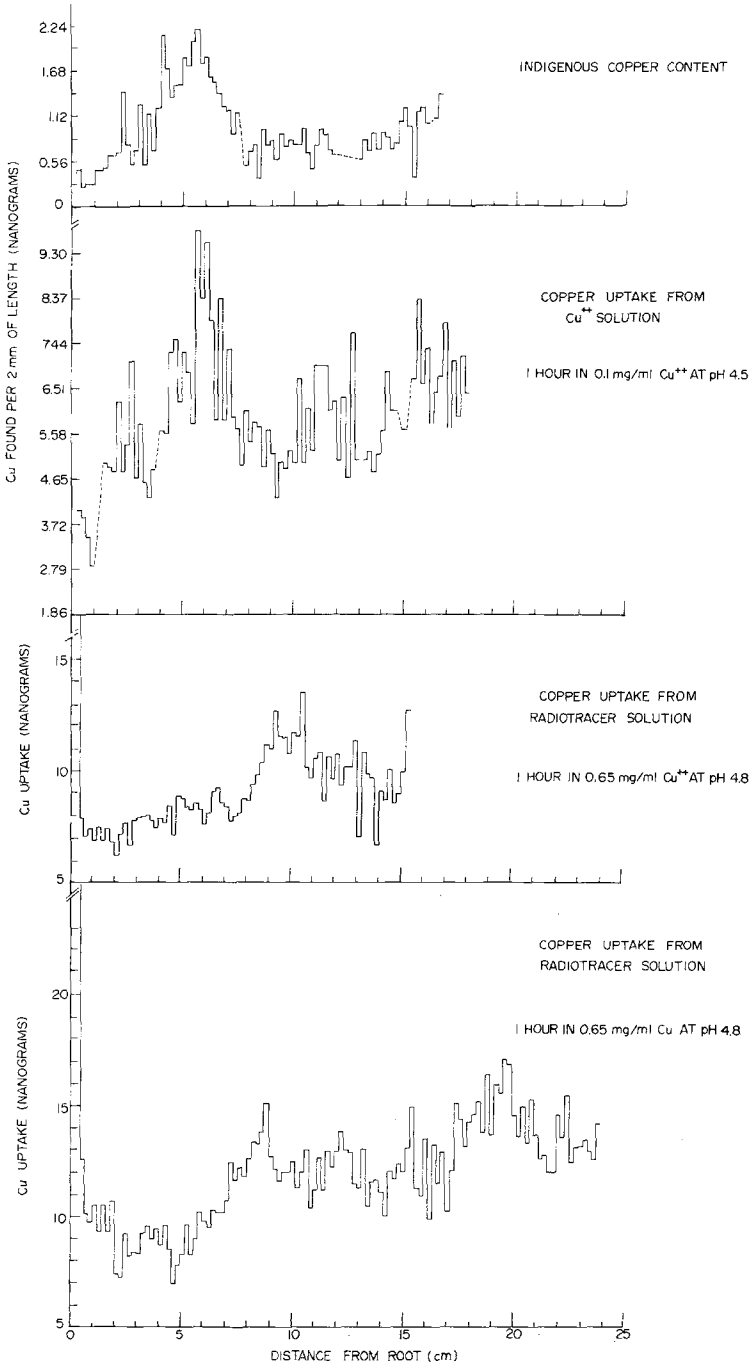


FIG. 10—*Copper patterns in head hairs from Subject A; indigenous copper, total copper after soaking in cupric ion solution, and added copper after soaking in radioactive cupric ion solution.*

is found, for the first two hairs at about 7 cm from the root and in the case of the latter two hairs at about 10 cm. The displacement in the position of the region of increased concentration for the latter two hairs is consistent with an increase in the length of the hairs during the four-month period of additional growth, given growth rates within the reported [*20*] range of 0.1 to 0.4 mm per inactive Cu tracer by giving very similar results.

Additional experiments were conducted with the hair drawn from Subject G, who had used a bleaching agent on her hair, with the result that the hairs plucked exhibited brown and bleached regions with a relatively sharp color change between the two. Figure 11 shows the results of indigenous Cu measurements (performed in an undergraduate exercise by the subject concerned) and uptake of radioactive Cu tracer measured via the foregoing technique. It is seen that the region of the hair treated with the bleach solution exhibits an increased indigenous Cu concentration, as well as an increased capacity to take up Cu from solution.

## Discussion

The foregoing data suggest that, in the case at least of the Cu content of hair (if not in the case of mercury [*4*] or arsenic [*7*]), the observed concentration patterns reported in this work may have arisen entirely from the element added to the hair from external sources. These would include not only Cu from sources external to the subject concerned but also dietary Cu, which found its way into sweat and sebaceous secretions with which the hair came into contact. Such external sources are to be distinguished from dietary Cu that might enter the hair directly during the growth processes occurring in the follicle itself. The present data contain no features that might be positively identified as arising from this latter mechanism.

As mentioned above, the generally observed increase of Cu content with increasing distance from the root may be due to an increasing capacity with distance to take up Cu from external sources. In addition, certain subjects show regions 1 to 2 cm long in the hair structure capable of increased Cu absorption from external sources compared with nearby parts of the hair. Such regions also appear to be associated with the hair structure, since they recede from the root at a rate consistent with that at which the hair itself grows. Further, the data contain evidence that, in all the hairs studied from a particular subject, such regions exist and are located at similar distances from the root for hairs in the anagen phase.

A preliminary attempt has been made by means of a scanning electron microscope (coupled when necessary with an X-ray detection system permitting microanalysis for Cu) to recognize features in the hair structure characteristic of regions of increased Cu absorbability. No such general features have been observed, except that the distal end of uncut hairs generally display splitting and other damage suggestive of abrasion of the cuticle layer. In the case of Subject E, who used a hair bleach, the bleached regions (the regions where increased Cu uptake was observed) did show evidence of damage from chemical attack. In untreated hair from the other subjects examined, however, no difference in morphology between highly absorbent and less absorbent regions was observed and no strong Cu fluctuations (corresponding to the 2-mm to 2-mm variations observed as described earlier) were measured down to spatial separations in the order of 0.1 mm, perhaps (though) due to inadequate sensitivity.

The origin and nature of these regions of increased Cu uptake capacity are a matter for some speculation. Preliminary experiments (to be reported) to determine whether the same regions also have an increased capacity for uptake of other cations suggest that they do not, but that regions with an increased capacity for uptake of zinc, for example, exist elsewhere on the same hair. Thus, the possibility exists that determination of the pattern for uptake of one or more elements may permit characterization of anagen hairs from a given subject.

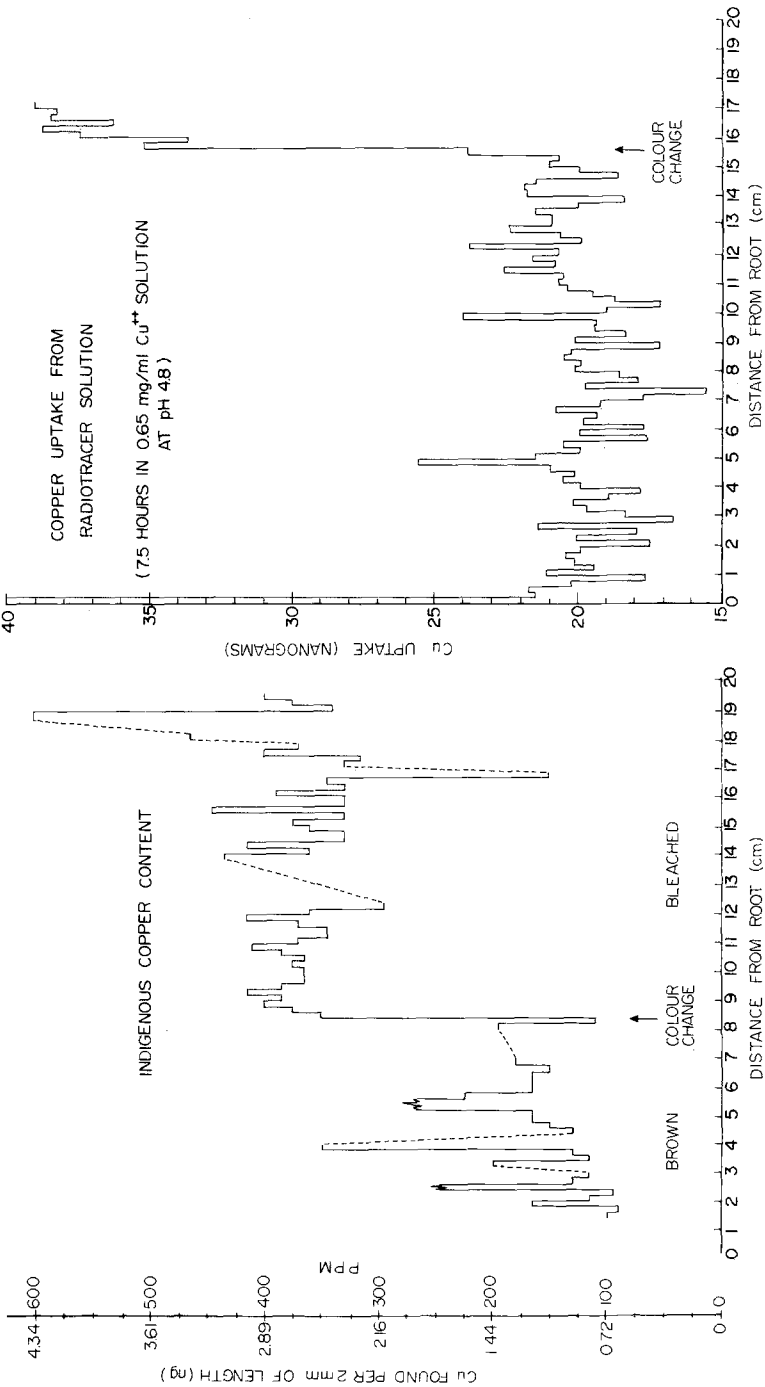


FIG. 11—*Copper patterns in head hairs from Subject G; indigenous copper and added copper after soaking in radioactive cupric ion solution.*

In forensic applications it is telogen hairs which are more often encountered. However, preliminary experiments appear to confirm the expectation that the absorption patterns in anagen and telogen hairs from the same subject are similar, and differ significantly only in the relative distance of pattern features from the root (anagen hair patterns being displaced from the root relative to telogen hair patterns).

Thus, due allowance being made for this effect, characterization of telogen hairs may also be possible.

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**Errata**

Maes, D. and Pate, B. D., "The Spatial Distribution of Copper in Individual Human Hairs," *Journal of Forensic Sciences,* JFSCA, Vol. 21, No. 1, January 1976, pp. 127–149. On p. 129, line 10, the sentence should read, "In addition, a 1-cm segment ..." not "a 1-mm segment." On p. 147, lines 4 and 5 should read "... given growth rates within the reported [*20*] range of 0.1 to 0.4 mm per day. Thus the experiments with radiotracer support those with inactive Cu tracer by giving very similar results." On p. 147, under Discussion, third paragraph, line 6, the sentence should begin "In the case of Subject G" instead of "Subject E."

Thornton, J. I. and McLaren, A. D., "Enzyme Characterization of Soil Evidence," *Journal of Forensic Sciences,* JFSCA, Vol. 20, No. 4, October 1975, pp. 674–692. The manufacturer of Spectronic® 20 was incorrectly identified; Spectronic® 20 is a registered trademark of Bausch & Lomb, Inc.

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