

# Genetic Structure of a Tribal Population, the Yanomama Indians

## XIII. DENTAL MICRODIFFERENTIATION <sup>1</sup>

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**ABSTRACT** Data are presented on the frequency of the following eight dental traits in 635 Yanomama and 65 Makiritare Indians: upper central incisor rotation or winging, shoveling of maxillary incisors, maxillary molar hypocone reduction, Carabelli's trait, mandibular molar cusp number, mandibular molar cusp pattern, rotation of second lower premolar, and pattern of second lower premolar cusps. Yanomama dentition is unusual in the high frequency of six cusps on the mandibular molars. There is marked dental microdifferentiation between villages; significant agreement was observed between a matrix of pairwise "dental distances" based on six morphological traits and corresponding matrices based on 11 genetic systems and on geographic location.

One of the principal objectives of our studies of the Yanomama Indians of Southern Venezuela and Northern Brazil has been to evaluate the degree and pattern of microdifferentiation between the demes (villages) of this relatively undisturbed tribe. To this end extensive data have been presented on genetic traits (summary in Tanis et al., '73; Ward et al., '75), anthropometrics (Spielman et al., '72), and dermatoglyphics (Rothhammer et al., '73). A significant question for those characterizing microdifferentiation in subdivided populations is how well the pattern revealed by one set of characteristics agrees with the pattern revealed by another; in the absence of significant correspondence it would be difficult to regard the microdifferentiation as corresponding to meaningful biological diversification. As a contribution to this question, the patterns of intratribal differentiation revealed by these traits in the Yanomama have been compared with each other and with geographic location and linguistic subdivision in a variety of ways (summary in Neel et al., '74; Migliazza and Neel, '74). In this communication we present the results of studies on dental morphology carried out in the course of four different expeditions (1966,

1968, 1969, 1971), with especial reference to village differences, and how well these differences correspond to other kinds of differences. Studies on oral hygiene, periodontal disease, and caries will be presented elsewhere. Although the bulk of the data concern the Yanomama, a small amount of information is reported on a neighboring tribe, the Makiritare. The precise location of these tribes together with a brief characterization will be found in Chagnon ('68) and Gershowitz et al. ('70).

### PROCEDURES

Dental morphology was recorded either by standard full-mouth impressions or wax-bite impressions. A total of 811 impressions were obtained of which 18% were full-mouth. When taking wax-bite impressions, a double thickness of wax was used anteriorly; the strength of the Indian bite in gen-

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eral resulted in relatively good impressions. With either method, plaster casts were prepared from the impressions. Although the standard full-mouth impressions are of course superior, the necessary cooperation could not be obtained in the most remote villages (whereas the wax-bite impressions were a "game"). None of the traits reported involve fine measurements such as tooth dimension, for which the wax-bite impressions would not be adequate. Unfortunately, because of attrition, mixed deciduous and adult dentition, or absence (usually traumatic, rarely because of caries), many teeth could not be scored. On the other hand, as the data will show, most impressions could be scored for at least several of the traits. In any instance where the impression was not sharp, the trait was not scored. Deciduous teeth were excluded from consideration.

#### THE TRAITS

Data are presented on eight traits, as follows:

*Upper central incisor rotation or winging.* Upper central incisor rotation or winging was scored in five categories, as described by Dahlberg ('63a): 0, normal; 1, unilateral counterwinging; 2, straight; 3, unilateral winging; and 4, bilateral winging. An individual had to retain both incisors to receive a score for this trait. The asymmetric categories 1 and 3 were very rare, so the data are presented with category 1 combined with 2, and 3 with 4, resulting in three classes. Although there was occasional uncertainty as to the borderline between classes 0 and 2, the distinction between 2 and 4 was clear.

*Maxillary incisor shoveling.* Maxillary incisor shoveling has been codified by Hrdlička ('20) and Carbonell ('63). We followed the nomenclature as used on Dahlberg's widely disseminated "standard" casts. Both medial and lateral shoveling were coded as follows: 0, no shoveling (Dahlberg's a); 1, trace shoveling (Dahlberg's b); 2, semi-shoveling (Dahlberg's c); and 3, marked shoveling (Dahlberg's d,f,g). The decision as to the degree of shoveling was based on visual inspection of the casts. The very great anterior attrition seen in the Yanomama made scoring of some individuals quite difficult and the category "semi-shoveling" was difficult to standardize and is thereby possibly under-represented. For

this trait and all other traits (except winging), each tooth was scored separately and the counts given are for teeth, not individuals. Thus, for central and lateral incisors, each individual can be represented in the tabulation by 0, 1, or 2 teeth.

*Maxillary molar hypocone reduction.* Maxillary molar hypocone reduction was scored for all three upper molars, following the classification of Dahlberg ('49): 4, four well-developed cusps; 4<sup>-</sup>, a reduction in size of the hypocone; 3<sup>+</sup>, three cusps, but a small distal cuspule; and 3, three definite cusps (hypocone absent).

Our scoring of 4<sup>-</sup> was not identical to Dahlberg's. We scored any reduction of the hypocone as 4<sup>-</sup>. Dahlberg ('49: p. 169, plate 16) pictures M<sup>2</sup> and M<sup>3</sup> hypocones that we would have recorded as 4<sup>-</sup> while he scores them as 4.

*Carabelli's trait.* Carabelli's trait of the maxillary molars was scored essentially following Kraus ('59): 0, Carabelli's trait completely absent, smooth surface; 1, pit; 2, grooves or furrows; and 3, 4, 5, true tubercle of some form. The occurrence of either pits or pronounced tubercles was infrequent. Because of this and because there is some difficulty in scoring this trait on impressions from wax-bites, the data have been reduced to only two classifications, derived from combining categories 0, 1 and 2, and 3, 4, and 5.

*Mandibular molar cusp pattern.* Mandibular molar cusp patterns were divided into three categories: (1) Y pattern, the buccal-distal cusp in contact with the mesial-lingual cusp; (2) + pattern (the four main cusps meet at a common point or the line of contact was less than 0.1 mm); (3) X pattern, the buccal-mesial cusp was in contact with the lingual-distal cusp.

*Mandibular molar cusp number.* In the scoring of mandibular molar cusp number, the definitions present some problems. One can require a sixth cusp to be separated from the fifth cusp by a groove that runs down the distal side of the molar. We did not make such a requirement, in part because of the difficulties in scoring wax-bite impressions. If the fifth and sixth cusps are significantly smaller than the first four, they can be considered cusplets. As Goldstein ('31) points out, some workers do not count these cusplets in determining cusp number. However, we did include cusplets

and cuspules in our counts. A very few individuals had a cusp located between the two lingual cusps, known as the seventh cusp (Dahlberg, '45). This trait appeared to have a low frequency but it is difficult to score for its presence without full-mouth impressions; we have ignored the possible presence of this cusp in the scoring.

For this and the preceding two traits, the third molar was so poorly recorded in waxbite impressions that only data for  $M_1$  and  $M_2$  are presented.

*Second lower premolar rotation.* During the scoring of the sample, it was noted that the second lower premolars had a tendency to rotate so that the mesial end of the sagittal sulcus was more lingual than usual. This trait was scored in three categories: 1, no inward rotation; 2, slight rotation; and 3, rotation exceeding approximately  $30^\circ$  from normal orientation. This trait was not scored if either the adjacent first premolar or first molar was absent, due to the frequent "drifting" of the second premolar in such cases.

*Second lower premolar cusp pattern.* The relative position of the deutoconid and protoconid for the mandibular second premolars was scored as described by Morris ('70): 1, deutoconid mesial to the protoconid; 2, deutoconid medial to the protoconid; 3, deutoconid distal to the protoconid. Morris' second category, as defined, is unclear. Medial has been interpreted as referring to the situation where the deutoconid is neither mesial or distal to the protoconid, but where both are in line. Only the first two of Morris' categories were observed.

All traits were scored by one person. Sofaer et al. ('72) have emphasized the subjectivity and the amount of nonreproducibility in the scoring of dental traits. We have no doubt this is true of the present series, but restricting the scoring to casts and to a single individual at least helps to ensure that observer bias is uniform.

#### THE FINDINGS

Data were collected in 25 different Yanomama villages and in three Makiritare villages. Most of the village samples were quite small. The findings in the seven villages presenting the largest numbers will be given by village, to document the basis for certain analyses to be presented below. The

findings in the remaining villages (03B, 03E, 03F, 03G, 03J, 08E, 08F, 08G, 08H, 08K, 08N, 08Q, 11L, 11M, 11S, 11V, 11W and 11X) have been summarized under a "miscellaneous" category, and the findings in the three Makiritare villages (10BD, 10C, 10F) have been combined. The locations of these villages are shown in Gershowitz et al. ('70) and Ward ('72).

The raw data are presented in table 1. To conserve space, no age (all estimated) and sex breakdown is given, but these are available to the interested reader. In general, the data are based on individuals of age 15–30; after that age attrition makes scoring extremely difficult. Restricting the data only to mouths in which all teeth could be scored for all traits would have reduced the numbers for each village to the point where an analysis was scarcely justified. Accordingly, the individuals scored for central incisor winging and shoveling may not completely coincide with those scored for the molar traits, and with respect to the latter, an individual may be represented by one or two teeth. Since there may be correlation not only between the patterns of corresponding teeth ( $r -$ ) but also between the patterns of different teeth, there is non-binomial variation in these data. In addition, the village samples contain biologically related persons, introducing further non-binomial variation. For these reasons, we shall refrain from conventional statistical tests of village differences.

A distance matrix based on the dental traits has been derived for these seven villages by the formulation originally designated by Pearson ('26; also Sokal and Sneath, '63) as the Coefficient of Racial Likeness. This is defined as follows:

$$D_{XY}^2 = \frac{6}{i \sum 1} \frac{(\bar{X}_i - \bar{Y}_i)^2}{S_i^2} \quad (1)$$

where

$\bar{X}_i$  = mean for trait  $i$  for village  $X$   
 $\bar{Y}_i$  = mean for trait  $i$  for village  $Y$   
 $S_i$  = pooled "standard deviation" over all villages for trait  $i$ .

Because so many individuals could not be scored for all traits, it was not feasible to determine accurately the inter-correlations of the various dental characteristics. We have accordingly chosen for this analysis those six traits that exhibited the most inter-village variability, and that appear

TABLE 1

The frequency of eight dental traits among the Yanomama and Makiritare Indians. For all except the first trait, a given individual may be represented by 0, 1, or 2 entries, depending on the scorable teeth

Trait	Group	03A	03C	03D	03H	03I	08ABC	08R	Misc. Yanomama	Total Yanomama	Total Makiritare
<b>Central incisor</b>											
<i>winging</i>											
None (0)		.095 (6)	.068 (3)	.151 (8)	.079 (3)	.222 (6)	.182 (12)	.178 (8)	.173 (49)	.150 (95)	.292 (19)
Straight (1, 2)		.286 (18)	.318 (14)	.208 (11)	.237 (9)	.333 (9)	.333 (22)	.378 (17)	.359 (102)	.318 (202)	.292 (19)
Winged (3, 4)		.619 (39)	.614 (27)	.641 (34)	.684 (26)	.445 (27)	.485 (32)	.444 (20)	.468 (133)	.533 (338)	.415 (27)
		(63)	(44)	(53)	(38)	(42)	(66)	(45)	(284)	(635)	(65)
<b>Maxillary incisor</b>											
<i>shoveling</i>											
Central incisors											
Trace (1)		.042 (4)	.023 (2)	.000	.000	.043 (2)	.106 (14)	.166 (12)	.204 (120)	.128 (154)	.479 (66)
Semi (2)		.064 (6)	.159 (14)	.145 (16)	.027 (2)	.348 (16)	.394 (52)	.528 (38)	.330 (194)	.281 (338)	.391 (54)
Marked (3)		.894 (84)	.818 (72)	.855 (94)	.973 (72)	.609 (28)	.500 (66)	.306 (22)	.466 (274)	.591 (712)	.130 (18)
		(94)	(88)	(110)	(74)	(46)	(132)	(72)	(588)	(1204)	(138)
<b>Lateral incisors</b>											
None (0)		.156 (10)	.143 (8)	.049 (4)	.000	.000	.035 (4)	.028 (2)	.059 (26)	.059 (54)	.044 (6)
Trace (1)		.250 (16)	.393 (22)	.390 (32)	.148 (8)	.333 (6)	.351 (40)	.457 (32)	.591 (260)	.452 (416)	.809 (110)
Semi (2)		.281 (18)	.214 (56)	.390 (32)	.445 (24)	.667 (12)	.421 (48)	.429 (30)	.218 (96)	.343 (316)	.132 (18)
Marked (3)		.313 (20)	.250 (14)	.171 (82)	.407 (22)	.000 (18)	.193 (22)	.086 (6)	.132 (58)	.146 (134)	.015 (2)
		(64)	(100)	(82)	(54)	(18)	(114)	(70)	(440)	(920)	(136)
<b>Hypocone reduction</b>											
M <sup>1</sup> : 4		.324 (33)	.418 (33)	.816 (71)	.579 (44)	.472 (25)	.771 (111)	.927 (76)	.596 (366)	.616 (759)	.563 (63)
4-		.676 (69)	.582 (46)	.184 (16)	.421 (32)	.528 (28)	.208 (30)	.061 (5)	.401 (246)	.379 (467)	.438 (49)
3+		.000 (102)	.000 (79)	.000 (87)	.000 (76)	.000 (53)	.021 (3)	.012 (1)	.003 (2)	.005 (6)	.000 (112)
							(144)	(82)	(584)	(1232)	
M <sup>2</sup> : 4		.043 (4)	.000	.087 (6)	.049 (3)	.000	.122 (10)	.224 (11)	.070 (31)	.070 (65)	.043 (3)
4-		.344 (32)	.500 (34)	.725 (50)	.525 (32)	.366 (19)	.610 (50)	.571 (28)	.462 (204)	.482 (449)	.478 (33)
3+		.505 (47)	.382 (26)	.130 (9)	.426 (26)	.442 (23)	.183 (15)	.122 (6)	.303 (134)	.314 (292)	.217 (15)
3		.109 (10)	.113 (7)	.058 (4)	.000 (61)	.192 (10)	.085 (7)	.083 (4)	.165 (73)	.125 (125)	.261 (18)
		(93)	(67)	(69)		(52)	(82)	(49)	(442)	(931)	(69)
<b>Carabelli's cusp</b>											
M <sup>1</sup> : None		.118 (11)	.013 (1)	.011 (1)	.052 (4)	.225 (9)	.320 (38)	.352 (25)	.304 (168)	.229 (257)	.377 (43)
1 + 2		.656 (61)	.500 (39)	.237 (22)	.403 (31)	.625 (25)	.453 (54)	.493 (35)	.485 (268)	.476 (535)	.430 (49)
3 + 4		.226 (21)	.487 (38)	.753 (70)	.546 (42)	.150 (6)	.227 (27)	.155 (11)	.212 (117)	.295 (332)	.193 (22)
		(93)	(78)	(103)	(77)	(40)	(119)	(71)	(553)	(1124)	(114)

GENETIC STRUCTURE OF THE YANOMAMA INDIANS

TABLE 1 (Cont'd.)  
 The frequency of eight dental traits among the Yanomama and Makiritare Indians. For all except the first trait, a given individual may be represented by 0, 1, or 2 entries, depending on the scorable teeth

Trait	Group	03A	03C	03D	03H	03I	08ABC	08R	Misc. Yanomama	Total Yanomama	Total Makiritare
$\underline{M}_2$ : None		.930 (80)	.809 (56)	.677 (44)	.733 (44)	.850 (34)	.779 (67)	.807 (46)	.858 (387)	.830 (758)	.829 (58)
1 + 2		.070 (6)	.191 (12)	.292 (19)	.250 (15)	.150 (6)	.198 (17)	.193 (11)	.135 (61)	.161 (147)	.171 (12)
3 + 4		.000 (86)	.000 (68)	.031 (65)	.017 (60)	.000 (40)	.023 (86)	.000 (57)	.007 (451)	.009 (913)	.000 (70)
<i>Lower molar cusp pattern</i>											
$\underline{M}_1$ : Y		.560 (37)	.619 (39)	.635 (47)	.517 (30)	.525 (21)	.581 (43)	.548 (17)	.608 (259)	.592 (493)	.440 (22)
+		.409 (27)	.254 (16)	.216 (16)	.345 (20)	.300 (12)	.135 (10)	.097 (3)	.282 (120)	.269 (224)	.320 (16)
X		.030 (2)	.127 (8)	.149 (11)	.138 (8)	.175 (7)	.284 (21)	.355 (11)	.110 (47)	.139 (115)	.240 (12)
		(66)	(63)	(74)	(58)	(40)	(74)	(31)	(426)	(832)	(50)
$\underline{M}_2$ : Y		.073 (5)	.046 (3)	.048 (3)	.000 (3)	.045 (2)	.044 (2)	.111 (5)	.038 (15)	.046 (35)	.065 (3)
+		.073 (5)	.154 (10)	.238 (15)	.160 (9)	.341 (15)	.244 (11)	.289 (13)	.340 (135)	.283 (213)	.413 (19)
X		.853 (58)	.800 (52)	.714 (52)	.840 (47)	.614 (27)	.711 (32)	.600 (27)	.622 (247)	.670 (504)	.522 (24)
		(68)	(65)	(32)	(56)	(44)	(45)	(45)	(397)	(752)	(46)
<i>Lower molar cusp number</i>											
$\underline{M}_1$ : 5		.423 (33)	.478 (32)	.442 (34)	.164 (12)	.619 (26)	.611 (44)	.778 (28)	.519 (242)	.495 (451)	.750 (42)
6		.577 (45)	.522 (35)	.558 (43)	.836 (61)	.381 (16)	.389 (28)	.222 (8)	.481 (224)	.505 (460)	.250 (14)
		(78)	(67)	(77)	(73)	(42)	(72)	(36)	(466)	(911)	(56)
$\underline{M}_2$ : 4		.155 (11)	.162 (11)	.030 (2)	.054 (3)	.222 (10)	.300 (12)	.032 (1)	.144 (49)	.135 (99)	.345 (20)
5		.775 (55)	.691 (47)	.939 (62)	.678 (38)	.644 (29)	.625 (25)	.581 (31)	.628 (214)	.685 (501)	.535 (31)
6		.070 (5)	.147 (10)	.030 (2)	.268 (15)	.133 (6)	.075 (3)	.387 (12)	.229 (78)	.179 (131)	.121 (7)
		(71)	(68)	(66)	(56)	(45)	(40)	(44)	(341)	(731)	(58)
<i>Lower second premolar Rotation:</i>											
None		.743 (52)	.886 (62)	.794 (8)	.800 (16)	.454 (20)	.816 (89)	.742 (49)	.849 (444)	.801 (740)	.896 (60)
Slight		.200 (14)	.114 (8)	.118 (8)	.100 (2)	.500 (22)	.165 (18)	.182 (12)	.122 (64)	.160 (148)	.104 (7)
Present		.057 (4)	.000 (70)	.088 (6)	.100 (2)	.045 (2)	.019 (2)	.076 (5)	.029 (15)	.039 (36)	.000 (67)
		(70)	(70)	(22)	(20)	(44)	(109)	(66)	(523)	(924)	(67)
<i>Cusp pattern:</i>											
Mesial		.571 (40)	.417 (30)	.500 (30)	.450 (18)	.619 (26)	.473 (35)	.314 (11)	.546 (218)	.515 (408)	.317 (26)
Medial		.439 (30)	.583 (42)	.500 (30)	.550 (22)	.381 (16)	.527 (39)	.686 (24)	.454 (181)	.485 (384)	.683 (56)
		(70)	(72)	(60)	(40)	(42)	(74)	(35)	(399)	(792)	(82)

TABLE 2

*Below diagonal: a distance matrix between seven villages based on the application of the Coefficient of Racial Likeness to six dental traits; above diagonal: a geographic distance matrix for these same villages. Since the exact location of most villages is somewhat uncertain, distances are given to the nearest kilometer. Further explanation in text*

	03A	03C	03D	03H	03I	08ABC	08R
03A	—	9	31	49	15	67	62
03C	0.643	—	22	40	23	70	69
03D	1.480	0.920	—	19	45	86	83
03H	1.217	0.853	1.102	—	61	96	101
03I	0.657	0.903	1.576	1.560	—	52	64
08ABC	1.134	1.102	1.445	1.578	0.671	—	108
08R	1.716	1.707	1.888	2.194	1.134	0.656	—

from the dental literature to be the most independent of each other. In particular, where the same trait can be scored for adjacent teeth such as is the case for shoveling or Carabelli's trait, etc., data for only one of these teeth were included in the analysis. This is because the scanty data indicate that the expression of traits in adjacent teeth is correlated (Dahlberg, '63b). The six traits chosen were as follows: winging of central incisors, shoveling of lateral incisors, Carabelli's trait of the first molar, hypocone reduction of the first molar, first mandibular molar cusp number and first mandibular molar cusp pattern. For each trait a numerical value (1, 2, . . . , m) was assigned to the categories shown in table 1, a mean and standard deviation derived for each village, and the between-village distances based on these means computed with Formula (1). The resulting matrix is shown in table 2. With this approach, considerable variation in the distance between villages is apparent, ranging from 0.643 to 2.194.

Recently we have devoted considerable effort to the question of how well matrices of "distance" between Indian villages based on various biological traits correspond. In all of the instances studied thus far (genetic markers, anthropometrics, and dermatoglyphics), the genetic contribution to the trait has been more clearly defined than in the case of the traits here under consideration. Accordingly, a similar comparison was thought to be of interest for these data. Unfortunately, due to the exigencies of field work, only for genetic markers among the other biological traits do the data permit such a comparison. In addition, geographic distance is also available.

TABLE 3

*Spearman rank-order correlations between corresponding entries in village distance matrices for dental traits, genetic markers and geographic distance*

	Dental traits	Genetic markers
Genetic markers	0.597 <sup>1</sup>	—
Geographic distances	0.492 <sup>2</sup>	0.310

<sup>1</sup>  $p < 0.001$ .

<sup>2</sup>  $0.05 > p > 0.01$ .

Table 3 presents Spearman rank-order correlations between the entries in the lower triangular matrix of table 2 and the corresponding elements in the matrix of genetic distances based on 11 genetic systems published by Ward ('72). It has been empirically demonstrated that in such complex circumstances (triangular matrix, multivariate distances), the error term appears to be distributed corresponding to  $n-1$  degrees of freedom where  $n$  is the number of entries in the matrix, rather than the number of populations on which the matrix is based (Lingoes, '73). The correlation between the corresponding entries in the dental and genetic distance matrices is highly significant, that between dental distances and geography, less so. Interestingly, the correlation between the genetic and geographic matrix entries, significant in other studies (Spielman, '73; Neel et al., '74), is not significant here.

As a second measure of fit, we have employed the matrix superimposition techniques of Schönemann and Carroll ('70), using the measure of fit ( $S$ ) developed by Lingoes and Schönemann ('73), for which

TABLE 4

Values of *S* for comparisons of dental trait, genetic marker and geographic distance matrices. Genetic marker and dental trait data transformed to two-dimensional data by principal component method<sup>1</sup>

	Dental traits	Genetic markers
Genetic markers	0.442 <sup>2</sup>	—
Geographic distances	0.394 <sup>2</sup>	0.559

<sup>1</sup> See text for explanation of significance values.

<sup>2</sup> 0.05 > *p* > 0.01.

empiric significance values have been developed by Spielman ('73). However, the significance values are generated in an alternative fashion to that employed earlier, namely, by comparison with the distribution of fit for 250 pairs of 7-village sets placed randomly in a unit hypercube of six dimensions (cf., Spielman et al., '74) (see table 4). With this approach the correspondence between the two matrices based on biological data is again significant (but barely so), the correspondence between the dental and the geographic matrix again also significant, but the correspondence between the geographic and the genetic matrices again non-significant.

As a third measure of fit, following Spielman ('73) all possible dendrogram representations of the seven villages contributing to the dental matrix were obtained by the technique described by Cavalli-Sforza and Edwards ('67) and ranked in the order of the total path length of the net. The same was done for the matrix based on genetic traits. The number of nets in common among the 50 shortest nets for each series was seven. Spielman ('73) through simulation has derived empiric probabilities which permit the statement that this number of nets in common will occur by chance in between 12 and 15% of such comparisons, i.e., a significant correspondence is not observed in this contrast.

#### DISCUSSION

##### *A comparison of the Yanomama with other groups*

While our concern is not to compare these groups exhaustively with all other Indians, the data summarized by Dahlberg ('49, '63a) as well as additional more re-

cent studies do allow us to determine in a general way how these two groups fit within the New World dental pattern. Winging of the incisors is present in 53% of the Yanomama and 42% of the Makiritare. Contrasted with other American Indians, as summarized by Dahlberg ('63a), this appears to be a higher frequency than that of most North American Indian groups (some of whom have some Caucasian admixture), although the Zuni have 49%. However, this frequency is within the range of South American groups, as the Pewenche have 55.5% (Rothhammer et al., '68), the Diaguitas have 66.2% (Campusano et al., '72) and the Jivaro have between 50–70% (Wright, '41).

Shoveling of some form (including the trace category) was found in all Yanomama and Makiritare. The data on the central incisors are in good agreement with those on other American Indians (Dahlberg, '49, '63a). The frequency of marked or semi-shoveling in the lateral incisors of the Makiritare is, however, exceptionally low (cf. Dahlberg, '49; Rothhammer et al., '68; Bang and Hasund, '71).

There is little reduction in the maxillary hypocone of the Yanomama. The first molar, as in many other populations, shows almost no reduction. The second molars were typed as either 4 or 4<sup>-</sup> in 55% of the specimens (52% for the Makiritare); this is somewhat higher than is common for most Indian groups, e.g., 23% for the Tarahumara (Snyder et al., '69), 25% for the Aleuts (Turner, '69), and 28.9% for five groups of Peruvian Indians (Goaz and Miller, '66), but 57% for the Hopi (Turner, '69) and 58% for the Pima (Dahlberg, '49).

Some form of Carabelli's cusp is very common on the first molar of both groups. As with other Indian groups, its expression tends to be slight. Although present in 77% and 62% of the teeth, it was expressed only as a pit or groove in 48% and 43% of the first molars of the Yanomama and Makiritare, respectively. These frequencies are somewhat lower than the average of those given by Dahlberg ('63a) for other American Indian groups. The incidence of Y patterns (either 5 or 6 cusps) on the first and second lower molars also appears to be low.

The only really striking feature in this study is the incidence of six cusps on the mandibular molars in the Yanomama,

which appears to be unparalleled in studied populations. Over 50% of all individuals had six cusps on  $M_1$ . Although the literature is scanty for this trait, the 18.5% incidence found for the Papago by Morris ('70) appears to be a high value for other populations. While to some extent this extreme value may result from our definition of cusp (see above), we feel the incidence of this trait to be high even when allowance is made for scoring procedures.

No quantitative records were made of the Yanomama's dental attrition. However, on a subjective basis, the degree of posterior attrition of the Yanomama dentition is quite marked, although it was probably exceeded by populations such as Southwestern or California Indians. On the other hand, the Yanomama anterior attrition is quite extreme and not matched by any populations (including prehistoric) known to us. In some individuals there is a complete lack of incisor occlusion with a gap remaining. This same conclusion was reached by Pereira ('72) who examined Brazilian groups of Yanomama.

#### *Inter-village variability in the Yanomama*

The number of different villages sampled provides an opportunity to compare inter-village variation lacking in most other studies (as well as a better estimate of the tribal means). The impropriety of applying the usual statistical tests such as a heterogeneity  $\chi^2$  to a comparison of villages given the qualifications mentioned earlier is clear. However, inspection alone reveals some rather striking village differences. Some of the most marked variability between villages is seen for the shoveling trait. Village 03H (97% marked) is strikingly different from 08R (31% marked). While much of this variability is presumably real, some may be a result of the difficulties in determining the degree of shoveling in teeth with heavy attrition. Yanomama villages also show marked differences in hypocone reduction, e.g., 03A (68% reduced for  $M^1$ ) and 03D (18% reduced).

Less but probably significant inter-village variability is observed for the degree of winging, frequency of Carabelli's trait, mandibular molar cusp numbers, and mandibular molar cusp patterns. Low variability is found for both  $PM_2$  rotation and  $PM_2$  cusp

patterns, although for the  $PM_2$  rotation trait village 03I was quite different from the overall pattern; while 08R showed an equal discrepancy for  $PM_2$  cusp pattern.

#### *How do these matrix correspondences compare with other similar studies of the Yanomama?*

As noted earlier, similar 7-village distance matrices have been obtained and compared for a variety of other Yanomama traits, with the objective of testing the biological significance of the differences on which the distance matrices are based; in the absence of any correspondence one would be forced to conclude the microdifferentiation was more noise than signal. The comparison has usually been limited to seven villages for a very practical reason, namely, that in one type of comparison, involving dendrograms, one must generate all possible dendrograms, and the difference between the 945 possible dendrograms of seven villages and the 10,395 possible dendrograms of eight villages is formidable. With respect to the correlation approach, Spielman ('73) has reported for a set of seven Yanomama villages quite variable Spearman rank correlations between the corresponding entries in marker gene, anthropometric and geographic matrices, ranging from 0.73 (anthropometric-geographic) to -0.25 (marker gene-anthropometric). He found that in a comparison of these same seven villages by the Lingoes-Schönemann-Spielman technique of matrix superimposition, the anthropometric-geographic comparison was significant ( $p < 0.01$ ) but the anthropometric-genetic marker and the genetic marker-geographic were not, and that in the comparison for "number in common among the best 50 dendrograms," the number in common for anthropometric traits and marker genes and for marker genes and geographic distance was quite significant, but no significance in the anthropometric traits-geographic distance comparison. Neel et al. ('74), employing the *tau* rank-order correlation of Kendall ('62), compared corresponding entries in matrices based on genetic traits, anthropometric, dermatoglyphics, and geographic distance for an essentially different set of villages from that employed by Spielman (only three in common). Significance levels very similar to the present were obtained



for the comparison of genetic with anthropometric matrices, genetic with dermatoglyphic matrices, and for all three comparisons of biological distance matrices with geographic distance, but no significant correspondence in the anthropometric-dermatoglyphic comparison. With respect to matrix superimposition, all six tests were significant at the  $0.05 > p > 0.02$  level. Finally, for the dendrogram comparisons, five of the six were significant at the  $p < 0.02$  level. The various problems in such comparisons are discussed extensively by these authors.

The present results are quite preliminary, presented as much to illustrate the approach as because of the conclusions to which they lead. Because in prehistoric material teeth are better preserved than any other tissue, the potential usefulness of establishing that dental distance matrices correspond significantly with other measures of biological differentiation is clear. Elsewhere (Neel et al., '74) we have discussed the many reasons why the Yanomama data are not ideal for comparisons of this type, especially the smallness of the village samples (imposed by village size) and the fact that the individuals contributing to one set of measurements are not always identical to those contributing to another. We note in the present comparisons two still further complications, which suggest caution in comparing these results too explicitly with the results of other similar comparisons of Yanomama village matrices. Firstly, the degree of dental attrition repeatedly interfered with scoring procedures and further reduced sample sizes. Secondly, the villages in which the dental studies were done cover a much smaller portion of the Yanomama distribution than that represented by the two previous studies of this type. The effect of this difference in "sampling" — imposed by availability of personnel — is not clear. At this point we can only say that despite the recognized imperfections of the data, the pattern of microdifferentiation suggested by dental traits is roughly comparable to that projected by other types of biological traits whose genetic basis is more firmly established. The manner in which the different sets of data on various characteristics (blood groups, anthropometrics, dermatoglyphics, and now dental traits) reveal a similar pattern of microdifferentiation suggests that a

treatment combining all these characteristics would provide a much better (and more stable) picture of the biological relationships of villages to one another than a treatment based on only one data set. Furthermore, given our interest in the evolutionary process in tribal-type populations, we feel reinforced in the view that the village differences we have been measuring provide a point of departure for understanding the origin of the phenotypic diversity of Amerindian tribes (cf. Neel, '69).

There has been one other similar attempt to compare a dental and genetic distance matrix (Sofaer et al., '72). Data were available for only three populations (Zuni, Pima and Papago), an inadequate number for the types of analysis practiced in this paper. A comparison based on their full battery of traits (10) led to the paradoxical finding that the Pima and Papago, most similar genetically, were most dissimilar dentally. Analysis based on various subsets of the dental traits reduced the paradox. No objective criteria for measuring matrix congruence were employed. Despite this, it was concluded that "the value of tooth morphology as an indicator of genetic differences between populations can be viewed with cautious optimism." While we agree with the conclusion, it is not one we could have reached from their data.

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