

The dimorphism in human normal cerumen*

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INTRODUCTION

Among a number of polymorphic traits which have been discovered in man, the dimorphism in human normal cerumen or ear-wax has been studied almost exclusively in Japan, while European and American workers have hitherto paid very little attention to this phenomenon. This may perhaps be due to the fact that the variation in cerumen is not so marked among Caucasians and Negroes as in the Mongolian race. The purpose of this paper is to review, on the basis of the author's own observations in addition to the results collected by other investigators, the various aspects of this dimorphism with special reference to the anthropological significance of the findings on this trait.

NORMAL VARIATION IN HUMAN CERUMEN

It is well known that the mammalian cerumen is usually moist and soft, while there are two distinct types in human normal cerumen. The usual type of cerumen among Japanese is grey, brittle and dry in its nature; this type is commonly called 'rice-bran ear-wax' (Nuka-mimi) in Japan because it looks like a particle of rice-bran. The colour of cerumen of this type varies from light-grey to brownish-grey, and when accumulated in the external ear canal for a long period a thin slice of cerumen of fairly large size will often be formed. The other type of cerumen, which is less common in Japan, is brown, sticky and wet in its nature; because it looks like honey, this type of cerumen is sometimes called 'honey ear-wax' (Ame-mimi), 'oily ear-wax' (Abura-mimi) or 'cat ear-wax' (Neko-mimi). The colour may be darkened when exposed to air for a long time, but the sticky nature will never be lost. For the convenience of description, these two types will be referred to simply as wet and dry types, respectively.

The distinction between the two types is usually sharp, so that diagnosis can easily be made by inspection of the external ear canal if no pathologic complication is involved. It is necessary to inspect both ear canals according to the routine method of otological examination, and to confirm the finding in the right ear canal to be consistent with the finding in the left ear canal. Ambiguous cases may be encountered not infrequently, but diagnosis can be made accurately in most cases if the removed sample of cerumen is tested for the stickiness, the presence or absence of which is the most important criterion. In fact, an 'intermediate' type which can be classified neither as wet nor dry, occurs at a rate of only about 0.5 % among healthy Japanese (Matsunaga, Itoh, Suzuki & Sugimoto, 1954; Hayashi, 1958).

The secretory function of the ceruminous glands is apparently dependent to some extent upon age, probably due to a hormonal effect. However, it is to be noted that the two types of cerumen are markedly manifested soon after birth (Matsunaga *et al.* 1954*a*), and they do not seem to be subject normally to any remarkable change in their nature throughout life. For this

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and other reasons that will be described, Ichida, Ichida & Ichida proposed in 1949 to use for the dimorphism in human cerumen the term 'ear-wax types', which has commonly been used ever since in Japan.

FORMAL GENETICS OF EAR-WAX TYPES

There have been a number of papers which reported the incidence of wet cerumen among Japanese. The results obtained by previous workers including the findings of the present author are summarized in Table 1. Frequencies of wet cerumen in different parts of Japan vary within the range 12.6–22.4 %, probably at least to some extent due to some local differences. It is to be noted, however, that the subjects tested so far were mostly inhabitants of large cities where local differences may sometimes be obscured owing to immigration from different rural areas. The mean frequency for the pooled data of about 23,000 persons tested falls at 16.3 %. As will be described later, there is no difference in frequencies of wet and dry types between the sexes.

Family studies have been carried out by many workers (Miyake, 1932; Adachi, 1937; Suzuki, 1938; Nozoe, 1943; Morita, 1947; Ichida *et al.* 1949; Takamiya, 1952; Matsunaga *et al.* 1954a; Hayashi, 1958). The results by these authors are generally consistent with the hypothesis that the ear-wax types are controlled by a pair of autosomal alleles with complete dominance, *W* and *w*, the genotype of wet cerumen being *WW* or *Ww* and the genotype of dry cerumen *ww*. A representative example of family data, comprising 321 families with 1081 children collected by the present author in Tokyo, is presented in Table 2. Since there is a close agreement between observation and expectation, the result strongly supports the above hypothesis.

Table 1. *Frequencies of wet cerumen among Japanese populations*

Place and population	No. examined	Frequency of wet cerumen		Authors
		No.	%	
Tokyo, college students and nurses	1,893	273	14.42	Nagashima (1934)
Kyoto, healthy	432	81	18.75	Nagai (1935)
Kyoto, insane	492	88	17.88	
Age: 15–59	7,816	1,255	16.06	Adachi (1937)
Amakusa island	419	85	20.29	Kutsuna (1939)
Kumamoto	611	95	15.55	
Fukuoka	405	69	17.04	
Kagoshima	208	19	9.13	
O-ita	416	73	17.55	Amako (1939)
Seoul, Japanese school children	2,813	355	12.62	Nozoe (1943)
Hokuriku district	831	185	22.26	Morita (1947)
Kyoto	1,018	179	17.58	Ichida <i>et al.</i> (1949)
Yokosuka	380	70	18.42	Takamiya (1952)
Tokyo, age: above 20	642	144	22.43	Matsunaga <i>et al.</i> (1954a)
Sapporo, pupils of a middle school	1,638	311	18.99	
Tokyo	3,403	528	15.52	Hayashi (1958)
	23,417	3,810	16.27	Total

It has been noticed, even by laymen, that there is an association between wet cerumen and axillary odour, the presence of which is deemed to be pathologic in Japan and is often considered to require medical treatment. This association may probably be due to pleiotropic effects of the dominant allele *W*. We shall come back to the discussion on this point in a later section.

Table 2. Japanese family data indicating single factor inheritance of ear-wax types

Type	Mating			Children					
	Number			Total	Wet		Dry		χ^2
	Obs.	Exp.	χ^2		Obs.	Exp.	Obs.	Exp.	
Wet $\times$ Wet	14	16.1	0.27	47	35	36.7	12	10.3	0.36
Wet $\times$ Dry	116	111.7	0.17	400	205	212.7	195	187.3	0.60
Dry $\times$ Dry	191	193.2	0.03	634	0	0	634	634.0	
Total	321	321.0	0.47	1081	240	249.4	841	831.6	0.96
For 2 D.F.				For 2 D.F.					
0.80 > P > 0.50				0.80 > P > 0.50					

Apart from the association with axillary odour, no association has yet been known between ear-wax types and other traits. In Table 3 are summarized the results obtained by the present author showing the distribution of ear-wax types in relation to sex, *ABO*-, *MN*- and *P* blood groups, and taste ability for phenyl-thio-carbamide. The taste ability was examined by the threshold method described by Hartmann (1939). The expected numbers of wet and dry types shown in the table were calculated on the assumption that there was no association between ear-wax types and the other traits. As is apparent from the table, a good agreement can be observed between observation and expectation, indicating that there is no association either with sex, or blood groups or taste ability.

Table 3. Distribution of ear-wax types in relation to sex, blood groups and taste ability for P.T.C.

Traits		Ear-wax type				χ^2	D.F.	P
		Wet		Dry				
		Obs.	Exp.	Obs.	Exp.			
Sex	Male	100	93.3	327	333.7	1.235	1	> 0.20
	Female	86	92.7	338	331.3			
ABO blood groups	A	75	68.4	238	244.6	3.490	3	> 0.20
	B	33	42.2	160	150.8			
	O	58	56.0	198	200.0			
	AB	20	19.5	69	69.5			
MN blood groups	M	52	51.1	182	182.9	0.706	2	> 0.50
	N	38	42.2	155	150.8			
	MN	96	92.7	328	331.3			
P blood groups	P	43	40.5	120	122.5	0.436	1	> 0.50
	p	56	59.2	182	178.8			
Taste ability for P.T.C.	Taster	260	259.3	1109	1109.7	0.023	1	> 0.80
	Non-taster	29	29.7	128	127.3			

It is now interesting to see whether or not there may be any linkage relationship between the locus for ear-wax types and those for the other traits. For this purpose, the author carried out an investigation on the inheritance of ear-wax types, *ABO*- and *MN*-blood groups with 574 families. Of these, 379 families were tested for *P* blood groups in addition to the above three traits. Moreover, an examination of taste ability for P.T.C. was carried out simultaneously with

members of 120 families. As a method for linkage test, the sib-pair method devised by Penrose (1935) was used. Since this method is obviously less efficient when applied to data from only one single generation, we have ascertained, on the basis of phenotypes of both parents and children, those families which can significantly be used for linkage tests, and then applied the method to the sibships from these families.

The procedure will be exemplified for the linkage test between loci for ear-wax types and taste ability. The taste ability for P.T.C. appears to be controlled by a pair of autosomal alleles, T and t , the genotype of taster being TT or Tt and the genotype of non-taster tt (Blakeslee, 1932; Blakeslee & Fox, 1932; Snyder, 1932; Gottschick, 1937; Matsunaga, Suzuki, Sugimoto & Kawashima, 1954; Tsuji, 1957; Das, 1958; Pons, 1960). In our family data, there were eleven families in which at least one of the parents was ascertained to be doubly heterozygous for both traits. These are listed in Table 4 together with the phenotypes of children. When the sibs are paired according to whether they are alike or unlike in these traits, the distribution of the four alternatives, n_1 , n_2 , n_3 and n_4 defined by the 2×2 table is shown to be 9, 11, 14 and 19, respectively. The χ^2 is calculated to be 0.034, which, for one degree of freedom, gives the value of P larger than 0.80, indicating no close linkage between the loci for ear-wax types and tasting ability.

Table 4. *Family data for linkage test between loci for ear-wax types and taste ability for P.T.C.*

Family no.	Genotypes of parents. Father x Mother	No. of children				No. of sib-pairs				Total
		Wet cerumen		Dry cerumen		Alike for both traits	Alike for taste ability but unlike for ear-wax	Alike for ear-wax but unlike for taste ability	Unlike for both traits	
		Taster	Non-taster	Taster	Non-taster					
32	<i>TtWw</i> x <i>Ttww</i>	1	1	1	1	0	2	2	2	6
57	<i>TtWw</i> x <i>Ttww</i>	1	0	1	1	0	1	1	1	3
59	<i>Ttww</i> x <i>TtWw</i>	1	0	0	1	0	0	0	1	1
465	<i>Ttww</i> x <i>TtWw</i>	0	1	1	0	0	0	0	1	1
498	<i>TtWw</i>	1	0	1	2	1	1	2	2	6
510	<i>ttww</i> x <i>TtWw</i>	0	0	1	1	0	0	1	0	1
520	<i>TtWw</i> x <i>Ttww</i>	1	0	0	3	3	0	0	3	6
675	<i>ttww</i> x <i>TtWw</i>	1	1	2	0	1	2	1	2	6
H-2	<i>TtWw</i> x <i>Ttww</i>	1	2	2	0	2	2	2	4	10
A-1	<i>TtWw</i> x <i>Ttww</i>	1	0	1	1	0	1	1	1	3
S-41	<i>ttww</i> x <i>TtWw</i>	1	0	2	2	2	2	4	2	10
Total						9	11	14	19	53

The results of our data for the linkage test between the loci for ear-wax types and ABO -, MN - and P blood groups are summarized in Table 5. As is shown in the table, there was no significant deviation from randomness in the observed distribution of the four alternative classes of sib-pairs with regard to the characters concerned. This indicates that there is no close linkage relationship between the locus for ear-wax types and those for ABO -, MN - and P blood groups. However, our data demonstrate beyond doubt that the ear-wax types can be used as a useful marker for chromosome mapping in human genetics.

Table 5. *Linkage test by the paired-sib method applied to those sib-pairs where parental genotypes are known*

Traits		Ear-wax types Sib-pair		Total	χ^2	<i>P</i> for 1 D.F.
		Like	Unlike			
Antigen <i>A</i>	Like	83	86	342	0.012	> 0.90
	Unlike	86	87			
Antigen <i>B</i>	Like	42	39	139	0.346	> 0.50
	Unlike	33	25			
Antigen <i>M</i>	Like	153	119	365	2.795	> 0.05
	Unlike	43	50			
Antigen <i>N</i>	Like	140	128	365	0.864	> 0.30
	Unlike	56	41			
Antigen <i>P</i>	Like	42	35	145	0.299	> 0.50
	Unlike	34	34			

RELATIONSHIP BETWEEN EAR-WAX TYPES, APOCRINE
SWEAT GLANDS AND AXILLARY ODOUR

It is needless to say that normal cerumen is a mixture of secretory products of both ceruminous glands and sebaceous glands distributed in the external auditory canal, in addition to some exfoliated epithelial cells. Among these components, it is considered that the difference in the nature of wet and dry cerumen is attributed to the difference in the secretory products of the ceruminous glands.

From an histological view-point, the ceruminous gland is a kind of major sweat gland or apocrine sweat gland, to which also the axillary gland belongs. Not only the morphological structure of the ceruminous glands is quite similar to that of the axillary glands (Ishizawa, 1956), but also physiological reactions of the ceruminous glands to heat, certain drugs such as epinephrine and acetylcholine, or mechanical expression are similar to those of the axillary glands and differ markedly from those of eccrine sweat glands (Perry, 1957). Although the anlagen of both ceruminous and axillary glands are seen earlier in foetuses, the function of ceruminous glands begins soon after birth, while the secretion of axillary glands will be marked at puberty. Adachi (1937) observed by histological examinations that the apocrine sweat glands in the axillary skin are generally much more numerous in persons with odour than in persons without odour. He stated that the degree of individual odour is largely dependent upon the development of apocrine sweat glands.

There have been a few papers reporting the histological difference in the ceruminous glands between persons with wet and those with dry cerumen (Nagashima, 1934; Hirayama, 1942). Nagashima observed that there were abundant lipid droplets and pigment granules in the cytoplasm of the secretory cells in persons with wet cerumen, while in persons with dry cerumen these cytoplasmic components were very scarce. The striated cuticular borders of the secretory cells were found in nearly every cell in persons with wet cerumen, but in persons with dry cerumen they were found only in a small number of the secretory cells.

It appears, therefore, that the alleles for ear-wax types may control the development of apocrine sweat glands and the nature of their secretory products. In persons with wet cerumen,

the axillary glands usually develop much better than in persons with dry cerumen, and this may often cause the axillary odour at puberty. However, it is not likely that every person with wet cerumen gives off the odour. According to the results by Nagashima (1934) who examined 1893 persons aged 16–30, 211 out of 273 persons with wet cerumen, i.e. about 77.3 % of wet type were observed to be affected with axillary odour. If Nagashima's finding is correct, a question may arise whether the manifestation of axillary odour is controlled by a third allele at the same locus, or whether a modifier gene or genes at another locus may be involved. In order to answer this question, further family studies are needed.

CHEMICAL COMPOSITION OF CERUMEN

In view of the recent advances in biochemical genetics in man, as well as in lower animals, it would be interesting to find the biochemical basis for the differences between the two types of cerumen. So far as the present author knows, no attempt has yet been made to elucidate these points. This may perhaps be due to the obvious difficulty in collecting specimens of individual cerumens large enough to be used for chemical analysis. However, results of two independent studies on the chemical composition of cerumen may serve for comparison of the two kinds of normal cerumen. The one was carried out by Nakashima (1933) who analysed pooled specimens of cerumen taken from Japanese. Although he did not specify the ear-wax types in his analysis, it is supposed that most of his specimens were made up of dry cerumen, since the majority of Japanese are of dry type. The other study was reported by Senturia and his school (1957), who analysed the chemical composition of Caucasian specimens, which were undoubtedly composed of wet cerumen.

Nakashima (1933) analysed 70 g. of dried cerumen which he collected from thousands of persons over 2 years, and found 18 % lipid and 43 % protein material. On the other hand, Chiang, Lowry & Senturia (1955) found the average lipid content in dried, individual samples of normal cerumen to be 59.0 % for 38 children and 48.9 % for 82 adults. In estimating the protein in cerumen, they found the average of 16.6 % protein for children and 23.8 % for adults. From these results, it is likely that the cerumen of dry type is composed of more protein and less lipid material than the cerumen of wet type.

Nakashima (1933) found 2.48 % cholesterol in dried pooled cerumen, cholesterol constituting 13.8 % of the lipid material. Chiang, Gessert, Lowry & Senturia (1956) reported that the mean percentage of cholesterol in the ether-soluble substances was found to be 16.4 in casual specimens. Since the proportion of lipid appears much less in the cerumen of dry type than in the cerumen of wet type, cholesterol may also be less in absolute amount in the cerumen of dry type than in the cerumen of wet type.

In addition to cholesterol, Nakashima (1933) was able to find the following substances, using a scheme of fractional extractions: arginine, cerotic acid, cystine, hexone bases, histidine, lysine, neurostearic acid, proline, tyrosine, an acid $C_{17}H_{34}O_2$, a substance $C_8H_{14}NO_2$, and 'a bitter substance'. By means of paper chromatographic method, Bauer, Carruthers & Senturia (1953) showed that in addition to the above amino acids cerumen has the following free amino acids: leucine, isoleucine, valine, alanine, threonine, serine, glutamic acid, aspartic acid, glycine, and γ -amino-butylic acid. As for the various fractions of the lipid material, chromatograms obtained by Akobjanoff, Carruthers & Senturia (1954) indicated that the ear-wax possibly contained the

following fatty acids: α -eleostearic, arachidic, behenic, lignoceric, stearic, cerotic, erucic, myristic, and palmitic.

These results do indicate that cerumen is a very complex material. However, considering the distinct variation in the nature of cerumen, we are not far from understanding the difference on a molecular level. If a significant difference in the chemical composition could be found between wet and dry cerumen, it would be possible to identify the heterozygote *Ww* from the homozygote *WW*.

ANTHROPOLOGICAL ASPECT OF EAR-WAX TYPES

Adachi (1937) seems to be the first anthropologist who pointed out, in his extensive study, the racial difference in axillary odour in connexion with the ear-wax types. He collected data on the incidence of ear-wax types as well as axillary odour not only from various parts of Japan, but also from northern China, Korea, Ryukyu islands, Micronesia, Formosa and the Ainu in Hokkaido. The results showed that there is a marked racial difference in the relative frequencies of ear-wax types among different ethnic groups, and that the incidence of axillary odour is proportionately higher with the incidence of wet cerumen in the populations.

Since this pioneer work of Adachi, several papers have appeared providing additional information on some other ethnic groups in eastern Asia and Pacific areas (Kinoshita, 1939; Kutsuna, 1939; Yamashita, 1939; Yamamoto, 1941; Imamura, 1942; Imamura & Tomomatsu, 1943). The results have been compiled by the present author and are summarized in Table 6.

As is apparent from the table, the differences in the frequencies of wet cerumen appear to be very marked between the ethnic groups beyond the fluctuations found within the tribes concerned. It is to be noted that the incidence of wet cerumen seems to be about 10 % among Tunguses and Mongols, and still less among northern Chinese and Koreans, whereas it is more than 20 % among southern Chinese and Ryukyu islanders. Further, among the Li tribe in Hainan island, Formosan aborigines, Micronesians and Melanesians, the frequency of wet cerumen usually amounts to 50 % or more. Although the number of Ainu tested is very limited, the frequency of wet cerumen was observed at a rate of about 87 %, indicating that the majority of pure Ainu have wet cerumen.

Adachi (1937) stated that Caucasians are usually of wet type, but he gave no basic material for this argument. The present author has investigated together with a German collaborator (Matsunaga & Ebbing, 1956) the incidence of ear-wax types among a German population living in the district of Münster in Westphalia. The results obtained were consistent with the view stated by Adachi. Of 514 persons tested 91.6 % were found to have wet, sticky and yellowish-brown cerumen, while dry, brittle and grey cerumen occurred at a rate of only 3.1 %. The remaining 5.3 % had dry and yellowish-brown cerumen, which could be classified neither as wet nor dry type. Incidences of these three types were almost equal in both sexes.

In order to see whether the genetic hypothesis which has been proposed on the basis of Japanese family data could also be applied to Caucasian, we examined eleven German families, the propositus being of dry type found among the above 514 persons. The wet cerumen is apparently inherited as a dominant over the dry cerumen, in accord with the genetic hypothesis. In one pedigree (HUM), a woman with 'intermediate' type had married a man with dry cerumen and produced two daughters with wet cerumen and a son with dry cerumen. This demonstrated that the phenotypically intermediate type should be considered to belong genetically to wet

type. Consequently, the incidence of wet types in the German population studied may be calculated, including the intermediate type, to be 96.9%.

As for the incidence of ear-wax types among Negro populations, there seem to have been no appropriate data regarding gene frequencies. According to the observation of Yamada (quoted from Adachi, 1937), almost every Negro in Central Africa had an odour specific to Negro people,

Table 6. *Frequencies of wet cerumen in various ethnic groups in the neighbourhood of Japan*

Population	No. examined	Frequency of wet cerumen		Authors
		No.	%	
Northern Chinese	216	9	4.2	Adachi (1937)
Koreans	381	29	7.6	
Tunguse				
Dakhori	368	37	10.1	Kinoshita (1939)
Solon	138	19	13.8	
Orochon	331	18	5.4	Yamamoto (1941)
Manchu	171	21	12.3	Imamura & Tomomatsu
Total	1008	95	9.4	(1943)
Mongols				
Khalkha	321	30	9.3	Kinoshita (1939)
Khalkha	778	103	13.2	Imamura (1942)
Total	1099	133	12.1	
Southern Chinese living in Formosa				
Hoklo	463	98	21.2	Kutsuna (1939)
Hakka	245	86	35.1	Yamashita (1939)
Total	708	184	26.0	
Ryukyu islanders				
Amami-oshima	471	195	41.4	Adachi (1937)
Okinawa	199	67	33.7	
Yonakuni-shima	228	75	32.9	Miyauchi & Wada
Total	898	337	37.5	
Li in Hainan Island	549	304	55.4	Hasegawa
Micronesians				
Ponape	152	109	71.7	Adachi (1937)
Truk	100	54	54.0	
Yap	206	125	60.7	
Total	458	288	62.9	
Formosan aborigines				
Ami	1085	812	74.8	Adachi (1937)
Puyuma	256	170	66.4	
Tayal, Ami, Bunun	79	32	40.5	
Total	1420	1014	71.4	
Melanesians	732	529	72.2	Hsu <i>et al.</i>
Ainus (Shira-oi)	30	26	86.7	Adachi (1937)

and their ear-wax was usually found to be oily, flowing out from the external ear canal. Perry (1957), who observed the cerumen of 26 American whites and 83 American Negroes, found that there was no detectable difference in colour or consistency of the cerumen between the two races. These observations suggest that the Negroes are usually of wet type.

Even if there is no direct information concerning the distribution of ear-wax types in one racial population, it is possible to estimate the gene frequencies for this population from data on F_1 -hybrids between this and other racial populations, when the gene frequencies for the latter group are known. Fortunately, there are some data which provide us with the incidence of ear-wax types among F_1 -hybrids between Japanese and American Negroes and those between Japanese and American whites (Suda, 1959). Since the gene frequencies for Japanese are known, a maximum likelihood method will be described in the following, which enables us to estimate the gene frequencies for both American Negro and white populations.

Let the frequencies of the alleles W and w be $1 - q$, q , respectively, for one population which we wish to estimate, and $1 - q'$, q' , respectively, for the other which is known to us. Then, the probability that a hybrid with dry cerumen is produced in a marriage between the two populations is $q'q$, and the probability that a hybrid with wet cerumen is born in such a marriage is $1 - q'q$. If we assume that the number of observed F_1 -hybrids is N , and that every child is produced from a different parental combination, then the likelihood, say L , of obtaining n_d children with dry cerumen among the given sample will be

$$L = \frac{N!}{(N - n_d)! n_d!} (1 - q'q)^{(N - n_d)} (q'q)^{n_d}. \quad (1)$$

If the log of both sides of the equation is taken, then

$$\log L = \log k + (N - n_d) \log (1 - q'q) + n_d \log q'q, \quad (2)$$

where $k = \frac{N!}{(N - n_d)! n_d!}$. Now $\log L$ can be maximized by taking the derivative with respect to q and setting this derivative equal to zero. If we differentiate with respect to q , then

$$\frac{d \log L}{dq} = \frac{-(N - n_d)q'}{1 - q'q} + \frac{n_d}{q} = 0. \quad (3)$$

And for q we obtain the estimate

$$q = \frac{n_d}{Nq'}. \quad (4)$$

We determine the variance of q by differentiating equation (3), replacing the observed values in the various classes by the expected values, and equating the latter to $-1/\sigma^2$, thus

$$\frac{d^2(\log L)}{dq^2} = - \left[\frac{(N - n_d)q'^2}{(1 - q'q)^2} + \frac{n_d}{q^2} \right].$$

The expected values of $(N - n_d)$ and n_d are $N(1 - q'q)$ and $Nq'q$, respectively. When we replace $(N - n_d)$ by $N(1 - q'q)$, and n_d by $Nq'q$, we find

$$\frac{d^2(\log L)}{dq^2} = \frac{-Nq'}{q(1 - q'q)},$$

hence

$$\sigma_q^2 = \frac{q(1 - q'q)}{Nq'}. \quad (5)$$

We can now apply the data obtained by Suda (1959) to the above equations. According to his observation of the ear-wax types of 63 F_1 -hybrid children living in Elisabeth Saunders Home, who were born to Japanese mothers married to American Negroes, there were 4 with dry cerumen and 59 with wet cerumen. As the estimate for q' , we may use the data shown in Table 1. Since the mean frequency of wet cerumen among Japanese has been calculated to be 16.27%,

the value for q' may be estimated as 0.9150. Introducing this value as well as $N = 63$ and $n_d = 4$ into the equations (4) and (5), we obtain $q = 0.0694$; the standard error of q is 0.0321. Using the value for q , the frequency of wet cerumen among the American Negroes is calculated to be about 99.5%, the frequency of dry type occurring once in 200 persons. If this estimate is correct, frequency of wet cerumen among Negro people is even higher than among Caucasians. In this connexion, it may be interesting to refer to Perry's observation (1957). He states as follows: 'From the material that we studied, one gains the general impression that the ceruminous glands of Negro subjects are more numerous and more highly developed than those of Caucasian subjects. This finding was borne out in the physiologic studies.' It may be suspected, therefore, that our estimate is close to the true situation.

Suda (1959) reported further on the distribution of ear-wax types among F_1 -hybrid children between Japanese and American whites. Among 83 of such children 12 were found to be of dry type while 71 were of wet type. From this finding, the frequency of the gene w may be estimated for the American whites as 0.1580 with standard error of 0.0422. Accordingly, the frequency of wet cerumen is calculated to be about 97.5%, which is very close to the 96.9% previously obtained for the German population.

Based on the data presented, the frequencies of the alleles for ear-wax types with standard error have been estimated for various ethnic groups so far studied. The value for q and its variance were calculated according to the following equations derived by the maximum likelihood method (Neel & Schull, 1954):

$$q = \sqrt{\frac{n_d}{N}}$$

and

$$\sigma_q^2 = \frac{(1 - q^2)}{4N},$$

where n_d is the number of individuals with dry type observed among a sample of N persons. The results are shown in Table 7, yielding many interesting points relevant to the anthropology of the populations concerned.

There is no doubt that the majority of both Negroes and Caucasians belong to the wet type, while classical Mongolians are predominantly of the dry type. The fact that the gene frequency

Table 7. *Frequencies of the alleles for ear-wax types with standard error in various ethnic groups, p and q standing for the frequency of the alleles W and w , respectively*

Population	p	q	σ_q
Northern Chinese	0.0211	0.9789	0.0069
Koreans	0.0378	0.9622	0.0071
Tunguse	0.0483	0.9517	0.0048
Mongols	0.0625	0.9375	0.0052
Japanese	0.0850	0.9150	0.0013
Southern Chinese	0.1397	0.8603	0.0096
Ryukyu islanders	0.2096	0.7904	0.0102
Li in Hainan Island	0.3320	0.6680	0.0159
Micronesians	0.3908	0.6092	0.0185
Formosan aborigines	0.4653	0.5347	0.0112
Melanesians	0.4734	0.5266	0.0157
Ainus	0.6349	0.3651	0.0850
German	0.8236	0.1764	0.0217
American whites	0.8420	0.1580	0.0422
American Negroes	0.9306	0.0694	0.0321

among the Ainus is close to that of Caucasians supports the generally accepted hypothesis that they were originally proto-Caucasians who migrated to Hokkaido at some time (Simmons, Graydon, Semple & Kodama, 1953). Other ethnic groups in Pacific areas and south-eastern Asia show intermediate frequencies between Caucasian and Mongolian groups. The relatively high frequency of the allele *W* in the present Japanese as compared with northern Chinese, Koreans, Tunguse and Mongols, to which the Japanese are akin with respect to physical characteristics, may perhaps be due to some racial intermixtures. It is generally believed that the Japanese are the offspring of Malayan, Mongolian, and, perhaps, Polynesian immigrants into Japan who have intermarried with one another and also with the aboriginal Ainus (Stern 1960). If this is true, we may be justified in dividing the original populations into two groups with respect to the ear-wax types; the one is the Mongolian group with low frequency of the allele *W* and the other comprises non-Mongolian people with much higher frequency of this allele. If this assumption be allowed, then the proportion of the racial intermixture can easily be calculated in terms of allele frequencies (Boyd, 1950). If the frequencies of wet cerumen in the original Mongolians and non-Mongolians were, say 10% and 70%, respectively, then the racial intermixture should have taken place at a ratio of about 92:8 in order to result in the frequency of 16% in the present Japanese. It is necessary, of course, to collect further data from various parts of Asia for more exact information on the hybrid origin of the Japanese.

IMPLICATIONS OF THE CERUMEN DIMORPHISM FROM THE VIEW-POINT OF NATURAL SELECTION

We have seen that the incidence of the ear-wax types is highly variable among different ethnic groups. This may be considered to be due to several factors, such as selection, racial intermixture and random genetic drift which is of particular significance when a population of small size is isolated or immigrated. Thus, the relatively high frequency of wet cerumen in the present Japanese may have been caused by intermixture of a Mongolian population with some non-Mongolian people having a higher incidence of wet cerumen. The fluctuations in the frequency of wet cerumen found within several tribes or islanders of the same ethnic groups, such as seen in Table 6, may probably be due to the effect of random genetic drift. However, the distinct differences between Caucasians, Negroes and Mongolian races in the frequencies of ear-wax types cannot be accounted for by random genetic drift or racial intermixture alone, but may be explained by considering the effect of natural selection.

The genetic mechanism by which a polymorphism is maintained in a stable equilibrium is one of the central problems in present population genetics. Fisher (1930) and Ford (1940) have long insisted that most cases of polymorphism in natural populations now observed are maintained in a balanced state through natural selection operating in such a way that the heterozygotes are at an advantage over both homozygous genotypes. If it is true that the marked genetic differences among the major races of mankind are a consequence of natural selection having acted in a long history of evolution, then, there must be some differences in the selective value between individuals with wet cerumen and those with dry. Such differences may be found in fertility or in viability, usually in connexion with resistance or susceptibility to diseases. However, it seems that no study has yet been carried out along such a line.

At this point, it should be noted that the physiological function of the cerumen has been little

understood, except that the cerumen prevents dryness of external auditory canal. No antibacterial or antifungal properties were demonstrated in the cerumen. Some believed that the wet cerumen, because of its stickiness, plays a role as a 'fly-paper' to insects, but experimental results showed that the cerumen was neutral to flies and mosquitoes (Perry, 1957). The general impression of otologists in Japan seems to be that there is no association between ear-wax types and any diseases of the ear. It is, therefore, not likely that selective difference between wet and dry types, if any, could be expressed directly through a local effect of the cerumen itself. In view of the apparent associations between wet cerumen and development of apocrine sweat glands or axillary odour, it may be assumed that the effect of genes responsible for ear-wax types is concerned with certain metabolic processes, presumably of lipid material, through which individuals with different types of cerumen may display different reactions to environmental changes. It is hoped that investigations will be carried out to seek for an association between ear-wax types and some internal diseases, such as atherosclerosis and other related diseases.

Finally, it is perhaps worth while to mention that the cerumen of mammals including monkeys is generally of wet type and their characteristic odours of apocrine sweat glands undoubtedly play a significant role in attracting a partner for mating. The monomorphism in mammalian cerumen, therefore, seems to have been fixed as a result of natural selection, since animals with their characteristic odour are at an obvious advantage in mating. A question may arise whether or not such a selective mechanism as in mammals could occur also in man. As has been stated, the axillary odour is usually deemed to be pathologic in Japan and is often considered to require medical treatment. This suggests that there may be some more or less preferable mating systems with respect to ear-wax types in this country. However, our family data in Table 2 revealed a good agreement of the observed frequencies of various mating types with the expected ones from random matings, indicating that assortative matings do not occur, at least to an appreciable extent, in Japan. Even though there may be assortative matings, it is clear that no change will be caused thereby in the frequencies of the alleles in the population. The selective mechanism which maintains the dimorphism in human cerumen seems to be quite different from that observed in mammals. In this respect, it is perhaps interesting to recall Adachi's finding (1937) that out of eight chimpanzees two had dry while six had wet cerumen. This suggests that the dimorphism was probably established in primates and it is not a specific property of man alone.

SUMMARY

Various aspects of the dimorphism in human cerumen have been described on the basis of the data collected mostly by Japanese investigators. It was shown that the ear-wax types are apparently determined by a simple genetic mechanism, and can be used as a polymorphic system for both genetics and anthropology. Frequencies of the alleles for the ear-wax types have been estimated for different ethnic groups. It was pointed out that the marked difference in the distribution of ear-wax types among the major races is probably a consequence of natural selection having acted in a long course of evolution, and there may be some differences in the selective value between individuals with wet cerumen and those with dry. In view of the apparent association with axillary odour, it was suggested that the alleles for ear-wax types may control certain metabolic processes, through which individuals with different types of cerumen may display different reactions to environmental changes. The need for future studies along this line is stressed.

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N.B.: Among the data shown in Table 6, those of Miyauchi & Wada were quoted from the paper by Kutsuna, and those of Hasegawa and Hsu *et al.* were quoted from the paper by Wada. Further, the data of Amako in Table 1 were quoted from the paper by Kutsuna.