

The World Distribution of Transferrin Variants and some Unsolved Problems

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The discovery in human serum of genetically controlled variants of the iron-binding protein transferrin (Smithies, 1957; Horsfall and Smithies, 1958) has been followed by extensive sampling of human populations in many parts of the world to determine the number and frequency of such variants. The situation was last reviewed comprehensively by Giblett (1962). Since that time several new transferrin variants have been described; further progress has been made in distinguishing some variants by finger-printing and amino acid analysis and the results of many additional studies of populations in various parts of the world have been published.

At this juncture several patterns of the distribution of transferrin variants in human populations are emerging, but certain anomalies are apparent and further work is needed to clarify some of these problems. The present review has been written to stimulate research in parts of the world where information is still sparse or where further clarification is needed.

1. Existing Variants

Published papers have described 19 variants of transferrin in human serum (Tab. I). In addition, a number of other variants have been detected by various investigators but so far have not been adequately studied to permit differentiation from established variants.

The recognition of these transferrin variants has depended on their relative mobility after electrophoresis in starch gel. This may give rise to errors of four types:

a) Different substitutions in the transferrin molecule having identical electrophoretic mobility: no examples of this kind have been detected up to the time of writing but they may exist.

b) Variants with closely similar mobilities which can be resolved only under special conditions. The separation of the variants D_1 and D_{Chi} illustrates the problem (Parker and Bearn, 1961). Further, the relative mobilities of some variants vary in different buffer systems. This appears to be true of B_1 and B_2 , (Sutton, personal communication) and may be true for other variants.

Tab. I. List of established transferrin variants in order of decreasing mobility in starch gel

Variant	Original buffer system	Variant compared with	Original reference	Originally discovered in
B _{Lae}	Borate buffer: Vertical starch: pH 8.6	B ₂ C, B ₁ C, B ₀ C	Lai, 1963	Melanesians: Brother and sister B _{Lae} C and mother B _{Lae} B _{Lae} From near Lac, New Guinea
B ₀	Borate buffer: Vertical starch: pH 8.6	B ₂ C	Giblett et al, 1959	1 case observed in 100 American whites
B ₀₋₁	Borate buffer: Vertical starch: pH 8.6	B ₀ & B ₁	Parker and Bearn, 1961 <i>b</i>	A Navajo Indian population (8% B ₀₋₁ C)
B _{Atalanti}	Borate buffer: Vertical starch: pH 8.0 at 4°C: also in acrylamide at pH 9.0	B ₀₋₁ & B ₁ B ₁	Murray et al, 1964	A 12 year old boy in Atalanti. Thessaly, Greece
B ₁	Discontinuous trisborate buffer:	B ₂	Harris et al, 1958	One of 139 British + pedigree of family
B ₁₋₂	Borate buffer: Vertical starch: pH 8.6	B ₁ & B ₂	Arends et al, 1962	One person in Venezuela of Italian and Negro descent
B ₂	Discontinuous tris borate buffer: One and two dimensional starch	C & D B ₂ in Canada compared with B ₂ in England	Smithies, 1958 Harris et al, 1958	5 persons in 425 normal blood donors and families of these 5 in Toronto and 1 in 139 British
B ₃	Borate buffer: Vertical starch using High Voltage at 0°C:	B ₂	Parker and Bearn, 1961 <i>a</i>	One of 46 Japanese from Ube, Japan
C	—	—	—	The common variant, detected in all populations sampled
D _{Adelaide}	Borate buffer: Vertical starch: pH 8.9	D ₁ , D _{Chi} , D _{Montreal} , D ₀₋₁ , D _{Wig} .	Cooper et al, 1964	A single Australian family of Irish-Italian extraction

Tab I. (contd)

Variant	Original buffer system	Variant compared with	Original references	Originally discovered in
D ₀	Borate buffer: Vertical starch: pH 8.6	D ₁ , D ₃	Giblett et al, 1959	One of 493 American Negroes
D _{Wigan}	Borate buffer: Vertical starch: High Voltage at 0°C: pH 8.6	D ₀₋₁ , (D ₄)	Glen-Bott et al, 1964	A family in Wigan in England: incidence less than 1 in 2000
D ₀₋₁ (D ₄)	Borate and discontinuous tris- borate buffer	D ₁ , D ₀ (different from D ₀ in borate but not tris-borate)	Harris et al, 1960	8 individuals in two families, one English, one Italian. Frequency 1 in 500 English; 1 in 500 Italian; 0 in 250 African
D _{Montreal}	Borate buffer: Vertical starch: High Voltage 0°C:	D _{Chi}	Parker and Bearn, 1962	A Canadian of French and Irish descent
D _{Chi}	Borate buffer: Vertical starch: High Voltage pH 8.6	D ₁	Parker and Bearn, 1961a	N. Y. Chinese
D ₁	Borate buffer: One and two dimensional starch: pH 8.6	C	Smithies, 1957	U.S. Negroes and Australian Aborigines
D _{Finland}	Lithium hydroxide- borate buffer: Vertical starch: High Voltage at 0-4°C	D ₁ , D _{Chi}	Seppala, 1965	6 in 3893 Finns
D ₂	Discontinuous tris- borate buffer: pH 8.6	D ₁	Harris et al, 1958	One of 153 Africans from Gambia
D ₃	Borate buffer: Vertical starch: pH 8.6	D ₁ , D ₀	Giblett et al, 1959	One in 493 American Negroes: Harris personal communication to Giblett also found another sample — population not stated

c) Changed mobilities of transferrin due to partial removal of sialic acid residues (Parker and Bearn, 1960) or incomplete saturation with iron (Giblett, 1966). This can give rise to misdiagnosis of partially degraded transferrin as a D variant, particularly when sera collected under difficult field conditions are being screened.

d) Masking of transferrin by haemoglobin can occur when partially haemolyzed samples are used and where reliance is placed solely on protein staining of starch. Difficulties of this type can be overcome either by autoradiography using Fe^{59} , or more simply by preliminary partial purification with rivanol.

2. Chemical Differences between Variants

Eventually, transferrin variants will need to be characterized by differences in their primary, secondary or tertiary structure. Differences in primary structure are likely to be the easiest to determine, and at present there is evidence for differences in amino acid composition of four variants. These differences are summarized in Tab. II.

Of interest, is the finding of a chemical difference between the variants D_1 and D_{Chi} , confirming the reality of the slight, but reproducible difference in their mobility after starch-gel electrophoresis (Wang and Sutton, 1965; Wang et al, 1967a). Equally interesting is the demonstration that the chemical composition of the variant D_1 from an American Negro is identical with that of a D_1 from an Australian aborigine (Wang et al, 1967b). Implications of these findings will be discussed below.

It is clear that the correct identification of transferrin variants requires considerable care,* and this is particularly important in areas where more than one variant

Tab. II. Chemical differences in transferrin variants
(Comparison is with peptides of Tf C)

Variant	Enzyme used for digestion of intact molecule	Comments	References
D_1	Chymotrypsin	Glycine substituted for an aspartic acid residue in one peptide	Wang and Sutton, 1965
D_3	Trypsin	Three additional peptides: no further analysis	Sutton and Bowman, 1962
D_{Chi}	Trypsin	One peptide different. Evidence suggests arginine replacing a histidine residue	Wang et al, 1967a
B_2	Trypsin	Glutamic acid substituted for a glycine residue in one peptide	Wang et al, 1966

* The task can be facilitated by consultation with the World Health Organisation's International Reference Laboratory for Serum Protein Variants (Director: Dr. H. E. Sutton) at the University of Texas, Austin, Texas, USA.

with similar mobility may be present. As will be clear from the discussion below precise identification of variants present in many parts of the world still needs to be carried out.

3. World Distribution of Transferrin Variants

Published information has been summarized in Tab. III. The results will be discussed by broad geographical regions.

3.1. EUROPE

European populations have been inadequately studied. This is due possibly to the fact that many population genetic investigations in Europe are carried out for forensic purposes. Since transferrin variants in European populations have low frequencies they are unlikely to have significant forensic applications. It is unfortunate, however, that the opportunity has not been taken more frequently of screening serum samples obtained for other purposes, for transferrin variants.

Among European populations tested no transferrin variants have been identified in 402 Icelanders (Beckman and Johannsson, 1967); 193 Swedish gypsies (Beckman et al, 1965); 64 Finnish Lapps (Melartin and Kaarsalo, 1965); 226 Rumanians (Boia, quoted by Angelopoulos et al, 1967); 169 Cretans (Barnicot et al, 1965) and 103 Greeks from the Chalkidiki peninsula (Blumberg et al, 1964). All other populations have revealed the presence of B variants, D variants or both.

The first B variant was detected in a Canadian White by Smithies (1958) and compared with a similar variant in England by Harris et al (1958). At that time it was designated B_2 in contrast to a faster moving variant, B_1 , found in a single English family during the same investigation. Variants with a mobility similar to that of B_2 have been reported from Finland, Sweden, Norway, Greece and Italy and it is possible to consider B_2 as a characteristically European variant. The frequency, however, is everywhere low, particularly in Greece where only 3 B_2C persons were detected in over 2000 persons examined: elsewhere it approximates 1%.

An examination of Tab. III reveals however, that the B_2 variant is not the only, or even the most interesting transferrin variant in European populations. In an exhaustive study of nearly 4000 individuals in Finland, Seppala (1965) has identified four distinct variants in addition to C. The commonest (2.3%) is identified as D_{Chi} , a variant characteristic of Mongoloid peoples, whilst the next most common (1.8%) is identified as B_{0-1} , a variant found in American Indian populations. An additional D variant, $D_{Finland}$, was found in 6 persons, and only 9 persons carried the B_2 variant.

Transferrin D variants have been reported in other European populations, following Beckman and Holmgren's 1961 report of its occurrence in Sweden, both among Swedes and Lapps. Kirk et al (1964) were able to examine critically two Swedish and two Lapp samples from Beckman's series and concluded that the Swedish variants were indistinguishable from D_1 and the Lapp variants were indistin-

guishable from D_{Chi} . At that time $D_{Finland}$ had not been discovered, and it would be valuable to re-examine the Swedish D_1 variants together with fresh samples of $D_{Finland}$. This is necessary also for the D variants reported among Finns by Melartin and Kaarsalo (1965) and which were designated by these authors as D_1 .

The situation in Scandinavia among the B variants is equally confusing. Beckman and his colleagues have reported B_1C persons in Sweden, and Melartin and Kaarsalo (1965) have similarly reported B_1C persons in Norway, whilst Braend et al (1965) have reported $B_{1-2}C$ persons in Norway. Seppala (1965), however, states that the B_1C control serum from Sweden was indistinguishable from $B_{0-1}C$ in his laboratory and also that a specimen from the group reported by Melartin and Kaarsalo was also indistinguishable from $B_{0-1}C$. Further, Sutton (personal communication) states that the B_1 in Harris' laboratory has been compared with that in Giblett's laboratory and has been found to be different. A careful re-examination of all the European B variants is clearly necessary, and special attention to this is important for distribution studies in N.E. Europe.

In southern Europe B_2 variants have been reported in Italy, where, in contrast to Greece, they have a frequency of approximately 1.4% (Benerecetti-Santachiara and Modiano, 1964; Modiano et al, 1965). Elsewhere in southern Europe D_1 variants are rather more common than B variants, occurring in 0.6% of Greeks (Angelopoulos et al, 1967) and in Rhodes (Blumberg et al, 1964). Blumberg and his colleagues have reported also a single CD_{Chi} person in a small sample from Crete (Blumberg et al, 1964). The occurrence of D_1 variants in Greece is of great interest, and detailed mapping of its distribution in relation to the distribution of the Hb S gene should be undertaken.

The possibility that D_{Chi} has also been introduced from further east should not be overlooked, and careful discrimination of D_1 from D_{Chi} will be necessary in studies of this kind.

3.2. MIDDLE EAST

Information on the distribution of transferrin variants in the Middle East is almost non-existent. Ramot et al (1962) have studied 671 Israelis, and Bonn  (1966) a further 125 persons from the Samaritan isolate in Israel. No transferrin variants were detected in either of these investigations. Plato et al (1964) similarly found no variants among 197 Cypriots.

3.3. ASIA

Transferrin B variants are practically non-existent in Asia. Kirk and Lai (1961) reported two B_2C persons among the Pathans in West Pakistan and Steinberg and Matsumoto (1964) found one B_2C person in 822 Japanese. In addition, Parker and Bearn (1961) reported a new variant, B_3 , in one individual from a small sample of 46 Japanese studied by them.

On the other hand D variants are not uncommon in many Asian populations. In general they occur as a Mongoloid marker, and many of those that have been tested critically are of the D_{Chi} variety (Kirk et al, 1964). Approximately 5% of persons in Malaya, Thailand and Taiwan are CD_{Chi} the frequency being somewhat higher in northern Thailand and near 10% CD (probably CD_{Chi}) among Cantonese in Hong Kong. The frequency of CD persons in Japan is lower (1.4%) and in Korea only one person in 120 was CD . The Korean D variant is claimed to be a D_1 variant (Shim, 1964), but more detailed study both in Japan and Korea, as well as in North China and Siberia is desirable.¹

Of great interest is the extent of the penetration of the D_{Chi} variant into the Indian sub-continent. It is missing completely in the north west and in south India in both tribal and Tamil populations. In the north east, however, D_{Chi} occurs in about 5% of the Oraons of the Chota Nagpur Plateau (Kirk and Lai, 1961; Kirk et al, 1964) and it occurs also in a significant number of tribal populations in Andhra Pradesh (Siniscalco, private communication). Of particular interest is the occurrence of D_{Chi} among the Veddahs of Ceylon, and its absence from the Veddoid tribes of S. India (Kirk and Lai, 1961; Kirk et al, 1964).

One other D variant has been reported in Asia. Kirk and Lai (1961) found one CD among 15 CD persons in Northern Thailand, which was classified as D_0 . Because of the exhaustion both of the original sample and the D_0 standard it has not been possible to check this designation critically.

3.4. AUSTRALASIA AND OCEANIA

The Australasian and Oceanic areas comprise populations of many different ethnic backgrounds. In all areas, with two exceptions, transferrin B variants are rare or absent. By contrast, D variants are common in many populations in Australasia and Oceania, achieving in some populations frequencies among the highest in the world.

3.4.1. *Australia*

Transferrin D_1 variants are common in all populations of Australian Aborigines. Peptide analysis of transferrin from a homozygous D_1D_1 person in Australia reveals the same amino acid substitution in one of the peptide spots as found in transferrin D_1 from an American Negro (Wang et al, 1967b).

Frequencies of persons carrying the D_1 gene range from 5% in one locality in the Cape York Peninsula, Queensland to a maximum of 53% at Yalata in S. Australia. Frequencies of D_1 in the Western Desert areas in general are high, but range between 10 and 20% in most other parts of the continent.

¹ K. Omoto (personal communication) has found 1.9% CD_{Chi} in Japanese, and 3.2% CD_{Chi} among the Ainu in Hokkaido.

At the one locality in Cape York, where the D_1 frequency is low, a B transferrin variant occurs with a frequency of 11%. B variants have not been detected elsewhere in Aboriginal populations. (The example reported by Flory in 1964 was probably from the same locality). Kirk et al (1962) originally reported this variant as B_1 . Subsequent examination reveals it has a mobility intermediate between B_1 and B_2 but it has not been further characterized.

3.4.2. *New Guinea*

D_1 variants are common also in Melanesian populations of New Guinea. Phenotype frequencies range from 10% to 30%.

In addition to D_1 a new transferrin, B_{Lae} was reported by Lai (1963). B_{Lae} has a restricted distribution, occurring in New Britain in at least four linguistic groups and also in the Bukawa linguistic group in the Markham River Valley. The precise limits of distribution have not so far been determined, and one example has been reported from the Kukukuku people of the Eastern Highlands (Curtain et al, 1965).

3.4.3. *Fiji, New Hebrides and Solomon Islands*

Survey among other Melanesian populations in Fiji and the New Hebrides have shown the presence of transferrin D variants, and it is assumed that they are D_1 variants. However, no critical comparison with other D variants has been undertaken. No variants were found in the Solomons (Douglas et al, 1962).

3.4.4. *Polynesian Islands*

Studies in the Gilbert and Ellice Islands, Tonga and Western Samoa, which have predominantly Polynesian populations have revealed neither B nor D variants, and this is true also for a small sample of 75 Hawaiians (Beckman et al, 1964). More extensive studies of other Polynesian groups would be desirable.

3.4.5. *Micronesia*

Blumberg and Gentile (1961) report one study of 106 Marshall Islanders. No transferrin variants were detected. Further sampling in Micronesia is needed.

3.4.6. *The Philippines*

By contrast to the reported absence of transferrin variants in Polynesia and Micronesia, Filipinos have about 2% of D variants (Fraser et al, 1964). These were reported as D_1 , though it seems more likely that they are in fact D_{Chi} variants. Beckman et al (1964) also reported D variants in Filipinos and among Filipino-Caucasian crosses in Hawaii. Beckman and his colleagues further report the occurrence of D_2 variants in Hawaiian-Chinese and Hawaiian-Chinese-Caucasian crosses in Hawaii. These D_2 variants have not been critically compared with the original D_2 variant.

Tab. III. Distribution of transferrin variants by geographical regions

Population	Number tested	CC	B phenotypes	D phenotypes	References
EUROPE					
ICELAND	402	402			Beckman and Johannsson (1967)
FINLAND	3893	3719	B ₂ C 9, B ₀₋₁ C 69	CD _{Chi} 90, CD _{Fin} 6	Seppala (1965) and Seppala et al (1967)
S. W. Finns	614	583	B ₂ C 2, B ₁ C 16	CD ₁ 13	Melartin and Kaarsalo (1965)
N. W. Finns	107	99	B ₁ C 2	CD ₁ 6	Melartin and Kaarsalo (1965)
Finn-Lapps	63	62	B ₁ C 1		Melartin and Kaarsalo (1965)
Lapps	64	64			Melartin and Kaarsalo (1965)
SWEDEN					
Lapps	329	323		CD 6	Beckman and Holmgren (1961)
Swedes (a)	450	445	B ₂ C 4, B ₁ C 1		Beckman and Holmgren (1961)
Swedes (b)	2395	2370	B ₂ C 18, B ₁ C 4	CD 3	Beckman et al (1962)
Swedish Gypsies	193	193			Beckman et al (1965)
NORWAY	950	941	B ₂ C 7, B ₁₋₂ C 2		Braend et al (1965)
POLAND	252	244	BC 8		Prochnicka (1966)
RUMANIA	226	226			M. Boia, quoted by Angelopoulos et al (1967)
ENGLAND	139	137	B ₂ C 1, B ₁ C 1		Harris et al (1958)
GREECE					
Various places	2050	2041	B ₂ C 3	CD ₁ 6	Angelopoulos et al (1967)
Chalkidiki Peninsula	103	103			Blumberg et al (1964)
Thessaly	200	199	B _{Atalanti} C 1		Blumberg et al (1964)
Crete (a)	169	169			Barnicot et al (1965)
Crete (b)	171	170		CD _{Chi} 1	Blumberg et al (1964)
Rhodes	175	173	B ₁₋₂ C 1	CD ₁ 1	Blumberg et al (1964)
ITALY					
Milan province	599	591	B ₂ C 8		Benerecetti-Santachiara and Modiano (1964)
Lecce province	502	495	B ₂ C 7		Modiano et al (1965)

Tab. III. (contd)

Population	Number tested	CC	B phenotypes	D phenotypes	References
MIDDLE EAST					
CYPRUS					
Various places	197	197			Plato et al (1964)
ISRAEL					
Various populations	671	671			Ramot et al (1962)
Samaritans	125	125			Bonné (1966)
ASIA					
W. PAKISTAN					
Punjabis	207	207			Kirk and Lai (1961)
Pathans	185	183	B ₂ C 2		Kirk and Lai (1961)
BHUTAN	31	30		CD 1	Glasgow et al (1968)
INDIA					
Punjabis	161	161			Tiwari (1961)
Bengalis	176	176			Tiwari (1960)
Oraons	125	117		CDChi 8	Kirk and Lai (1961)
Todas	89	89			Kirk and Lai (1961)
Irulas	74	74			Kirk and Lai (1961)
Kurumbas	49	49			Kirk and Lai (1961)
CEYLON					
Tamils (a)	46	46			Kirk and Lai (1961)
Tamils (b)	94	94			Lai (1962)
Singhalese	159	157	B ₂ C 1	CD 1	Lai (1962)
Veddahs	64	57		CDChi 6, DChiDChi 1	Kirk and Lai (1961), Kirk et al (1964)
Wanni castes	99	99			Lai (1962)
MALAYA					
Malays	236	225		CDChi 11	Kirk and Lai (1961)
Chinese	103	95		CDChi 7, DChiDChi 1	Kirk and Lai (1961)
Tamils	133	133			Kirk and Lai (1961)
Proto-Malays	66	64		CDChi 2	Kirk and Lai (1961)
Aborigines	202	196		CD 6	Lie-Injo Luan et al (1967)

Tab. III. (contd)

Population	Number tested	CC	B phenotypes	D phenotypes	References
THAILAND					
Bangkok Thais	274	258		CD _{Chi} 15, D _{Chi} D _{Chi} 1	Kirk and Lai (1961)
Northern Thais	139	124		CD _{Chi} 15	Kirk and Lai (1961)
Maeo	34	33		CD _{Chi} 1	Kirk and Lai (1961)
Yaco	25	23		CD _{Chi} 2	Kirk and Lai (1961)
JAPAN (a)	822	809	B ₂ C 1	CD 12	Steinberg and Matsumoto (1964)
JAPAN (b)	46	45	B ₃ C 1		Parker and Bearn (1961)
TAIWAN					
Chinese	40	39		CD 1	Giblett (1962)
Taiwanese	300	287		CD 13	Giblett (1962)
HONG KONG					
Cantonese	122	109		CD 13	Sanford et al (1966)
KOREA					
	120	119		CD ₁ 1	Shim (1964)
AUSTRALASIA and OCEANIA					
AUSTRALIA					
<i>Queensland</i>					
Yarrabah	87	76		CD ₁ 11	Kirk et al (1962)
Mona Mona	33	29		CD ₁ 4	Kirk et al (1962)
Mitchell River	115	98		CD ₁ 17	Kirk et al (1962)
Edward River	87	73	CB 10	CD ₁ 4	Kirk et al (1962)
Aurukun	76	60		CD ₁ 15, D ₁ D ₁ 1	Kirk et al (1962)
Weipa	41	37		CD ₁ 4	Kirk et al (1962)
North Queensland	103	91	B ₂ C 1	CD ₁ 10, D ₁ D ₁ 1	Flory (1964)
Barkly Tableland	126	93		CD ₁ 31, D ₁ D ₁ 2	Curtain et al (1966)
Bentinck Island	43	34		CD ₁ 8, D ₁ D ₁ 1	Curtain et al (1966)
Mornington Island	95	73		CD ₁ 21, D ₁ D ₁ 1	Curtain et al (1966)
<i>Northern Territory</i>					
Alice Springs	19	14		CD ₁ 14, D ₁ D ₁ 1	Nicholls et al (1965)
Papunya	84	72		CD ₁ 13	Nicholls et al (1965)

Tab. III. (contd)

Population	Number tested	CC	B phenotypes	D phenotypes	References
Hermansburg	48	43		CD ₁ 5	Nicholls et al (1965)
Amoonguna	88	76		CD ₁ 18	Nicholls et al (1965)
Areyonga	86	73		CD ₁ 13	Nicholls et al (1965)
<i>South Australia</i>					
Yalata	190	89		CD ₁ 79, D ₁ D ₁ 22	Nicholls et al (1965)
<i>Western Australia</i>					
Western Desert	352	227		CD ₁ 111, D ₁ D ₁ 14	Lai (1962)
Nullagine	58	40		CD ₁ 18	Lai (1962)
Port Hedland and Marble Bar	119	97		CD ₁ 21, D ₁ D ₁ 1	Lai (1962)
Jigalong	62	52		CD ₁ 8, D ₁ D ₁ 2	Kirk (1965)
Derby	130	110		CD ₁ 117, D ₁ D ₁ 3	Lai (1962)
Halls Creek	153	136		CD ₁ 16, CD ₀ 1	Lai (1962)
Wyndham	65	45		CD ₁ 20	Lai (1962)
Kalumburu and Forest River	127	110		CD ₁ 15, D ₁ D ₁ 2	Lai (1962)
NEW GUINEA					
Various places (a)	518	434		CD ₁ 81, D ₁ D ₁ 3	Barnicot and Kariks (1960)
Various places (b)	136	110	B _{Lae} C 1	CD ₁ 23, D ₁ D ₁ 2	Lai (1963)
<i>Sepik River</i>					
Abelam	141	104		CD ₁ 36, D ₁ D ₁ 1	Curtain et al (1965)
Sause	482	381		CD ₁ 83, D ₁ D ₁ 18	Curtain et al (1965)
<i>Markham River</i>					
Numeng	135	106		CD ₁ 27, D ₁ D ₁ 2	Curtain et al (1965)
Bukawa	56	43	B _{Lae} C 2	CD ₁ 10, D ₁ D ₁ 1	Curtain et al (1965)
Wampur	66	50		CD ₁ 14, D ₁ D ₁ 2	Curtain et al (1965)
<i>Eastern Highlands</i>					
Various places	80	65		CD ₁ 13, D ₁ D ₁ 2	Bennett et al (1961)
Kukukuku	92	68	B _{Lae} C 1	CD ₁ 22, D ₁ D ₁ 1	Curtain et al (1965)
Gadsup	85	64		CD ₁ 20, D ₁ D ₁ 1	Curtain et al (1965)
Fore	68	56		CD ₁ 12	Curtain et al (1965)
Usurufa	74	56		CD ₁ 16, D ₁ D ₁ 2	Curtain et al (1965)
Auiyana	136	99		CD ₁ 35, D ₁ D ₁ 2	Curtain et al (1965)

Tab. III. (contd)

Population	Number tested	CC	B phenotypes	D phenotypes	References
Tairora	105	79		CD ₁ 22, D ₁ D ₁ 4	Curtain et al (1965)
Agarabi	69	58		CD ₁ 10, D ₁ D ₁ 1	Curtain et al (1965)
Kanite	48	42		CD ₁ 6	Curtain et al (1965)
Gimi	28	23		CD ₁ 3, D ₁ D ₁ 2	Curtain et al (1965)
<i>Southern Highlands</i>					
Mendi	104	81		CD ₁ 21, D ₁ D ₁ 2	Curtain et al (1965)
Huli	40	31		CD ₁ 8, D ₁ D ₁ 1	Curtain et al (1965)
Foi	46	34		CD ₁ 11, D ₁ D ₁ 1	Curtain et al (1965)
Pole	32	28		CD ₁ 4	Curtain et al (1965)
<i>Western Highlands</i>					
Enge	59	45		CD ₁ 12, D ₁ D ₁ 2	Curtain et al (1965)
<i>New Britain</i>					
Mangsing	71	47		CD ₁ 17, D ₁ D ₁ 7	Curtain et al (1965)
Sulka	64	46		CD ₁ 17, D ₁ D ₁ 1	Curtain et al (1965)
Taulil	51	40	B _{Lac} C 1	CD ₁ 10	Curtain et al (1965)
Uramet	174	136		CD ₁ 34, D ₁ D ₁ 4	Curtain et al (1965)
Kilenge	133	104		CD ₁ 26, D ₁ D ₁ 3	Curtain et al (1965)
Arawe	104	73	B _{Lac} C 1	CD ₁ 28, D ₁ D ₁ 2	Curtain et al (1965)
Tolai	170	123	B _{Lac} C 2	CD ₁ 37, D ₁ D ₁ 8	Curtain et al (1965)
Baining	54	39	B _{Lac} C 2	CD ₁ 12, D ₁ D ₁ 1	Curtain et al (1965)
OCEANIA					
Gilbert Islands	236	236			Douglas et al (1961)
West Solomon Islands	183	183			Douglas et al (1962)
Marshall Island	106	106			Blumberg and Gentile (1961)
Tonga	196	196			Staveley and Douglas (1960)
W. Samoa	80	80			Staveley (quoted Giblett - 1962)
Ellice Is.	108	108			Douglas et al (1961)
Cook Is.	98	97	B ₂ C 1		Douglas et al (1966a)
Rarotonga Is.	310	310			Douglas et al (1966b)
Fiji	93	91		CD ₁ 2	Staveley (quoted Giblett - 1962)
New Hebrides	110	108		CD ₁ 2	Staveley (quoted Giblett - 1962)
Philippines	403	395		CD 8	Fraser et al (1964)
<i>Hawaii</i>					
Hawaiian	75	75			Beckman et al (1964)
Chinese	70	70			Beckman et al (1964)
Japanese	414	407		CD 7	Beckman et al (1964)

Tab. III. (contd)

Population	Number tested	CC	B phenotypes	D phenotypes	References
Korean	26	25		CD 1	Beckman et al (1964)
Filipino	100	99		CD 1	Beckman et al (1964)
Puerto Rican	58	58			Beckman et al (1964)
Hawaiian-Caucasian	226	223	B ₃ C 1	CD 2	Beckman et al (1964)
Hawaiian-Chinese	148	144		CD ₁ 3, CD ₂ 1	Beckman et al (1964)
Hawaiian-Chin.-Caucasian	79	77		CD ₂ 1, CD ₁ 1	Beckman et al (1964)
Filipino-Caucasian	27	26		CD 1	Beckman et al (1964)
Miscellaneous	204	196	B ₂ C 1	CD 7	Beckman et al (1964)
Caucasian	405	402	B ₂ C 2	CD 1	Beckman et al (1964)
AFRICA					
ETHIOPIANS					
(3 Linguistic Groups)	312	312			Barnicot et al (1962)
GAMBIA	153	149		CD ₁ 3, CD ₂ 1	Harris et al (1958)
LIBERIA					
Northwest	179	172		CD ₁ 7	Neel et al (1961)
Central	52	45	BC 1	CD ₁ 6	Neel et al (1961)
Southeast	75	66		CD ₁ 9	Neel et al (1961)
Mandingo	27	26		CD ₁ 1	Neel et al (1961)
NIGERIA					
Fulani (a)	68	57		CD ₁ 10, D ₁ D ₁ 1	Blumberg and Gentile (1961)
Fulani (b)	111	104		CD ₁ 7	Barnicot et al (1960)
Habe	120	102		CD ₁ 18	Barnicot et al (1960)
Ibo	70	62		CD ₁ 8	Robson quoted by Giblett (1962)
CONGO					
Congolese	98	92		CD ₁ 6	Van Ros et al (1963)
Pygmies (Ituri forest)	121	113		CD ₁ 8	Giblett et al (1966)
Leopoldville (Mixed Bantu)	93	90		CD ₁ 3	Giblett et al (1966)
Stanleyville (Mixed Bantu)	93	88		CD ₁ 5	Giblett et al (1966)
Yaka	98	88		CD ₁ 10	Giblett et al (1966)
Ngbaka	57	51		CD ₁ 6	Giblett et al (1966)
Shi	110	102		CD ₁ 8	Giblett et al (1966)
Hutu	91	89		CD ₁ 2	Giblett et al (1966)
Tutsi	90	86		CD ₁ 4	Giblett et al (1966)

Tab. III. (contd)

Population	Number tested	CC	B phenotypes	D phenotypes	References
BURUNDI					
Tutu and Hutu	173	160		CD ₁ 12, D ₁ D ₁ 1	Van Ros et al (1963)
TANZANIA					
Baganda	165	160		CD ₁ 5	Allison and Barnicot (1960)
Bondei - Children	51	47		CD ₁ 4	Allison and Barnicot (1960)
- Adults	9	8		CD ₁ 1	Allison and Barnicot (1960)
KENYA					
Masei	50	50			Allison and Barnicot (1960)
Bantu (Misc.)	26	26			Allison and Barnicot (1960)
Karamojo - Adult Males	59	59			Allbrook et al (1965)
- Schoolboys	50	45		CD ₁ 5	Allbrook et al (1965)
S. AFRICA					
Bushmen (a) - Tribal	71	60		CD ₁ 10, D ₁ D ₁ 1	Barnicot et al (1959)
- Farms	42	39		CD ₁ 3	Barnicot et al (1959)
Bushmen (b)	125	114		CD ₁ 11	Jenkins and Steinberg (1966)
<i>Bantu</i>					
Zulus	116	110		CD ₁ 3	Barnicot et al (1959)
Ngalagadi	54	49		CD ₁ 4, D ₁ D ₁ 1	Jenkins and Steinberg (1966)
Baca	97	96		CD ₁ 1	Barnicot (1961)
Tswana	152	137		CD ₁ 15	Barnicot (1961)
Shangaan	172	162		CD ₁ 10	Barnicot (1961)
Xhosa (a)	69	67		CD ₁ 2	Barnicot (1961)
Xhosa (b)	265	259		CD ₁ 6	Giblett et al (1966)
Msutu	218	198		CD ₁ 20	Giblett et al (1966)
African (Misc.)	100	94		CD ₁ 6	Gordon et al (1964)
Hottentot	59	55		CD ₁ 4	Barnicot et al (1959)
Cape Coloured (a)	100	97		CD ₁ 3	Gordon et al (1964)
Cape Coloured (b)	88	86		CD ₁ 2	Barnicot et al (1959)
MADAGASCAR					
Various Places	282	251		CD ₁ 30, D ₁ D ₁ 1	Buettner-Janusch, J. and Buettner-Janusch V. (1964)

Tab. III. (contd)

Population	Number tested	CC	B phenotypes	D phenotypes	References
NORTH, CENTRAL and SOUTH AMERICA					
NORTH AMERICA					
Greenland Eskimo (a)	274	273		CD 1	Persson (1962)
Greenland Eskimo (b)	1277	1273	B ₂ C 1	CD ₁ 3	Persson (1968)
Alaskan Eskimo	167	167			Giblett (1962)
Canadian Eskimo	67	67			Parker and Bearn (1961a)
Alaskan Indian	49	49			Giblett (1962)
Navajo Indian	230	213	B ₂ C 1, B ₀₋₁ C 16		Parker and Bearn (1961b)
Seneca Indian	112	112			Doebelin et al (1968)
Canadian Whites	425	420	B ₂ C 5		Smithies (1958)
U.S. White (a)	471	465	B ₂ C 5, B ₀ C 1		Giblett (1962)
U.S. White (b)	107	103	B ₂ C 1, B ₁₋₂ B ₂ 1	CD ₁ 2	Cooper et al (1963)
U.S. White (c)	2221	2194	B ₁ C 2, B ₂ C 15	CD ₁ 10	Roop et al (1968)
U.S. Negro (a)	133	120		CD ₁ 13	Cooper et al (1963)
U.S. Negro (b)	493		B ₂ C 1	CD ₁ Apprx. 10%, CD ₃ 1, CD ₀ 1	Giblett et al (1959)
U.S. Negro (c) New York	99	89		CD ₁ 9, D ₁ D ₁ 1	Parker and Bearn (1961a)
U.S. Negro (d) Sapelo	38	28		CD ₁ 10	Parker and Bearn (1961a)
U.S. Negro (e) Florida	418	399		CD ₁ 19	Roop et al (1968)
U. S. Japanese	242	239	B ₁ C 1, B ₁ B ₁ 1	CD ₁ 1	Giblett (1962)
U. S. Chinese	116	109		CD _{Chi} 7	Parker and Bearn (1961a)
CENTRAL AMERICA					
MEXICO					
Italians	150	144	BC 5	CD 1	Lisker et al (1966)
Spaniards	469	469			Lisker et al (1967a)
Mestizo	17	17			Sutton et al (1960)
<i>Indians</i>					
Various	386	386			Lisker et al (1965)
Maya	680	679		CD 1	Lisker et al (1967b)
Mixtec	318	315	BC 2	CD 1	Lisker et al (1967b)
Nahua	355	343	BC 2	B ₀₋₁ C 10	Lisker et al (1967b)
Itza	86	84		CD 2	Sutton et al (1960)
Chol	16	16			Sutton et al (1960)
Tzotzil (a)	88	87	B ₀₋₁ C 1		Sutton et al (1960)
Tzotzil (b)	79	75		CD 4	Matson et al (1963)
Tzeltal	97	97			Sutton et al (1960)

Tab. III. (contd)

Population	Number tested	CC	B phenotypes	D phenotypes	References
Zapoteca	80	78	B ₀₋₁ C 2		Sutton et al (1960)
Chiapaneca (a)	47	45		CD 2	Sutton et al (1960)
Chiapaneca (b)	40	38		CD 2	Matson et al (1963)
Totonaca	45	45			Sutton et al (1960)
Chinanteco	53	50	B ₀₋₁ C 3		Matson et al (1963)
Lacandon (a)	31	31			Matson et al (1963)
Lacandon (b)	59	49	B ₀₋₁ C 10		Matson et al (1963)
Mixes	54	54			Matson et al (1963)
Zoque	31	29		CD 2	Matson et al (1963)
GUATEMALA					
Mam (a)	27	27			Sutton et al (1960)
Mam (b)	116	112		CD ₁ 4	Matson et al (1963)
Quiche	94	92	B ₀₋₁ C 1	CD 1	Sutton et al (1960)
Cakchiquel (a)	10	10			Sutton et al (1960)
Cakchiquel (b)	150	142		CD ₁ 8	Matson et al (1963)
Kekchi	162	153		CD ₁ 9	Matson et al (1963)
BRITISH HONDURAS					
Maya	212	195		CD 16, DD 1	Matson et al (1965)
Kekchi	65	58	B ₀₋₁ C 1	CD 5, DD 1	Matson et al (1965)
Jicaque	200	191		CD ₁ 9	Matson et al (1963)
Lenca	161	157		CD ₁ 4	Matson et al (1963)
Paya	68	59		CD ₁ 9	Matson et al (1963)
NICARAGUA					
Chorettega	106	100		CD ₁ 6	Matson et al (1963)
Miskito	152	146		CD ₁ 15	Matson et al (1963)
Rama	37	25		CD ₁ 8, D ₁ 4	Matson et al (1963)
Subtiaba	28	27		CD ₁ 1	Matson et al (1963)
Sumo	108	108			Matson et al (1963)
COSTA RICA					
Bribri	38	33		CD 5	Matson et al (1965)
Boruca	45	36	B ₂ C 1	CD 8, DD 1	Matson et al (1965)
Cabecar	25	24		CD 1	Matson et al (1965)
Terraba	31	29		CD 2	Matson et al (1965)
PANAMA					
Cuna (San Blas)	174	174			Matson et al (1965)
Choco	74	74			Matson et al (1965)
Guaymi, Cricamola	204	180		CD 24	Matson et al (1965)

Tab. III. (contd)

Population	Number tested	CC	B phenotypes	D phenotypes	References
CUBA					
Cubans	182	172	BC 2	CD 8	Herzog and Gonzales (1967)
S. AMERICA					
SURINAM					
Upper Surinam	303	265		CD 34, DD 4	Pectoom et al (1965)
Brokopondo area	331	279		CD 52	Pectoom et al (1965)
Tapahoni	87	68		CD 18,, DD 1	Pectoom et al (1965)
North areas	116	104		CD 12	Pectoom et al (1965)
FRENCH GUIANA					
Galibi	153	106	BC 7 (Not B ₀₋₁)	CD 34, DD 6	Cabannes et al (1965)
Palikour	56	26		CD 30	Cabannes et al (1965)
Oyampi	80	67	BC 5 (Not B ₀₋₁)	CD 8	Cabannes et al (1965)
Emerillon	30	16	BC 3 (Not B ₀₋₁)	CD 9, DD 2	Cabannes et al (1965)
Roucouyenne	95	62	BC 8 (Not B ₀₋₁)	CD 22, DD 3	Cabannes et al (1965)
BRITISH GUIANA					
Acawi	84	84			Arends and Gallango (1965)
Macushi	116	116			Arends and Gallango (1965)
Wapishana	116	116			Arends and Gallango (1965)
VENEZUELA					
Mestizos (Caracas)	102	99	B ₁₋₂ C 1	CD ₁ 1, CDChi 1	Arends and Gallango (1962), Arends (1967)
Irapa	89	84		CDChi 5	Arends and Gallango (1962), Arends (1967)
Paraujano	75	71		CDChi 4	Arends and Gallango (1962), Arends (1967)
Macoita	42	38		CDChi 4	Arends and Gallango (1965)
Pariri	69	27		CDChi 27, DChiDChi 15	Arends and Gallango (1964)
Shaparu	22	11		CDChi 11	Arends and Gallango (1964)
Gauhibo	112	112			Arends and Gallango (1965)
Makiritare	54	54			Arends and Gallango (1965)
Motilon	71	53		CDChi 18	Arends and Gallango (1965)
Pemon	96	96			Arends and Gallango (1965)
Piaroa	77	52		CDChi 20, DChiDChi 5	Arends and Gallango (1965)
Shirishana	74	74			Arends and Gallango (1965)
Waica	136	136			Arends and Gallango (1965)
Yupa	91	38		CDChi 38, DChiDChi 15	Arends and Gallango (1964)
Warrau	123	121		CDChi 2	Arends and Gallango (1964)
Yanomama	429	429			Arend et al (1967)

Tab. III. (contd)

Population	Number tested	CC	B phenotypes	D phenotypes	References
BRAZIL					
Awaikomo/Caingang	37	37			Salzano and Sutton (1965)
Guarani	29	29			Salzano and Sutton (1965)
Mestizos (a)	82	81		CD ₁ 1	Salzano and Sutton (1965)
Mestizos (b)	46	45	BC 1		Salzano and Sutton (1963)
Canella	147	147			Arends and Gallango (1965)
Xavante (a)	79	79			Neel et al (1964)
Xavante (b)	521	521			Shreffler and Steinberg (1967)
Caingang	116	115	BC 1		Salzano and Sutton (1963)
COLOMBIA					
Ica	116	116			Gallango and Arends (1966)
Paez	103	98		CD _{Chi} 5	Gallango and Arends (1966)
PERU					
Shipibo (a)	70	70			Buettner-Janusch et al (1964)
Isconahua	16	16			Buettner-Janusch et al (1964)
Quechua (a)	117	116	B ₂ C 1		Giblett and Best (1961)
Quechua (b)	38	37		CD _{Chi} 1	Arends (1967)
Aymara (a)	56	56			Giblett and Best (1961)
Aymara (b)	71	71			Matson et al (1966a)
Piro	86	83		CD 3	Matson et al (1966a)
Campa	93	93			Matson et al (1966a)
Shipibo (b)	129	129			Matson et al (1966a)
Aguaruna	151	151			Matson et al (1966a)
Ticuna	122	122			Matson et al (1966a)
Yagua	9	9			Matson et al (1966a)
ECUADOR					
Quecha	192	165		CD 27	Matson et al (1966b)
Colorado	36	36			Matson et al (1966b)
Jivaro	221	220		CD 1	Matson et al (1966b)
Cayapa	226	206		CD 20	Matson et al (1966b)
Secoya	48	47		CD 1	Matson et al (1966b)
CHILE					
Araucanian Indians	34	34			Parker and Bearn (1961b)
Alacalufa and Aracamenos Indians	122	122			Matson et al (1967)

3.5. AFRICA

The African continent is extremely heterogeneous in the ethnic composition of its population, and some parts of the continent have not yet been studied at all from the point of view of the distribution of transferrin variants, whilst other parts have still to be investigated in detail. Up to the present no survey has been reported for the northern part.

The continent, as surveyed, is characterized by an apparent complete absence of B variants (a single BC individual only is reported by Neel et al, 1961). D variants, however, except in Ethiopia, are common, and it is assumed that these are all of D₁ type though no critical comparisons with other D variants of similar mobility have been carried out.

The frequency of D variants varies considerably. In Ethiopia it is zero, and elsewhere ranges from 1% to about 15%, with many values around 10%. No consistent pattern or cline can be discerned within this range, although the frequencies in West Africa tend to be higher than elsewhere. More detailed studies, with larger series could be profitable.

3.6. NORTH, CENTRAL AND SOUTH AMERICA

As in many other parts of the world, the Americas are populated by peoples from a number of different ethnic backgrounds. In particular, we will note below results for Eskimos, Negroes, Caucasians and American Indians.

3.6.1. Eskimos

A relatively small number of Eskimos in Alaska and Canada have been studied: transferrin variants are absent. Among Greenland Eskimos Persson (1962, 1968) has reported one B₂C and 4 CD₁ in more than 1500 persons examined. No careful discrimination between D₁ and D_{Chi} was made.

3.6.2. Negroes

Transferrin D₁ occurs in about 10% of American Negroes, although one study of the Sapelo Negro isolate gives a frequency of 26%. In the largest survey three other variants were also discovered: B₂, D₃ and D₀, each occurring in heterozygous form in one individual.

3.6.3. Caucasians

The detection of B transferrin variants was made first in a sample of Canadian whites (Smithies, 1958). The frequency of the B₂C persons in this survey was approximately 1%, and similar values have been reported in two surveys of whites in the U.S. In addition, two other rare phenotypes have been reported: one B₀C by Giblett (1962) and an unusual heterozygote classified as B₁₋₂B₂ by Cooper et al (1963). This

last phenotype was supported by a family study in which B_2 and B_{1-2} persons were also found. Cooper and his colleagues further reported two CD_1 persons among their white sample, a result suggesting some admixture of Negro genes in this population. Roop et al (1968) also found 0.5% CD , among more than 2000 whites in Florida.

In Central America, Lisker et al (1966) studying an Italian isolate in Mexico found 5 BC and one CD in a total sample of 150 individuals, but among 469 Spaniards Lisker et al (1967a) found no transferrin variants. Cubans, on the other hand (Herzog and Gonzales, 1967) possess both B and D variants, the latter having a frequency of 4%.

3.6.4. American Indians

The majority of studies on the distribution of transferrin variants in the Americas have been concentrated on Indian populations, and the results are of considerable interest in relation to the genetic diversity of these populations.

Parker and Bearn (1961b) studying Navajo Indians in the United States discovered that in addition to one person typed as B_2C , 7% were also heterozygotes for a new transferrin variant B_{0-1} . No other studies of transferrin variants among Indians in the U.S. have been published (with the exception of a very small sample of Alaskan Indians), but this deficiency has been compensated by numerous detailed studies in Central and South America.

B_{0-1} variants have been reported both in Maya and non-Maya populations in Central America, the highest frequency reported being 6% among the Lacandon. A frequency of B variants of the same order has been reported also by Cabannes et al (1965) among Indians in French Guiana, but the B variant was not differentiated. Many Indian populations, however, do not have B variants of any type, and the B_{0-1} variant is certainly absent over the greater part of South America. More detailed studies on its distribution, particularly in North and Central America, certainly are desirable.

Transferrin D variants have been found in more than half of the Indian populations sampled in Central and South America, and where the D type has been discriminated carefully it has been found to be D_{Chi} except in a few cases where miscegenation with Negroes could have introduced the D_1 gene.

It is probable that the number of populations in which D_{Chi} occurs is higher than that apparent from Tab. III, for in many cases the number of persons sampled in any particular case is relatively small. The absence of D_{Chi} under these conditions does not mean, therefore, that it is completely absent from the population. More extensive sampling in some areas will be needed therefore, to clarify the distribution picture.

There does, however, appear to be a real difference in frequency in various parts of the area under discussion. D variants are present in many populations of Central America often having a frequency of 10%. In the northern part of South America the frequencies are higher, and in French Guiana and Venezuela some populations have frequencies of 30-40%.

By contrast, frequencies of D variants in Peru, Brazil and Chile are very low, and in many populations in these countries neither B nor D variants have been noted. The interpretation of the significance of these results in terms of ancestral relationships among American Indian populations demands serious attention.

4. Conclusions

Transferrin variants used as a tool in anthropo-genetic studies have already demonstrated their usefulness. The discussion above has indicated that in many areas of the world larger surveys are still needed, and in particular the need is apparent that careful discrimination of the type of variant present in a population is of great importance.

In broad terms the world distribution of the variants D_1 , D_{Chi} and B_{0-1} is of great interest. The D_1 variant is widespread in Africa, with frequencies of the order of 10% in most localities. It is present in similar frequency in American Negro populations, and in other groups which could have been influenced by crossing with Negroes in the recent past. It is present also in all aboriginal populations studied in Australia and among the Melanesian populations of New Guinea, New Hebrides and Fiji. In some parts of Australia the frequency of D_1 variants is more than 30%, and elsewhere in Australia and New Guinea values average 10%.

It is interesting that the D_1 variant in Africans has the same amino acid substitution as that present among Australian aborigines (Wang et al, 1967*b*). Whether the widespread D_1 variants in these two large areas of the world have a common origin at some distant time in the past, or whether they arose as independent mutations is a question that cannot be answered at the moment.

It is relevant to note in this context that other examples of D_1 have been reported in places where it seems plausible to consider that they arose independently. These examples are the D_1 variant detected by Shim (1964) in Korea, and those found by Beckman and his colleagues (1962) in Sweden. More careful study of these variants is needed to be certain that they have identical amino acid structure with the African and Australian D_1 forms, and also to define better the limits of their distribution in Northeast Asia and Scandinavia respectively. The type of transferrin variants present among the Ainu, because of their postulated relationships with Australian aborigines (Birdsell, 1949) would be very interesting, particularly in view of the reported presence of D_1 in Korea.¹

The other transferrin variant with very wide distribution is D_{Chi} . Its limit of distribution is still not known definitely, but it is certainly present as a universal feature of Mongoloid populations in Southeast Asia and it is probably the form of D variant found in Hong Kong, Taiwan and Japan. Of interest is its value as a marker

¹ K. Omoto (personal communication) reports 3.2% CD variants among the Ainu and finds that these are CD_{Chi} .

of the penetration of Mongoloid populations into the Indian sub-continent, where D_{Chi} has been found among the Veddahs of Ceylon, the Oraons of the Chota Nagpur Plateau, and D variants which are probably D_{Chi} have been reported in significant frequencies among tribal populations of Andhra Pradesh. Transferrin variants have not so far been detected in other parts of the Indian sub-continent, except for B_2 in the extreme North-West.

D_{Chi} is found also, sometimes with high frequency, among at least half of the American Indian populations studied. Its presence among American Indians is not surprising, in view of their supposed Mongoloid relationships. What is also of interest, however, is that some American Indian populations are devoid of D_{Chi} , and this seems to be true both in North and South America. The American Indian situation appears even more interesting if one notes the presence of the B_{0-1} variant among the Navajo and a number of other populations in Central America, some of whom, incidentally, also possess D_{Chi} . If one notes also that both these variants are present in Finland, where the influence of Mongoloid populations from the East is apparent from other studies, it suggests that the Mongoloid dispersion took place in North Asia both east and west. The charting of the distribution of transferrin variants in Siberia, N. China, Central Asia and Russia is likely to yield valuable information pertinent to this problem.

Finally, the widespread distribution of the D_1 and D_{Chi} variants suggests that these mutations are of considerable antiquity and have survived in polymorphic form in so many populations because of selective pressures operating, at least in the past, if not at the present time.

The low frequency of transferrin variants in European populations has detracted from their study in that continent by population geneticists. Such cannot be argued for studies in Africa and many other parts of the world and there is need for careful age-structure analysis, association with disease states, and for tests of segregation distortion in family material.

The pattern of distribution, number of variants and biological function of transferrin, suggests that it is a field of investigation as fascinating, and potentially as valuable, as that of human haemoglobins.

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Summary

Nineteen variants of the iron-binding protein, transferrin, have been described in human serum. The world literature on the distribution of these variants in human populations is surveyed in comprehensive tables and attention is drawn to some of the outstanding deficiencies in our present knowledge of this distribution. It is pointed out that transferrin variants are important markers in anthropological studies.

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RIASSUNTO

Sono state descritte nel siero umano 19 varianti della transferrina, portatrice di ferro. La letteratura mondiale sulla distribuzione di queste varianti nelle popolazioni umane viene analizzata in tabelle dettagliate, e vengono messe in rilievo le lacune fondamentali delle nostre conoscenze attuali di questa distribuzione. È anche messo in rilievo il fatto che tali varianti forniscano delle importanti indicazioni negli studi di antropologia.

RÉSUMÉ

Dix-neuf variantes de transferrine conductrice du fer ont été décrites dans le sérum humain. La littérature mondiale sur la distribution de ces variantes dans les populations humaines est analysée dans des tables détaillées, et l'auteur fait remarquer les lacunes les plus importantes dans notre connaissance actuelle de cette distribution. Il fait remarquer que les variantes de transferrine fournissent des indications importantes dans les études d'anthropologie.

ZUSAMMENFASSUNG

Neunzehn verschiedene Varianten des Eisen-bindenden Proteins, Transferrin, sind im menschlichen Serum beschrieben worden. Die Weltliteratur über die Verteilung dieser Varianten in der menschlichen Bevölkerung wird in zusammenfassenden Tabellen dargestellt. Es wird aufmerksam gemacht auf einige bedeutende Mängel in unserer gegenwertigen Kenntnis in Bezug auf diese Verteilung. Es wird hervorgehoben, dass Transferrin-Varianten wichtige Charakteristika in antropologischen Studien darstellen.

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Note added in proof

Since this paper was submitted for publication, Rouslahti, Seppälä, Simons and Seppälä (*Nature*, 220: 480-481, 1968) have published the results of a comparison between D_{Chi} obtained in Finland and a D_{Chi} standard. Peptide analysis show these two D_{Chi} samples to be identical.