Blood Types of Brazilian Indians
(Matto Grosso)

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AMERICAN Indians occupy a unique position in mankind with regard to the distribution of the various hereditary blood factors. For example, the frequency of group O generally exceeds 70 per cent among U. S. Indians, and not infrequently reaches 100 per cent among Central American and South American Indians. In contrast, the frequency of group O among most other peoples is less than 50 per cent, though in some, such as Indonesians, Melanesians, Filipinos, and Australian aborigines on the one hand, and in Eskimos and Icelanders on the other, values have been encountered ranging from 50 to 65 per cent.

In Brazil, observations have been made on tribes from the southern and northern extremes of the country. In Guaraní Indians of Rio Grande do Sul (Berardinelli & Roiter, 1934; Ribeiro, 1934) and in Tucano Indians of Alto Rio Negro, Amazonas (Biocca & Ottensooser, 1944), every individual tested belonged to group O. In Caïngangue Indians of Paraná (Fernandes, 1939), and in Canela Indians of Maranhão (da Silva, 1948), the frequency of group O reaches 92 to 93 per cent, the small difference from 100 per cent probably being due to slight racial admixture. The same interpretation may explain the similar percentage of group O among other North and South American tribes. It is obviously difficult to exclude mixing with other ethnic groups which had centuries to take place.

The predominance of type M among Indians is another well known feature, though investigations on the M-N types in Indians have been relatively scanty. Caucasians have about 30 per cent type M individuals, U. S. and Chilean Indians (Henckel *et al.*, 1941), about 60 per cent, while the incidence among North Brazilian Indians is intermediate (Biocca & Ottensooser, 1944; da Silva, 1948).

Only a few investigations on the Rh factor have been made in Indians, because sufficient quantities of antiserum have not become available until recently. The three main racial groups, Caucasoids, Negroids, and Mongoloids, are distinctly differentiated by the incidence of the Rh-negative type.[1] Most

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[1] An exceptional people are the Basques (Etcheverry, 1945, 1949; Chalmers *et al.*, 1948; Vaccaro *et al.*, 1948) with 30 to 35 per cent Rh-negatives and other peculiarities, such as low percentage of group B and lack of rh^w.

Caucasoids have 13 to 15 per cent Rh-negatives, Negroids 5 to 10 per cent, while Mongoloids have still lower frequencies, often zero. The incidence of Rh-negative individuals among Asiatic Indians (Greval & Roychowdhury, 1946; das Gupta, 1944; Khanolkar & Sanghvi, 1945; Ranganathan *et al.*, 1946), is 2 to 10 per cent, which is intermediate between Caucasoids and Mongoloids and similar to that of Negroids, from whom they deviate, however, with regard to the frequencies of the other Rh types. The frequency of Rh-negative individuals among Japanese was found to be 0.3 to 1.3 per cent (Waller & Levine, 1944; Miller & Taguchi, 1945; Pinkerton, 1944; Graydon & Simmons, 1945), among Chinese 0.7 and 1.5 per cent (Wiener, Sonn & Yi ,1944; Levine & Wong, 1943), among Filipinos 0.3 and 0 per cent (Simmons & Graydon, 1945; Pinkerton, 1944), and among Australian aborigines 0.2 per cent (Simmons, Graydon & Hamilton, 1946). In the following series of 200 or more individuals all were found to be Rh-positive: Maori (Graydon & Simmons, 1946), Fijians (Simmons, Graydon & Barnes, 1945), Hawaiians (Pinkerton, 1945), Papuans (Simmons, Graydon, Woods, Smith & Lancaster, 1946), Burmese (Mollison & Reddy, 1946), and Eskimos (Jordan, 1946).

In American Indians, similarly, the frequency of Rh-negatives is small or zero: 1 to 2 per cent in two series of 100 and 120 U. S. Indians, according to Landsteiner, Wiener, and Matson (1942) and Wiener, Hassler, *et al.*, respectively. The same low incidence was observed by Sandoval, Henckel and Givovich (1945) among 205 Chilean Mapuches. Moreover, among 98 Mexican Indians (Wiener, 1947; Wiener, Zepeda, Sonn & Polivka, 1945), and 104 U. S. Indians (Matson & Piper, 1947), all were Rh-positive. Summing up, American Indians are, with rare exceptions, all Rh-positive; in the cases where among 100 Indians a single Rh-negative individual is encountered it is difficult to exclude the possibility of more or less recent admixture with other races.

While the distributions of the A-B-O groups and of the M-N types are unique among American Indians, they do not enable one to classify Indians as Mongoloids; a better criterion of such a relationship is provided by the Rh-negative element. The latter is not the only serological indication, however, because the relationship of Indians to Mongoloids is also shown by the absence of subgroup A_2 and by the distribution of other Rh factors. These more refined differences will be discussed later.

MATERIAL AND METHODS

The preceding brief discussion shows how scanty have been the serological investigations on Indians in Brazil, where there are so many tribes of differing cultures. We had an opportunity to study the incidence of the blood factors in a considerable number of Brazilian Indians, when during the months of May to July of 1947 Dr. Ernani Martins da Silva made excursions to the south of Matto Grosso, where he studied Caiuá Indians in the frontier

regions of Paraguay, and Bororo Indians in the north in the São Lourenço Valley[2]. He sent us blood samples from these two tribes in six series, three from Caiuá Indians and three from Bororo Indians (table 1).

From Caiuá Indians (comprising one large and several small families) samples were taken in the following places:

1st series at the José Bonifácio Post (municipality of Ponta Porã).

2nd series at the Francisco Horta Post near the town Dourados.

3rd series at the Reserva Cerro Peron and the Benjamin Constant Post, near the place of Amambaí.

From the Bororo samples were taken in 3 villages within a period of 4 days:

1st series at Quejara.

2nd series at Colônia.

3rd series at Córrego Grande.

In both tribes there was a predominance of pure Indians; the few mixed Indians were easily recognized. Separation was carried out rigorously by inquiring concerning their ancestry, and by examining their somatic characteristics such as the color of the skin, color of the eyes, quality of the hair, slit of the eyelids, and manner of implantation of the lobe of the ear. Only individuals who passed all tests are included in the following statistics. The reliability of our method of selecting pure-bred Indians is confirmed (da Silva), by comparing the blood group distribution among Whites, Indians and mixed Indians in that region with the aid of the race mixture formula derived by one of us (Ottensooser, 1944). Venous blood was difficult to obtain from these Indians, so that finger puncture had to be employed. Several drops of blood were distributed among 2 or 3 capillary tubes which were put into numbered slips of paper.

Dr. Ernani Martins da Silva carried out tests for the common A-B-O blood groups and the Rh_0 factor on Bororo Indians and on the last series of Caiuá on the spot, in a makeshift laboratory at a post or in a "hotel". The capillaries were broken and placed into test tubes with a few drops of saline solution. Blood suspensions were obtained by shaking. The common blood grouping tests were carried out on slides. In the Rh tests, the tubes containing the mixture of serum and blood suspension were tied together, wrapped in cotton, and placed into a saucepan with water heated to 37°C by means of an alcohol burner. Readings were taken after ½ to 1 hour.

Our own examinations were made in São Paulo, 3 to 6 days after the blood specimens had been drawn. The blood samples were sent by air mail in a small wooden box, and arrived in good condition. Due to the low temperature (below 20°C) of the season hardly any specimens were spoiled. In order to prepare the blood suspensions, the capillaries were opened and placed into numbered tubes with 1 to 2 c.c. of saline solution and then centrifuged, in batches of about 40 at a time, for 15 minutes at about 1,500 r.p.m. This made the small clot come out of the capillaries producing a sediment in the tube. The supernatant fluid was siphoned off and saline added again to suspend the red cells. In rare cases, where centrifugation yielded no sediment, the capillaries were broken as described above. The 1 to 2 per cent blood suspensions were examined on the day of their preparation whenever possible.

The common blood groups were determined on slides or dishes with sera of groups O, A, and B. A few doubtful reactions, possibly due to changes in the blood sample during transportation, were checked further with group AB serum.

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[2] Our good friend, Dr. Ernani Martins da Silva, died a victim of his exploring zeal in December 1948, during an expedition in Goiaz.

To test for the M-N types, equal parts of blood suspension and serum (from Certified Blood Donor Service, N. Y. C.) were mixed; control tests with samples of known M-N types were also included. Readings were taken after 10 minutes with a hand lens.

For Rh typing we used anti-Rh_0 sera prepared by ourselves, and also anti-Rh_0, anti-rh′, and anti-rh″ sera kindly furnished by Dr. A. S. Wiener and by the Certified Blood Donor Service. For some of the latter sera we are obliged to Dr. Arnaldo Amado Ferreira. We are also indebted to Dr. J. M. Hill for supplying us with anti-hr′ serum. Tests with these sera were carried out by mixing, in small tubes, equal parts of diluted serum and blood suspensions, the first reading was taken after ½ to 1 hour of incubation at 37°C, and a second reading after keeping the tubes at room temperature (15°C to 20°C) for a few hours or overnight. Duplicate tests with sera of the same specificity always gave identical results.

TABLE 1. DISTRIBUTION OF THE BLOOD TYPES AMONG MATTO GROSSO INDIANS

TRIBE	SERIES NO.	NO. OBS.	GROUP O	NO. OBS.	Rh-POS.	NO. OBS.	Rh_1	Rh_2	Rh_1Rh_2 (Rh_3)	NO. OBS.	M	N	MN
Caiuá													
	1	89	89	89	89	89	23	17	49	88	68	1	19
	2	46	46	46	46	46	7	11	28	46	39	0	7
	3	102	102	38	38								
	Total	237	237	173	173	135	30	28	77	134	107	1	26
	%		100		100		22.2	20.7	57.1		79.9	0.7	19.4
Bororo													
	1	39	39	39	39	39	8	9	22				
	2	31	31	31	31	31	7	5	19				
	3	49	49	33	33	33	9	4	20				
	Total	119	119	103	103	103	24	18	61				
	%		100		100		23.3	17.5	59.2				

RESULTS

A-B-O System—Table 1 shows that the 237 Caiuá and 119 Bororo all belonged to group O. Also all other Matto Grosso Indians investigated at the same time invariably proved to be group O (da Silva). As already mentioned several South American tribes behave in this way, including Brazilian Indians.

M-N System—As shown in table 1, among the 134 Caiuá examined 79.9 per cent belonged to type M, 0.7 per cent to type N, and 19.4 per cent to type MN. As shown in table 2, these values satisfy the theoretical statistical requirements. Although based on a relatively small series of tests, the results are interesting. The percentage of type M is the highest observed among any Indians, and holds the second place in the world literature, the record still being retained by East Greenlanders (Fabricius-Hansen, 1939), who have 83.5 per cent type M, 0.9 per cent type N, and 15.6 per cent type MN.

Rh factor (Tests with anti-Rh_0)—As can be seen in table 1, the 173 Caiuá and 103 Bororo Indians tested were all Rh positive. The same results had been

obtained in a previous study on 165 Matto Grosso Indians (da Silva). Thus, in all, 441 Indians in that State tested with anti-Rh_0 serum proved to be Rh positive. These observations agree well with previous investigations on North American Indians.

Rh types—To our best knowledge, the incidence of the various Rh types among South American Indians has not been determined previously.

Since the frequencies found by us in Caiuá and Bororo do not differ beyond the limits of error (tables 1 and 3), the results may be combined. A little more than 20 per cent of 238 Indians belong to type Rh_1, almost the same incidence exists for type Rh_2 individuals, while Indians of type Rh_1Rh_2 constitute more than half of the total. Among these Indians, therefore there exists only the three types, Rh_1, Rh_2, and Rh_1Rh_2, while among an equal number of Whites, other types would also be found including dozens of type rh individuals, some Rh_0, and possibly representatives of the rare types rh′ and rh″.

TABLE 2. DISTRIBUTION OF THE M-N TYPES AMONG CAIUÁ INDIANS

NUMBERS OBSERVED				GENE FREQUENCIES		TEST OF BINOMALITY
Total (N)	M (a)	MN (b)	N (c)	$m = \frac{2a+b}{2N}$	$n = \frac{b+2c}{2N}$	$\chi^2 = \frac{N(b^2-4ac)^2}{(2a+b)^2(b+2c)^2}$
134	107	26	1	0.896	0.104	0.1825 D.F. = 1, $P = 0.67$

The fact that only three Rh types were found in this study simplifies the genetic analysis. Nevertheless, we must bear in mind that the absence of a serological type, even in a large material, does not necessarily exclude the presence of the corresponding gene in the population. Type rh, for example, was not encountered among the 441 Indians of Matto Grosso, and we therefore may estimate the frequency of this type as not exceeding 1 in 400; even so, the incidence of the corresponding gene r could be as high as 5 per cent, because $r = \sqrt{\text{rh}} \leqslant \sqrt{.002} \leqslant .05$. But when our observations are combined with those of other authors, the existence of gene r among pure Indians becomes improbable. Similarly, the other genes r', r'', r^y, and R^1, have not been detected serologically in our series of Indians. For this reason and others to be discussed later, these genes will not be taken into account in the following statistical analysis.

Therefore, we may assign to all the Indians of type Rh_1 the genotype R^1R^1 and to all the Indians of type Rh_2 the genotype R^2R^2. The calculated gene frequencies are given in table 3. The incidence of gene R^1 among Caiuá, for example, is obtained from the frequency of type Rh_1 as follows:

$$R^1 = \sqrt{R^1R^1} = \sqrt{\text{Rh}_1} = \sqrt{0.222} = 0.471$$

In the same manner, we obtain $R^2 = 0.456$. The sum $R^1 + R^2$ is less than unity or 100 per cent by the relatively high value of 7.3 per cent. In the Bororo, there is a corresponding shortage of 9.9 per cent. Since these two values (7.3 and 9.9 per cent) agree within the limits of statistical error for the two tribes, they are almost surely significant.

Wiener *et al.* (1947; 1945), had observed previously that among Mexican Indians there is a similar deficiency in the sum of the gene frequencies and explained it by postulating the existence of a third gene R^Z in addition to R^1 and

TABLE 3. DISTRIBUTION OF THE RH TYPES AND OF THE CORRESPONDING GENES AMONG MATTO GROSSO INDIANS

TRIBE	NO. OBS.	PERCENTAGE OF TYPES			INCIDENCE OF GENES		
		Rh_1	Rh_2	Rh_1Rh_2 (Rh_Z)	$R^1 = \sqrt{Rh_1}$	$R^2 = \sqrt{Rh_2}$	$R^z = (1-R^1-R^2)$
Caiuá	135	22.2	20.7	57.1	0.471	0.456	0.073
Bororo	103	23.3	17.5	59.2	0.483	0.418	0.099
Total	238	22.7	19.3	58.0	0.476	0.440	0.084

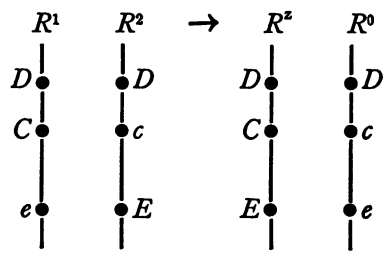
TABLE 4. RH PHENOTYPES AND GENOTYPES AMONG MATTO GROSSO INDIANS

PHENOTYPES	REACTIONS OF BLOOD CELLS WITH ANTISERA				GENOTYPES	FREQUENCY OBSERVED FOR PHENOTYPES Rh_1 AND Rh_2; COMPUTED IN THE OTHER CASES	
	rh′	Rh_0	rh″	hr′		Caiuá	Bororo
Rh_1	+	+	−	−	R^1R^1	0.222	0.233
Rh_2	−	+	+	+	R^2R^2	0.207	0.175
Rh_1Rh_2	+	+	+	+	$2\ R^1R^2$	0.430	0.404
					$2\ R^2R^z$	0.067	0.083
(Rh_z)	+	+	+	−	$2\ R^1R^z$	0.069	0.096
					R^zR^z	0.005	0.010

R^2. Our results support this interpretation. By introducing gene R^Z into the calculations, as shown in table 4, results are obtained which are in accord with the genetic theory, while this is not true if one postulates the presence of other genes such as R^0 or r^y. Moreover, the hypothesis of the presence of gene R^z is supported by the results of tests with anti-hr′ serum.

Hr Factor (Tests with anti-hr′ serum). In the Bororo Indians, the blood type Rh_1Rh_2 (or Rh_Z) has the frequency 0.592 or 59.2 per cent. This type can be subdivided, as shown in table 4, into four genotypes whose frequencies can be calculated. Two of these genotypes, R^1R^2 and R^ZR^2 possess the factor hr′,

while the two other genotypes R^zR^z and R^zR^1, which together should have the incidence among type Rh_1Rh_2 Bororo Indians of 1.0 + 9.6 = 10.6 per cent, have no hr′. The existence of hr′-negative individuals of type Rh_1Rh_2 would be proof of the existence of gene R^z. The expected proportion of such individuals among type Rh_1Rh_2 Bororo Indians is 10.6:59.2 or approximately one in six. Tests were made with anti-hr′ serum on 12 Bororo of type Rh_1Rh_2, and one proved to be hr′ negative instead of the expected two such individuals. However, this is as good an agreement between calculation and observation as one could reasonably expect, the number of tests being very small due to the scar-



The CDE notations used by British workers are readily understood with the aid of the following equivalents:

Blood Factors		*Genetic Units*	
American nomenclature (Wiener)	British notations (Fisher-Race)	Genes	"Chromosomes"
		r	*cde*
Rh_0	D	r'	*Cde*
rh′	C	r''	*cdE*
rh″	E	r^y	*CdE*
Hr_0	d	R^0	*cDe*
hr′	c	R^1	*CDe*
hr″	e	R^2	*cDE*
		R^z	*CDE*

FIG. 1. HYPOTHESIS OF CROSSING-OVER ACCORDING TO R. A. FISHER

city of anti-hr′ serum. On the whole, therefore, the results corroborate the assumption of the presence of gene R^z in these Indians.

Gene analysis from the standpoint of the hypothesis of crossing-over. Fisher attempted to explain the Rh gene frequencies among the English by crossing-over. He postulated that in meiosis the common genotype R^1r would be able to form by exchange of the "elementary genes" D and d a small proportion of germ cells carrying the rare gene R^0 and r'. Similarly, by crossing-over, the common genotype R^2r could give rise to the rare genes R^0 and r'', while genotype R^1R^2 could give rise to genes R^0 and R^z (cf. Fig. 1). Therefore, R^0 would always originate whenever genes R^z or r' or r'' are formed, and in fact, in England the sum

of the frequencies of these last three genes approximately equals the frequency of R^0. Gene r^y would be expected to be extremely rare because it would have to be formed from a rare genotype such as R^2r' or R^1r''. However, Fisher's suggestion has not been confirmed serologically, so that one is justified in assuming that in the Rh gene complex the three postulated elementary genes are linked together permanently to form units. In practical cases of disputed paternity (Ottensooser & Versiani, 1949), the cross-over hypothesis can therefore be disregarded at the present stage of our knowledge.

Extensive family studies on the heredity of the Rh-Hr types have shown that crossing-over, if it occurs at all, must be extremely rare (Wiener, Belkin, & Sonn, 1944). For example, in the case of genotype R^1r, which is the most common in the United States, the formation of genes R^0 and r' has not yet been observed. A case explicable by crossing-over has been claimed recently by Glass (1948), but this single case is not conclusive because it can be explained far more reasonably on the basis of illegitimacy.

A further test of Fisher's hypothesis is provided by the results of serological-anthropological investigations. The Rh gene frequencies of various populations which we have calculated are summarized in table 6, but some of the series are too small to be of much value. On the whole, the results do not favor the crossing-over hypothesis, because the relations $R^0 = R^z$, or $R^0 = R^z + r' + r''$ do not hold, except in Mexican Indians where the frequencies of R^0 and R^z approximate one another.

In order to test whether the crossing-over hypothesis is supported by our own observations, arbitrarily chosen R^0 values will be introduced into the gene analysis, to determine which assumption conforms best with the actual observations.

1st assumption: R^0 lacking.

The sum of the gene frequencies $R^1 + R^2 = 91.6$ per cent; the difference from 100 per cent is 8.4 per cent. We believe that the entire difference represents the frequency of gene R^z, but since only a few Hr tests have been made it could be that the percentage of R^z makes up only part of the difference 8.4 per cent.

2nd assumption: Equal frequencies of R^z and R^0.

According to this assumption the difference, 8.4 per cent, comprises equal percentages of genes R^z and R^0.

If $R^0 = 4.2$ per cent the frequency of type Rh_0 should be very small $(0.042)^2 = 0.18$ per cent, which agrees with the actual observation that not one type Rh_0 individual was found among more than 200 Indians.

The frequencies of genes R^1 and R^2 can then be recalculated as follows:

$$Rh_1 = 0.227 = R^1R^1 + 2R^1R^0,$$
$$R^1R^1 + 2R^1(0.042) + (0.042)^2 = 0.227 + (0.042)^2,$$
$$R^1 + 0.042 = \sqrt{0.227 + 0.002},$$
$$R^1 = \sqrt{0.229} - 0.042 = 43.6\%.$$

Similarly, $R^2 = \sqrt{0.193 + 0.002} - 0.042 = 38.4\%$,

and the sum $R^1 + R^2 + R^0 = 43.6 + 38.4 + 4.2 = 86.2\%$,

which is very low. Correspondingly, the difference from 100 per cent is considerable, namely, 13.8 per cent.

Therefore, the first assumption that $R^0 = 0$, in which the difference is much smaller (only 8.4 per cent), appears more plausible.

3rd assumption: Relatively high R^0 value.

According to the serological findings, the R^0 frequency could also be greater than 4.2 per cent. If, for instance, it were 7 per cent, only one type Rh_0 individual among 200 Indians would be expected. Actually no type Rh_0 individual was found, but this is not necessarily contrary to the assumption $R^0 = 0.07$.
On this assumption we get the following gene frequencies:

$$R^0 = \sqrt{0.005} = 0.071 \text{ or } 7.1\%,$$
$$R^1 = \sqrt{0.227 + 0.005} - 0.071 = 41.1\%,$$
$$R^2 = \sqrt{0.193 + 0.005} - 0.071 = 37.4\%.$$

The sum of the gene frequencies, $R^1 + R^2 + R^0 = 41.1 + 37.4 + 7.1 = 85.6$ per cent. is accordingly still smaller, and the disagreement even greater than under the second assumption.

4th assumption: Small R^0 value.

Assume that $R^0 = 1$ per cent, so that the frequency of type Rh_0 would be very low, 0.01 per cent. The gene distribution would be then as follows:

$$R^0 = \sqrt{.0001} = .01 \text{ or } 1\%,$$
$$R^1 = \sqrt{0.227 + 0.0001} - 0.01 = 46.7\%,$$
$$R^2 = \sqrt{0.193 + 0.0001} - 0.01 = 42.9\%.$$

We see that when even a very small R^0 value is introduced into the calculation, the gene sum $R^1 + R^2 + R^0 = 46.7 + 42.9 + 1.0 = 90.6$ per cent already becomes smaller than under our first assumption.

The following table shows the gene sums and their differences from 100 per cent, resulting from different R^0 values arbitrarily assumed.

	R^0 PERCENTAGES ARBITRARILY ASSUMED			
	0	1	4.2	7.1
Gene sum $R^1 + R^2 + R^0$	91.6	90.6	86.2	85.6
Difference from 100% (= R^z?)	8.4	9.4	13.8	14.4

Even the assumption of a small R^0 value (1 per cent) lowers the gene sum, which decreases continually with increasing R^0 values. The introduction of higher R^z values to balance the difference from 100 per cent, however, is not a satisfactory solution.

Therefore, the assumption that there is a substantial proportion of gene R^0 in our material becomes improbable, and our observations do not support the crossing-over hypothesis.

TABLE 5. DISTRIBUTION OF THE RH TYPES IN VARIOUS POPULATIONS

POPULATION	INVESTIGATORS	NO. OBS.	rh	rh′	rh″	rh′rh″	Rh_0	Rh_1		Rh_2	$Rh_1Rh_2(Rh_Z)$	
								hr′−	hr′+		hr′+	hr′−
Basques	Chalmers, *et al.*, 1948	167	28.7	1.8			0.6	7.8	47.3	7.8	6.0	
Caucasoids												
U. S. A.	Wiener, 1947; Wiener, Sonn, & Polivka, 1946	766	12.5	0.9	0.5		2.2	20.9	33.8	14.9	13.9	0.1
England	Fisher & Race, 1946; Race, Mourant & McFarlane, 1946	927	14.8	0.7	1.3		2.5	19.7	35.2	12.2	13.6	0.1
Brazil	Ottensooser *et al.*, 1948	138	15.2	1.4	0.7		5.8	55.2		10.1	11.6	
Negroids, U. S. A.	Wiener, Belkin, & Sonn, 1944; Wiener, 1945	223	8.1	2.7			41.2	20.2		22.4	5.4	
	Levine, 1945	135	7.4	1.5	0.7		45.9	0.9	22.8	16.3	4.4	
Asiatic Indians	Wiener, Sonn, & Belkin, 1945	156	7.1	2.6			1.9	70.5		5.1	12.8	
Australian aborigines	Simmons & Graydon, 1948	100		1.0			4.0	39.0	14.0	21.0	15.0	6.0
Papuans	Simmons, Graydon, *et al.*, 1946	100						89.0	4.0		4.0	3.0
Filipinos	Simmons & Graydon, 1945	100						87.0		2.0	11.0	
Indonesians	Simmons & Graydon, 1947	200				0.5	0.5	74.0		2.5	22.5	
		(100)						(65)	(9)			
Chinese	Wiener, Sonn, & Yi, 1946	132	1.5				0.9	60.6		3.0	34.1	
Japanese	Miller & Taguchi, 1945	180	0.6					51.7		8.3	39.4	
	Chown *et al.*, 1946	217			0.5			42.8		12.4	43.8	0.5
	Waller & Levine, 1944	150	1.3			0.7		37.4		13.3	47.3	
American Indians												
Mexico	Wiener, Zepeda, *et al.*, 1945	95					1.1	40.7	7.4	9.5	38.1	3.1
U. S. A.	Wiener, Hassler, *et al.*	105		0.9			2.9	34.3	5.7	17.1	36.2	2.9
U. S. A.	Matson & Piper, 1947	104						33.7		28.8	37.5	
Brazil	Present study	238						22.7		19.3	53.2	4.8

TABLE 6. FREQUENCIES OF THE RH GENES IN VARIOUS POPULATIONS

The gene frequencies were calculated by means of the usual formulae (Wiener, Sonn, & Belkin, 1944) except in the following cases:

When computing the frequency of the gene R^2 in series where type Rh_2 is scarce (less than 5 percent), the percentage of type Rh_1Rh_2 was used instead of type Rh_2. Similarly, the frequency of gene R^0 in series with very few individuals of type Rh_0 was calculated on the basis of genotype R^1R^0, if tests with anti-hr′ serum showed a relatively high incidence of this genotype.

In most of the series the statistical control was satisfactory with a value of D (difference between sum of the gene frequencies and 100 percent) of less than 2 percent. In three series the value of D reached as high as 6 to 12 percent. One series of table 5 (Australian aborigines) with a still higher difference was excluded from table 6.

POPULATION	NO. OBS.	r	r′	r″	R^0	R^1	R^2	R^z	D
Basques	167	57.2	1.6		0.6	33.8	6.9		+ 0.1
Caucasoids									
U. S. A.	1468	36.5	1.3	0.3	3.2	43.3	14.5		− 0.9
England	927	37.9	0.8	1.7	3.1	43.6	12.8	0.1	0
S. Paulo	138	39.0	1.7	0.9	6.8	40.6	11.5		− 0.5
Negroids, U. S. A.	223	28.5	4.4		41.7	10.4	14.5		− 0.5
	135	27.2	2.6	1.3	45.8	13.0	9.6		− 0.5
Asiatic Indians	156	26.7	4.4		3.3	56.2	11.4		+ 2.0
Papuans	100	(2.1?)			(2.1?)	94.3	2.1	1.5	0
Filipinos	100					93.3	5.9		− 0.8
Indonesians	200				5.6	80.6	14.0		+ 0.2
Chinese	132	12.2			3.3	63.9	26.8		+ 6.2
Japanese	180	7.8				64.5	22.0	(5.7?)	0
	217					65.4	33.5	0.4	− 0.7
	150	11.4				50.8	26.8	(11.0?)	0
American Indians									
Mexico	95				5.8	63.8	26.8	2.4	− 1.2
U. S. A. (Oklahoma)	105		9.5?		17.0?	49.8	27.7	2.4	+ 6.4
U. S. A. (Utah)	104					58.0	53.7?		+11.7
Brazil (Present study)	238					47.6	44.0	8.4	0

DISCUSSION

Data on the distribution of Rh-Hr types in mankind have been compiled only in recent years and are therefore scarce. Among the populations examined there are rather variegated recent mixtures, and one cannot tell to what degree the material selected is representative without consulting the original papers, which are not always accessible. Nevertheless, the combined results of these investigations already have anthropological significance (Levine, 1945; Wiener, 1945; Wiener, 1947; Potter, 1947).

In table 5 our data are compared with those obtained in other countries, especially by Simmons, Graydon, *et al.* in Mongoloids, by Wiener, Zepeda, Sonn and Polivka (1945) in Mexican Indians, and by Wiener, Hassler, *et al.* and by Matson and Piper (1947) in U. S. Indians. Table 6 gives the corresponding gene frequencies for each population.

The Negroid group differs fundamentally from Caucasoids and Mongoloids in the high proportion of gene R^0. The Mongoloid group, on the other hand, is differentiated from Whites and Negroes and also Asiatic Indians by the scarcity or even lack of gene *r*.

The genes R^1 and R^2 together enable one to distinguish the three major races. The Negroids (Wiener, 1945; Wiener, Belkin & Sonn, 1944; Levine, 1945), have the lowest values of R^1 (less than 15 per cent), the Mongoloids the highest (more than 45 per cent), while the Caucasoids are intermediate (40 to 45 per cent). Some Mongoloids, namely, North American and Brazilian Indians, have relatively low R^1 values approaching those of Whites, but differ sharply from Whites as well as from Asiatic Indians in their high R^2 values.

POPULATIONS	PERCENTAGE OF GENE	
	R^1	R^2
Papuans and Filipinos	More than 90	Less than 10
Indonesians	About 80	About 15
Chinese, Japanese, Mexican Indians, 1 series of U. S. Indians	45–65	20–35
U. S. and Brazilian Indians	45–58	More than 40

Also among themselves, Mongoloid peoples differ in their R^1 and R^2 frequencies. The percentage of other genes being small, there is a roughly reciprocal relationship between the frequencies of genes R^1 and R^2. As a result, the different populations can be arranged according to the frequencies of genes R^1 and R^2, and almost the same order is obtained from the frequencies of the blood types Rh_1 and Rh_2. This is shown in tables 5 and 6, which have been arranged according to this principle.

Summarizing, gene R^1 seems to have its maximum frequencies in Australia and Indonesia, decreasing in the direction of the Asiatic, African and American continents. Gene R^2 behaves inversely. These gradients may be, as in the case of genes *A* and *B* in Eurasia, manifestations of old migrations. The most extreme distributions are especially interesting. The Papuans and Filipinos on one hand have the highest R^1 values and the lowest R^2 values of all the peoples examined; Brazilian and U. S. Indians (Matson & Piper, 1947), on the other hand, have the highest R^2 values and consequently, relatively low R^1 values. There are also American Indians whose R^1 and R^2 frequencies resemble those of Japanese and Chinese.

Even among the American Indians themselves, there occur distinct differences in the distribution of these genes. For example, gene R^1 is more frequent in Mexican than Brazilian Indians, the difference being statistically significant. This is a second variation in the otherwise uniform serological features of American Indians, the other difference consisting of a high percentage of group A in certain U. S. tribes.

The presence of a substantial quota of R^z seems characteristic of American Indians and some other Mongoloid peoples who possess this gene in a frequency 25 to 100 times as high as Whites (Simmons & Graydon, 1947, 1948; Simmons, Graydon, Woods, Smith & Lancaster, 1946; Wiener, 1947; Wiener, Zepeda, Sonn & Polivka, 1945; Wiener, Hassler, *et al.*). This is a positive serological attribute of Mongoloids in contrast to the negative ones, virtual absence of A_2 and Rh-negative individuals.

The particular distribution found in Matto Grosso Indians, with equal R^1 and R^2 frequencies and high proportion of R^z, extends over vast territories. The Caiuá and the Bororo, separated by hundreds of kilometers, have similar frequencies of all the blood types examined. We may therefore assume that our values are representative for certain other Brazilian and Paraguayan tribes also.

SUMMARY AND CONCLUSIONS

Investigations have been carried out on the distribution of the A-B-O groups, M-N types, and Rh types among Caiuá and Bororo Indians in the State of Matto Grosso (Brazil).

All 356 Indians tested (237 Caiuá and 119 Bororo) belonged to group O.

Among 134 Caiuá, 79.9 per cent belonged to type M, 0.7 per cent to type N, and 19.4 per cent to type MN.

Among 173 Caiuá and 103 Bororo, not a single Rh-negative individual was found.

The distribution of the Rh types among 135 Caiuá and 103 Bororo were almost identical. The average frequencies of the types are 22.7 per cent type Rh_1, 19.3 per cent type Rh_2, and 58.0 per cent Rh_1Rh_2. The sum of the gene

frequencies $R^1 + R^2 = 0.476 + 0.440$ is less than 1, and the difference .084 apparently is due to the presence of a third gene, R^z, as can be demonstrated by Hr tests. The findings do not support the crossing-over hypothesis.

American Indians are related to Mongoloids as shown by certain serological findings such as an appreciable frequency of R^z, scarcity or absence of the Rh-negative type, and they are also distinguished by their frequencies of O, M, and Rh_2. Among Matto Grosso Indians these frequencies are especially high.

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